EcoWISE
Innovative Approaches to Socio-Ecological Sustainability

Yuncai Wang

Landscape Pattern Language

A New Approach to Landscape Expression and Spatial Reasoning

Springer

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Series Editor

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EcoWISE (Ecological wisdom inspired science and engineering) series aims to publish authored or edited volumes that (1) offer novel perspectives and insightful reviews, through the lens of ecological wisdom, on emerging or enduring topics pertaining to urban socio-ecological sustainability research, planning, design, and management; (2) showcase exemplary scientific and engineering projects, and policy instruments that, as manifestations of ecological wisdom, provide lasting benefits to urban socio-ecological systems across all temporal and spatial scales; or (3), ideally, coalesce (1) and (2) under a cohesive overarching framework. The series provides a forum, the first of its kind, for the broad international community of scholars and practitioners in urban socio-ecological systems research, planning, design, and management.

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- Engineering science, technology and policy for environmental restoration (e.g., river, lake, hazardous waste sites, brown fields), low CO_2 emission, wastewater and soil treatment, renewable energy, urban green infrastructure and building materials.

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Series Editor's Preface

The construction of ecological civilization needs more practical scholars with ecological wisdom.

> We must learn to green the earth, to restore the earth, and to heal the earth.
>
> Ian L. McHarg: *A Quest for Life* (1996, p. 374)

> I would love to be here to witness when this process is apace. In my mind's eye I can see myself with a group of scientists, looking at the earth from space, viewing the shrinking deserts, the burgeoning forests, the clear atmosphere, the virgin ocean, smiling at the recovery, anticipating the day when a successor will announce, 'The earth is healed, the earth is well'.
>
> Ian L. McHarg: *A Quest for Life* (1996, p. 375)

As a student of McHarg in the 1980s, I think the *ecophronesis* of him provides great enlightenments and guides for us to explore and engage in ecological practice research under the guidance of ecological wisdom, so as to better promote the sustainable development of human beings. So what is the implication of ecological practice research under the guidance of ecological wisdom? As the first director of *Ecological Wisdom and Urban-rural Ecological Practice Research Center* of Tongji University, I was often asked this question. My answer is:

> Ecological practice is the social activity for human to create a safe and harmonious socio-ecological environment for their own survival and development, which includes five aspects of ecological planning, design, construction, restoration and management. Ecological practice research is the process in which people seek knowledge and tools to solve practical problems when they are engaged in ecological practice. It aims to provide useful knowledge and tools for the good environment construction, which is pertinent, actionable and efficacious. Ecophronetic practice research guided by ecological wisdom is the best quadrant of ecological practice research, which has two remarkable characteristics: Firstly, scholars engaged in practical research, who are scholar-practitioners, shoulder the dual responsibilities of creating knowledge and influencing practice. Secondly, it reflects the ecophronesis in the process of ecological practice research.

As the chief editor of *Ecological wisdom and ecological practice research*, I am very glad that this series of book provides a platform for practical scholars to fully display and share their ecological practice researches under the guidance of ecological wisdom.

According to Donald Schön, an American philosopher and planning theorist, scholars often need to choose between theoretical research and practical research when determining their academic position in disciplines which is closely related to various social practices, such as education, law, medicine, and ecological practice. Practical research is often facing the troublesome and irrational real problems, to which sometimes there are no scientific or technological solutions, while the theoretical research is usually facing the rational and even idealized problems which can be solved through scientific theoretical methods and modern technology. The problems of practical research often have the most direct impacts on human beings and concerned by people most, while the problems of theoretical research are often indirect and relatively less important at a short period and are not highlighted by people. According to the definition of ED Schein, a management scholar of the USA, scholar-practitioners are those who make a choice to study the practical problems and make their endeavors to seek new knowledge useful for practitioners.

What does it mean for a scholar to choose to be a scholar-practitioner? It means that he needs to be a scholar who studies implementation for the sake of practice instead of science or applied science. On the one hand, it needs to seek the useful but unnecessary novel knowledge in the traditional sense; on the other hand, it needs to actively influence the practical activities as a participant rather than give comments objectively or offer suggestions as a bystander. And it means to build the theoretical framework and bridge the gap between theory and practice. For an ecological scholar-practitioner, the choice also means that he has to undertake more responsibilities and face more challenges than practical scholars of other disciplines, such as pedagogy, mechanical engineering, medicine, and law, who only need to pay attention to and deal with human-related affairs in their research. Ecological scholar-practitioner should primarily face the relationship between man and nature and then the various human and social relationships in the context.

The second characteristic of ecophronetic research is the research process promoted under the guidance of *ecophronesis*. As an extension of the phronesis proposed by Aristotle in the field of ecological practice, *ecophronesis* is the excellent ability of people to make the right choice according to local conditions and moral standards in ecological practice and the skill of improvisation. People with the *ecophronesis*, who are *ecophronimos* or ecological practitioners of wisdom, can create safe and harmonious socio-ecological conditions for human survival and reproduction through their unremitting efforts, for example, the Dujiangyan irrigation system in Sichuan which was built 3000 years ago by Bing Li and his colleagues and the new community Woodlands in Texas half a century ago designed by Ian McHarg and his colleagues. The *ecophronesis* of these smart ecological practitioners plays an important role of enlightening and guiding for contemporary scholars engaging in ecological practice to deal with the challenges. For example, ecological practitioners of wisdom have the remarkable feature, who can establish the balance between the logic of ecological practice and ecological science, and for them, there is never an insurmountable gap between the preciseness of scientific theory and its application in ecological practice. The ways of ecological practitioners of wisdom to explore practical knowledge and tools are also very enlightening to the research of ecological scholar-practitioners, for whom the only purpose is to solve the problems in practice accurately and effectively. They produce knowledge and tools which are relevant, operable, and effective in ecological practice. The research method is not only completely different from ecological science, but also different from applied ecological research. Ecological practice is usually regarded as an experiment to verify and improve ecological knowledge, methods, and principles or as a platform to show the relevance of scientific principles in the research of applied ecology.

Therefore, I believe that the ecophronetic research under the guidance of ecological wisdom not only plays an irreplaceable role in ecological science and applied ecology, but also has a good prospect of development and will attract more conscious attentions and active participations. In fact, many scholars including some authors of this series have been engaged in such research as scholar-practitioners, but they may not realize or name their research as ecophronetic research.

I hope readers can not only learn the approaches and practical knowledge of ecological practice research, but also meet a group of outstanding scholars with ecological wisdom from the new perspective of ecophronetic practice research through this series of *Ecological Wisdom and Ecophronetic Practice Research*. I also believe that you will follow the examples in our research work and make your own contributions to carry out academic researches serving practice as better.

May 2022

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Preface

Landscape Pattern Language: Integrating Practice and Science

Ecology and life, and culture and art are the main attributes of landscape with configuration and function at multiple scales. After more than one hundred years of development in modern landscape architecture, it was clearly realized that landscape architecture is the discipline of land shaping by the combination of science, art, and engineering with the essential characteristics of context dependence, spatial variability, and human centricity.

The sustainable development of socio-ecological system composed of landscape space has become the focus of landscape architecture which was inspired and guided by *ecological wisdom*. Many theories and methods of landscape architecture especially emphasizing the ecological attribute of landscape, such as adaptive evaluation technology, cultural adaptation theory, landscape urbanism, green infrastructure, geographic design, pattern language, and landscape language, have emerged successively and made a big step forward in the field of landscape planning, design, maintaining, and management, and the composition and mechanism of landscape, landscape service and performance, and landscape construction and maintenance have always been the key fields of practice research.

It was a choice made 20 years ago that encouraged me step into the field of landscape architecture from human geography which provided a good foundation for my academic road with the scientific theories and methods of geography focusing on the relationship between man and nature and the scientific research training received at the Chinese Academy of Sciences. In the first decade, I was committed to the application of landscape ecology in landscape planning and design through the researches in ecological process and landscape pattern and began to establish the framework and approaches to landscape planning and design especially under the funding of National Nature Science Foundation of China.

Lots of books and articles on landscape ecological planning was published openly during the period, such as *Principles of Landscape Ecological Planning* (First edition, 2007; Second Edition, 2013; Third edition, 2022) as the Twelfth Five-Year National Planning Textbook of China, *Reviews on Landscape Ecological Planning and Design cases* (First edition, 2013) and translated the book *Ecological Planning: A Historical and Comparative Synthesis* (Forster Ndubisi, Chinese edition, 2013).

The series of textbooks and monographs including landscape ecological planning and design theories, methods, history, and classic cases has been established through our hard working, which is a huge academic project for me, and the research contributions had won several awards for *The National Planning Textbooks*, *The Excellent Textbooks for Universities in Shanghai*, and *The Excellent Textbooks of Tongji University*. However, I always thought that these achievements were made on the traditional path of landscape ecological planning and design in the field of landscape architecture and are also the primary accumulation and the first step of my personal academic road.

After a long-term research on planning and design of landscape architecture and the teaching experience and real practice of ecological planning, I found a big question and noticed that a possible approach might be constructed for landscape architecture to implement ecological planning and design. In the second decade, it was the dream of new theory and method that encouraged us to implement the researches on the innovative field. At the beginning, this thinking was confused because the traditional paths could neither fully answer the question of what is the essence of ecological space in landscape architecture nor completely and effectively solve the problems of practice in landscape ecological planning and design.

How to effectively understand the ecological characteristics and formative mechanism of landscape space and create the meaningful landscape with sustainability has become the big question of new thinking and practice. Based on this confusion and uncertainty, I went to School of Architecture and Design in Virginia Polytech Institute and State University as a visiting scholar, a six-month term without any specific tasks, I walked to campus, wondered in Blacksburg and hiked from Blacksburg to Christiansburg, and was attracted to experience landscape spaces of the beautiful countryside, forest roads, and community trails, by which it gradually became clearly to focus on finding new paths and breakthroughs in application of ecology through reading literature, communication, interviews, and meditation. With the strengthening of landscape space concept, the embodiment of excellent spatial wisdom, and the direct expression of pattern, the order of landscape language began to merge in my brain and reacted with the help of space experience as the catalyst, landscape pattern language was completely promoted and systematized until in July 2010, and acquired additional two projects funded by National Natural Science Foundation of China in next 10 years. It was the funding that urged us to start the systematic study of landscape pattern language.

As the result, we have made big contributions in theory, method, and practice. Two books of *Landscape and Regional Ecological Planning Methods* (2017) and *Pattern Language: A new approach to landscape expression and spatial reasoning* (Chinese edition, 2018) were both published as the Thirteen Five-Year National Key Books of China, and almost 50 articles were published in two journals which are *Journal of Chinese Landscape Architecture* and *Journal of Landscape Architecture*.

Now the theory and method of landscape pattern language have been accepted and applied in Chinese landscape architecture extensively.

Landscape pattern language is a new way of researching and shaping local landscape and spatial mechanism, which integrates the disciplinary advantages of geography understanding the environment and landscape architecture expressing the environment. The process of landscape planning and design is to help people who live in the natural system or use the limited resources in the system to find the most suitable way of life and production (In McHarg, 1969), to which landscape pattern language is an effective approach with innovative theory and method. Landscape pattern language is the practical tool for the research and application of local landscape expression and space mechanism, as well as the effective tool for landscape space teaching, research and practice judging from the results of the research, teaching and engineering practice of landscape ecological planning and design.

It seems that this book is only a phased achievement of landscape pattern language in the new century of academic freedom and diversified thoughts. We would continue to do more detailed researches to revise the results of landscape pattern language and share them with the constant deepening research in future. At the same time, the book also aims to attract more students, researchers, and practitioners to join the research and application of landscape pattern language or explore effective ways to transform ecological theory and knowledge into ecological practical wisdom. Meanwhile, it would stimulate more good ideas and great wisdom to guide the development of theory and practice in landscape ecological planning and design.

June
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1.1 Background and Key Point of Ideology

1.1.1 Quadrant Shift: Pasteur's Quadrant and Practice Research

Landscape architecture has always been the discipline which seeks to grow up and develop in practice, in which the practical knowledge and experience are the important ways of knowledge inheritance and the scientific knowledge and methods are in great contrast with the theories of empiricism. It is the common sense that different ways and various approaches had been formed for human to learn the new knowledge in history. Bohr's quadrant pursues the pure theoretical knowledge without specific use to reveal the laws of nature, and Edison's quadrant is the purely applied research of inventions which create specific products or functions without caring about the basic scientific principles behind them. The core of Pasteur's quadrant is to solve problems in practice, which could establish correct and effective solutions through the study of causes and reasons (Xiang 2017). Pasteur's quadrant not only explores the laws but also solves the practical problems emphasizing the usefulness and effectiveness of research knowledge. Landscape architecture has its own research object, and the ontology determines that its main research quadrant is the Pasteur's quadrant.

1.1.2 Theoretical Background: Cultural Adaptation Theory

The studies on socio-ecological system, cultural landscape, and ecoplanning and design have become the fastest developing fields in recent years because of the challenging relations between man and nature in the historical process of development. The planning and design shifted gradually from emphasizing on nature to

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cultural landscape and socio-ecological practice, which was based on the development of architecture, landscape architecture, ecology, anthropology, geography, computer technology, etc. The cultural and technical factors were brought constantly into the research methodology and enriched the connotation of ecological planning and design, which promoted the rapid development of this discipline. The theory and methodology aiming at the technology of optimization have been established to combine man with nature closely and scientifically, in which cultural landscape and human ecology have become the rapidly developing fields and the new branches of discipline have become the catalysts for the development of ecological planning and design in landscape architecture and culture adaptation.

1.1.3 Intellectual Approach: New Tools for Thinking

Professor Anne W. Spirn pointed out that landscape was the natural language of all living things and had all the characteristics of language in her book *The Language of Landscape* (1998), which could be explained and described in words, read and understood the meanings, and endowed the imaginations. The ways are different to tell and read the meanings of landscape at different times. The language of landscape was considered not only to create the structure, but also provide spaces for the stable, vegetal, and unexpected occurrences, by which the ability of landscape creation and perception of designers could be effectively trained and cultivated based on their background and experience (Meng 2006). Landscape was considered with the functions of potential rhetoric which could be used in landscape literature with the exception of some particularly inappropriate metaphors. The theory of landscape language provides a new thinking tool for people to understand, describe, and shape landscape in the expression system including the basic composition of landscape vocabulary, the order of landscape elements as spatial organization, the shaping context of landscape environment and their law as landscape grammar, and the application of landscape language with pragmatics, poetics, and dialectics.

1.1.4 Expressing Way: Fictitious and Realistic Approaches

The graphic, diagram, mode, pattern, and model are all the common ways to express in landscape architecture. The graphic is used to represent the abstract structure of cognition by means of graphs, images, and pictures and to reveal the information of the features, internal structures, and interrelationships. The diagrams is the visual expression after simplifying and organizing the concepts, ideas, structures, relations, etc., which could make the topic more vivid and clear. The diagram is a tool for organizing information conceptually by discarding the concrete forms, contents, fixed procedures, and types. The mode is the standard form or style which could be followed, and also the common framework for solving the problem has strong induction and extension. The model is the expression of system, process, object, or concept, which also refers to the sample made by testing, enlarging, or shrinking a picture. The pattern is a collection of existing knowledge and experience in human brain, which could not only represent the cognitive structure of specific concepts or events, but also refer to the occurrence of bio-morphologic patterns or forms. The Swiss psychologist Jean Piaget explained pattern as the structure and organization of actions. According to a modern psychologist David E. Rumelhart, the pattern is the unit of knowledge system, which includes both cognitive structure, strategies, and frameworks, and could describe the dynamic and static things, which has systematic structure of organization, corresponding characteristics of structure, function of adjustment automatically, and organic evolution consistently. The pattern is a way to regular expression which combines both the real and the imaginary.

1.1.5 Bridging the Gap: Inspired by Ecological Wisdom

How to integrate the ecological theory and knowledge into practice to implement ecological planning and design? This question has always been the difficulty in the development of landscape architecture. It is difficult to apply accurately the pure ecological knowledge and theories to the practice of landscape architecture because of the complexity of ecosystem and characteristics of landscape ontology, as well as the variability of ecological relations. The principle of ecology becomes too abstract to catch the essence in practice of landscape architecture, and the use of it just becomes a concept or a label which extrapolates to the totality from the part and reveals the ecological relationship inaccurately and unsystematically. The purpose of landscape pattern language is to shape the ecological space at macrolevel through microapproaches, which depicts the ontological features and processes of ecological space through language symbols and spatial logic, etc., transforms the ecological theory and knowledge into the basic vocabulary and logic to depict ecological space, thus it is needed for landscape architecture to transform ecological theory and knowledge into wisdom of ecological practice. Landscape pattern language builds a bridge between ecological theory and ecological practice of landscape architecture.

1.2 Origin and Development of Pattern Language

1.2.1 Concept and Connotation

Landscape pattern language is one of the important fields of landscape architecture theory, which is based on three main ideas including Anne Spirn's landscape language, Christopher Alexander's pattern language, and Simon Bell's pattern approach and also is the system about design vocabulary and spatial logic based on basic compositions of landscape space and spatial organization at horizontal and vertical dimensions with the process of stitching within single scale and nested structure crossing multiple scales. Landscape spatial diversity, horizontal stitching, and vertical nested structure are considered as the keynotes of landscape pattern language, and landscape pattern is considered as language style to establish the integration of landscape spatial form, function and meaning, as well as the formative process and mechanism of total landscape with features of scale, order, grammar, and significance. Different from the three ideas mentioned above, landscape pattern language reveals the diversity of approaches to solving landscape spatial problems, emphasizes the splicing, transformation and nesting of spatial patterns in both horizontal and vertical dimensions, and focuses on the universality and locality of pattern language. The study mainly includes spatial patterns and their characteristics, typical spaces and pattern language, scaling and nested reasoning, pattern language evolution, and verification of the validity.

1.2.2 Making up for the Deficiency

Christopher Alexander's pattern language is the study to generalize different ways of solving some specific problems which were proved to be useful into an alternative solution of the same category and created the new vitality by applying a series of related patterns based on the excellent samples of spaces which were proved to be successful design in the built environment. The pattern language was used more for the study of complex behavior than for the study of vocabulary, syntax, and grammar for communication. The vocabulary of pattern language is the definite solution which was considered as an established design pattern to a specific problem, each solution was described as the syntax which acted as association with the larger, more complex, or more abstract design, and each solution was also described as the grammar which acted as the reasoning for solving a problem or making benefit. Alexander's pattern language enables designers to link quickly from one pattern to another with a list of established design patterns through grammar and syntax. Therefore, it does not have the structure and organization characteristics of real language in his system which limits the research on spatial scale and spatial reasoning of pattern language and is quite different from the system of landscape pattern language. The theory of landscape language studies landscape with the real structure and organizational characteristics of language, but it also limits the research and application to regard landscape elements as the basic unit and core concept of landscape language.

Landscape pattern, spatial–temporal distribution, nested structure, and ecological process are all dependent on scales and characterized by time, space, or spatial–temporal processes. The internal orders could be grasped in the specific period of time only by investigating and studying at the continuous scale, and many researches could only be carried out at the single scale due to the limitations of scientific cognition level, financial resources, time, and energy.

Professor Stephen Kaplan (1990) of the University of Michigan believed that landscape architecture had been plagued by insufficient understanding of natural and humanistic processes and the lack of evaluation criteria. Landscape architects also knew that the natural and humanistic processes played the important role in human's surroundings, but the problems lied in the lack of systematic research on type, quality, and scale of these processes and also lack of consideration on scales. It is necessary to understand natural features and master cultural processes in the context of scale and apply their characteristics and orders for ecological planning and design.

Planner and designer pay generally less attention to the nested structure, spatial reasoning, and sequence of landscape scale. Professor Bobby Scarf (1990) of the University of Maryland proposed that geography would be theoretical landscape architecture and landscape architecture would be applied geography based on the diversity of landscape architecture, the complexity of solving problems, and the similarity of research targets. He revealed that the sequence of spatial scales and nested features is the intrinsic relationships and common features of space which both landscape architecture and geography have in essence although this is just his personal opinions. He believed that ecology would be a dynamic continuum of which human beings would act as an important component and maintain its sustainability, and life would be a continuous and interdependent flows of behavior. Thus, landscape space is the scale complex that relies on the ecological dynamic continuum and flows of human behaviors.

The scale research was noticed gradually, but the research on scaling and nested reasoning of pattern language based on scale context was neglected. *A Pattern Language* is one of the books in series of *The Timeless Way of Building*, *A Pattern Language,* and *The Oregon Experiment* wrote by C. Alexander. This series of books built a theoretical basis for the development of pattern language and their application in architectural design, which strong the theory with positive effects. C. Alexander put forward the summary of three scales of town, building, and construction, but the nested relationship of space and transformation of scales were not involved in his system. Spirn (1998) also studied the issue of scale in her book *The Language of Landscape*, in which landscape was divided into many types by scale, such as 1m^2, more than 10 m^2, garden, park, region, and she thought that landscape should not simply be divided into scales, which was the flaw in Alexander's system, but rather should be the continuous, combined, nested relationships and existed under the requirement of scaling.

It was showed that Anne W. Spirn had made a big step further than C. Alexander on the question of scale, but she still did not delve deeply into the process of scaling and the nested structure of space. The researches on the single scale have laid foundation for landscape architecture, but they still lack the in-depth study on scaling at multiple levels. Researchers and practitioners have formed their own unique spatial patterns and completed the accumulation and practice of basic theories corresponding to multiple scales, but in general, most of the researches focus on the single scale and neglect the systematic research on spatial relationship and nested structure of landscape at different scales.

1.2.3 Development of Design Language

The study of design language could be back to the eighteenth century, which experienced many kinds of architectural design language. The language of landscape is an important research field of landscape design and an important theoretical tool for understanding nature and human ecology. The study of landscape language originated early but developed slowly until the 1990s when it was launched in the United States as the research hotspot. The first conference on Language of Landscape Architecture (LOLA) hold by Lincoln University in New Zealand proposed formally the idea of landscape as language in 1995. The second conference (LOLA2) in 1998 mainly discussed the application of landscape language in design practice, theory, and education, which also focused on the narrative, metaphor, and meaning of landscape.

Anne W. Spirn's book *The Language of Landscape* was published in 1998, which is one of the most representative contributions in this field. The research on landscape language burgeoned closely with her experiences of teaching at the University of Pennsylvania, living in temperate forests of North America and Western Europe, studying art history at Art Department of Harvard University and practice in the studio WMRT (Wallace, McHarg, Roberts and Todd). It was the spatial pattern revealed by Alexander's pattern language, McHarg's ecological wisdom, Anne's abundant practical, and travel experience as well as the exploration of innovative teaching methods that had established a common basis for landscape language from perspectives of formative process. The Mill Creek community was selected by Anne Spirn as a case to carry out the practice researches, teaching materials, and discussion topics in MIT to perfect her researches on landscape language from perspectives of theoretical research.

The language of landscape is based on the principles of landscape architecture, landscape geography, landscape assessment, and human ecology, which discussed the linguistic rules of landscape constitution, such as modification, agreement, correspondence, subordination, coordination, and studies the basic composition of landscape language acting as vocabulary, the order of landscape elements acting as spatial organization, the shaping of context as landscape environment, the rules of language environment acting as the context and landscape grammar, and the application of landscape language with pragmatics, poetics, and dialectics.

Professor Mark Roskill in the University of Pennsylvania studied the relationship between language, landscape, and literature from the perspective of landscape language, explored the essential process of humanity in landscape design and the core content of landscape planning and design. He also published the book of *The Language of Landscape* (1997) with the same title as the book of Anne W. Spirn. Professor Frederick Steiner has also studied the language of landscape on the basis of Anne Spirn's works, who incorporated the research results into the book *Human Ecology—Follow Nature's Lead* (2002) based on his thoughts of planning and design. His works further expanded the research scope of landscape language on human ecosystem and the nature of cultural landscape in landscape architecture.

The language of landscape was first introduced in 2003 (Pu and Sun 2003), and some topics and fields are discussed almost at the first decade of the twenty-first century in China, which mainly included the application of pattern language, landscape semiotics and its significance (Chen 2007; Gao 2016; Dai 2016), vocabulary and linguistics of landscape (Huang 2008; Shen 2009), as well as the in-depth study of design language of well-known designers (Meng 2006, 2008, 2016). These studies had launched as the important forces to promote the researches on the language of landscape in China.

1.2.4 Development of Pattern Language

The pattern and its verbalization have been grown up as the most important fields in the theoretical research and practice of landscape architecture with the development of 3S technology in the past 40 years. *A pattern language* of architecture design and urban planning originated from the research of C. Alexander and had been one of the important theories in related disciplines, in which 109 out of 253 patterns were considered to be related closely to landscape architecture with important influence on architecture and urban planning.

Jellicoe and Jellicoe studied the shaping history of human environment from perspective of human cultural history and revealed the cultural pattern of human settlements from ancient times to the present through his book *The Landscape of Man: Shaping The Environment from Prehistory to The Present Day* (1987), which was consistent with the ideas of C. Alexander.

Boults and Sullivan (2010) summarized 46 basic principles of spatial pattern and 84 basic design vocabularies of landscape planning and design from perspective of historical development of landscape architecture in their book *Illustrated History of Landscape Design*, which revealed the essential source of thoughts and methods of landscape design, and explored the important academic value and practical significance of landscape design.

Dramstad et al. (1996) proposed 55 orders of landscape ecological planning and conceptual patterns of ecological design about patch boundaries, corridors, and mosaics in their book *Landscape Ecology Principles in Landscape Architecture and Land-use Planning*. Dube (1997) studied 48 natural landscape patterns through structural analysis of sketches, photographs, structural analysis, and esthetic qualities and deformed each pattern to adapt the needs of specific planning and design in the book *Natural Pattern Forms: A Practical Sources Book of Landscape Designers.*

Professor Simon Bell (1999) was influenced by the book *The Pattern of Landscape* of Dame Sylvia Crowe and the book *Design with Nature* of Ian McHarg and some ecologists such as US forest ecologist Jerry Franklin, landscape ecologist Richard Forman and Michel Gordon, and he absorbed the method of plant community patterns, applied the techniques of landscape analysis and evaluation by computer, and promoted the research on landscape pattern through integration of ecological and cultural landscape. He also studied the meanings of patterns and the approaches of perceptual patterns, discussed the forms of topographic, ecological, and humanistic patterns, and expounded them with theoretical analysis combined with practical examples. He believed that human beings were closely linked with the world in which they lived, and they should manage natural and cultural resources sustainably. The thoughts on landscape pattern of Simon Bell could be reflected in his book *Landscape: Pattern, Perception and Process.*

Booth (2012) specifically studied the spatial elements and their basic forms, characteristics, and utilization of landscape and the processes of functional coupling and design vocabulary in the book *Foundation of Landscape Architecture: Integrating Form and Space Using the Language of Site Design*, in which he especially discussed the strategies of site design language through integrating form and function of site. The site design language has been considered as an important theoretical and methodological basis for landscape architecture.

1.2.5 Development of Landscape Pattern Language

Pattern language is the basic theory and method in art teaching and the effective approach to learn traditional Chinese painting. Landscape pattern language is the new research system which combines the study of landscape language and pattern language and is different from pattern language of art teaching and pattern language used in architecture design. Landscape pattern language adopts spatial pattern as basic vocabulary of landscape expression and uses logic and organizational structure of language to study the spatial reasoning and formative mechanism of landscape based on landscape spatial units.

Professor Yuncai WANG in Tonji University began to focus on the organizational structure and formative reasoning of excellent landscape spaces with the characteristics of well-organized, high accessibility, high utilization rate, and strong services based on the researches of landscape space and ecological planning and design and appraised landscape services with its characteristics of fragmentation and isolation from the year of 2003 to 2011. He explored local characteristics and approaches of landscape and proposed landscape pattern language to solve the practical problems of cultural landscape from perspective of locality and their inheritance based on landscape pattern, process, and perception and also put forward the ecological design framework through landscape pattern language, in which ecological spaces were considered as the core concept of constructing the basic method of pattern language, implementing a large number of studies on the extraction of landscape pattern vocabulary and their logics and establishing the basic framework and system of landscape pattern language.

In this process, many new energetic forces joined in this study and exploration of landscape pattern language and formed an important team to promote the theory and practice of landscape pattern language which became the important part of landscape language and also the important extension and innovation of landscape language theory and had made great contributions to the transformation of landscape language theory into landscape practices with pertinent, actionable, and efficacious effects.

1.3 Organizing Landscape Space with Language Logic

1.3.1 Verbalization with Logic and Structure of Language

Language is a kind of ability which transcendentally exists in human thinking and can organize characters, words, phrases to generate complete meaning autonomously. The research based on pattern theory believes that language is the system of human cognition, of which language symbols, including words and images, reflect the objective world through cognition.

The cognitive system of pattern language should be formed on the basis of cognitive prototypes which are influenced by many factors including the inheritance of human group memory, individual growth environment, and experience, through which the cognitive activities are organized and translated into the storage mode. It could make the concept clear to form the process of abstraction and realize its manifestation through the symbolic expression.

In the history of architecture design and painting, the thinking of pattern is one of the main thinking modes, by which landscape space could be expressed through pattern language from concrete to abstract and to establish the basic vocabulary, spatial relationship, and logic of landscape through combination of spatial composition, organization, structure, function and perception image, context and meaning of landscape.

1.3.2 Space Units as the Basics of Total Landscape

Landscape pattern language is the method of landscape cognition established on the premise which the total landscape has the feature of strong structure and obvious deconstruction. Total landscape is composed of spatial units hierarchically with specific compositions and characteristics at multiple scales. The unit refers to space with its own landscape characteristics and services, is obviously different from the surrounding spaces in terms of function, composition, and form, and has the dynamic processes closely related to surroundings. There are similarities and differences among spatial units in terms of type, number, spatial distribution, and connection.

The ecological unit has the characteristics of dynamic change in time and space. The change in time aims to show the stable and dynamic process of function, shape, size, and structure of spatial units as time goes on, in this process, some traditional spatial reasons are endowed with new connotations, while some designs with traditional space reasoning still retain old implications. The change in space aims to show the dynamic process of type, size, and function in ecological unit caused by external factors or the relationship between competition and symbiosis among various parts in space unit.

There are two kinds of changes in time and space, one of which is dynamically stable, and the other is the abrupt changing process. The elements inside space unit and their interactions both change rapidly and correspondingly, and the functions of space unit would change accordingly under their influence. Therefore, the space unit acts as the basic unit of landscape cognition, understanding, learning, and shaping.

1.3.3 Space Units Lexicalized by Using Pattern to Symbolize

Landscape space as an integrated system could be understood as spatial complex with nested structure, of which the unit represents the complete space at specific scale, and is integrated structurally, independent functionally, and expressive ideographically in landscape. The structure, features, and meanings of landscape units are presented in the patterns which would be transformed to be vocabularies of landscape design corresponding to scales.

Landscape space could be divided into basic units and aggregated units which include composite and complex units, as well as holistic space from small to large. It constitutes the basic vocabularies of landscape planning and design by using patterns to express the diversity, locality, structure, and function of basic space units, which are the *'words'* in landscape pattern language. The representation, typicality, diversity, locality, structure, and function of complex spatial units are expressed by patterns which constitute vocabularies of aggregated spaces with specific structure in landscape planning and design, which are the *'phrases'*. There would be more complex landscape spaces in aggregation, which have the relatively complete spatial and organizational structure as well as specific landscape intention, but are still only working as the parts of the whole. These spaces are expressed by patterns which constitute the *'simple sentences'* in landscape pattern language.

The extraction of these vocabularies is the first step to design for landscape designers when they enter the site and begin to shape the personality of place based on in-depth understanding, analysis, and deconstruction of landscape. At the same time, the extraction and formation of design vocabularies are also known as the important sources for landscape designers to carry on designs innovatively, who could combine their own practical experiences and design trends of the era to form the personalized design language to adapt to the changes of design vocabularies. Although there are various forms of language expression, one of which is the expression method to use both the abstract and specific approaches to express space units in the form of pattern and to lexicalize landscape space units with pattern language of landscape.

1.3.4 Stitching and Nested Structure as Spatial Reasoning

Scale is the basic feature of landscape space, and scale design is the basic principle of landscape architecture. The structuring and deconstruction of landscape in design are two basic processes in landscape learning and cognition, by which the spatial relationship and reasoning among spatial units are extracted to construct the grammar system of landscape space described by pattern language, which could be attributed to the process and reasoning of the mosaic with horizontal structure and the matryoshka with vertical structure in landscape space. The design practices of landscape show that both scaling down and scaling up are the important spatial reasoning of landscape understanding and spatial logic of landscape design.

The modern art was use to shape stones which combined esthetics and technical supports to imitate natural surfaces of rock with the physical patterns formed by weathering in the work of New York Teardrop designed by MVVA landscape design firm in United States. The strong artistic interpretations of naturalism aimed to awaken people's memory of nature with landscape pattern language rather than simply imitated and forged nature.

The prototypes of vocabulary were extracted from the Waterfall Mountains in Oregon State and the Boniville Dam on the Columbus River in the work of Auditorium Forecourt Square designed and completed by Lawrence Halprin. The pattern of waterfall and the water overlay were showed through the features of rough and exposed concrete surface, and the bridge was provided through the large waterfall, rough ground, and dense woods in urban environment.

The patterns of ocean tides were transformed to design the features of special waterscape in the Jamison Square in Portland, a plaza landscape designed and completed by Peter Walker, which has become a famous designed landscape of urban tides pursued by lots of riders.

Japanese architect Kengo Kuma hang *'Urban Stories'* between the sculptural environment and buildings shaped an abstract and layered Japanese-style courtyard with Pieta Serena, bamboo, water, and pebbles in the work of *Nature-scape for Urban Stories* during the Design Week 2013 in Milan, Italy. This environmental design creates the landscape pattern with high and low terrains and various forms of water and paths.

The pattern of traditional Japanese garden with rocks was transformed from gardens at small scale to community landscape at mesoscale in the Haixing Tianxi residential area in Qingdao, designed by Shunmyo Masuno in 2010. In this case, it could be clearly felt that designers would make use of spatial logics of landscape pattern language to carry out scale transformation and design application at multiple scales.

1.4 A New Way to Spatial Reasoning of Landscape

1.4.1 A Nested Complex of Spatial Units with Multiple Scales

The scale of landscape space is one of the most important professional concepts for landscape planning and design, but the traditional method defines the scale mainly by experience and fuzzy size of space and always divided simply into micro, meso, and macroscale. In fact it is impossible to tell the accurate concept of scale and clear boundary of its division, which confuses the theory and practice of landscape planning and design and limits the implementation only being acted at the single scale for a long time.

It is considered that the scale feature of landscape space firstly is the objectivity in the theory of landscape pattern language, which is determined by scale effects and is related to factors of size, quantity, scope, and continuity, but these factors are just used to measure the scale and do not play a decisive role. The scale relationship between landscape spaces would not change if the changes of internal factors at the scale could not lead to a big change in scale effect. Only when scale effect changes greatly, the scale of landscape space would change, and it means that the process of scaling up and scaling down is possible at multiple scales.

Therefore, landscape basic units are spliced into larger units and scale effect would change corresponding with the lexical process in landscape pattern language, which means that a complete unit at one scale would be a basic component of another unit at a larger scale with the increase of unit aggregation. Landscape space is regarded as the scale complex with nested structure, designers could use the morphological and spatial nesting methods to internalize the scale processes in landscape shaping.

1.4.2 Revealing the Formative Process of Landscape Space

The spatial reasoning of landscape is the important part of spatial lexicon in the theoretical framework of landscape pattern language. The pattern vocabulary and logical relations are derived from landscape spaces working effectively, which are dependent highly on historical process of human–earth interaction and have the characteristics of context dependence and human centricity. On the one hand, it refers to the geographical environment that profoundly affects and restricts activities of human beings; on the other hand, it refers to activities of human beings that continuously transform the environment and landforms in order to survive and adapt to ecological environment.

Human beings interact with the natural environment and form the living community with nature. The natural processes are local processes of landscape environment evolution, while the shaping processes of human activities and social groups are the processes of modification added to the natural processes. The two processes are highly unified in the process of landscape formation.

The impact of environment on human beings is the great restriction on human activities which include human life and production, regional behavior, social development, ideology, and other aspects. All kinds of environment would urge people to accept the conditions and adapt to the material ways of life to some extent, while it provides the materials to satisfy human needs and plays an important and decisive role in people's cultural system.

With the development of science and technology, the impacts of social transformation on environment have been enhanced and the constraints of environment become less restrictive, which are the fundamental reasons for human becoming more and more detached from nature and shaping landscape with high intensity. Therefore, the reasoning of landscape space becomes the important basis for understanding landscape and is also the important syntactic and grammatical features of landscape pattern language.

1.4.3 Establishing Spatial Reasoning of Total Landscape

The spatial relations are the connections of space allocation within landscape space, among which the interdependent logics are spatial sequences subject to functions and processes, and they are always understood as spatial reasoning of landscape on the whole. The logics of landscape space include not only the morphology of pattern language, but also the syntax and rhetoric.

Landscape spatial reasoning could be understood as the complete relationship or the partial relationship, also could be understood as landscape order formed through perception, or behavior trajectory of the crowds in landscape and special compositions adopted by designers in landscape shaping. Spatial logics of landscape could be either the existing relations in the process of natural evolution or the spatial relationships created by designers. The spatial relationships are the main veins and inner connections which constitute the overall characteristics of landscape space.

The spatial reasoning of landscape is the important part of space lexicon in the whole framework of landscape pattern language. Different from the formative process of landscape, the relationships existing in the structure of pattern and driving forces behind are mainly analyzed to understand the reasoning of landscape space, which are also the big problems to be solved in the theoretical framework of landscape pattern language.

1.5 Conceptual Model and Knowledge Gap

1.5.1 Conceptual Model of Landscape Pattern Language

Landscape space is the integral space with structure, organization, and function, and space unit is the basic carrier to embody the characteristics of deconstruction and reconfiguration, through which landscape spatial unit and relationship could be understood and recognized, and the new landscape could be shaped through the innovation of spatial units and relations.

Spatial unit is the ideographical design vocabulary of landscape with the independent and complete characteristics. The basic, composite, and complex spatial units are the sources of words, phrases, and simple sentences of pattern vocabulary, respectively, which could be learned, inherited, and accumulated, and also could be design vocabularies of space formed through recognition of unique features. Therefore, the digging of pattern vocabulary is the key process of learning, mining, accumulation, reform, and innovation.

The effects of scale are the objective characteristics of space, but they are related to human feelings which are perceived both subjectively and objectively. The size of scale depends on the changes of scale effect, of which the big jumping always marks the state transition of scale. The processes and spatial organization at a specific scale are considered as the syntax of landscape pattern language, and the spatial processes and logical relations among scales are the grammar of landscape pattern language.

The context of landscape is determined by landscape elements acting as the matrix, and the total landscape is the landscape complex with a variety of landscape vocabularies highly dependent on local environment and context, which could be integrated as the organic whole in the process of horizontal stitching and vertical nested structure of spatial units. The overall landscape at the large scale would not be changed with the small changes in vocabulary and spatial relations at a short period of time and limited variation in space, but it would be made big changes over a long period (Fig. 1.1).

From the conceptual model of landscape pattern language, the theory of landscape pattern language needs to answer three big questions: What kind of landscape spatial units could be the prototypes of design vocabulary for designers to learn, accumulate and promote? What is the mechanism of scaling and spatial nesting in landscape pattern language based on its importance in application? How to apply landscape pattern language effectively in planning and design practice?

It could be concluded that four key studies of landscape pattern languages are of great importance to answer the three questions and establish the approaches to solve the problems: the selection criteria of excellent samples and landscape spatial performance evaluation based on ecosystem services, the principles, and methods of spatial unit identification and the framework of C-3P which means the component—pattern, process, and perception as the methods of spatial unit analyzing, the inflection point determination of scaling and landscape scale effects, the methodology and digitalization of landscape pattern language.

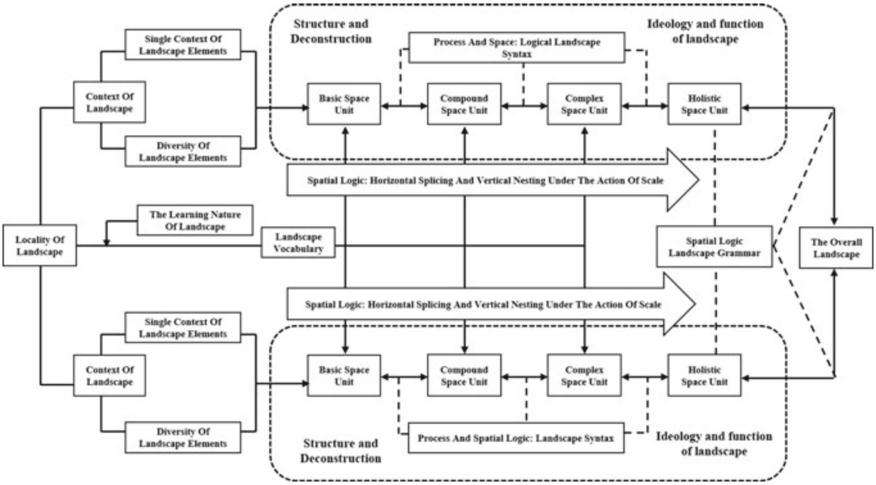

Fig. 1.1 Conceptual model of landscape pattern language

1.5.2 Knowledge Gap of Landscape Pattern Language

The theory of landscape pattern language is constructed systematically based on the researches of language and landscape language, ecosystem service and landscape performance, morphology and landscape configuration, man–earth relationship and human ecology, ecology, and landscape ecology from perspectives of questions and solutions.

What kind of space is the good landscape space? Landscape architecture could be unable to answer this question for a long time. The reason is that landscape space not only lacks the universal evaluation system, but also lacks the stable value orientation and pertinence. Based on the theory of ecosystem services and landscape spatial performance, indicators should be selected to measure landscape performance, which could reflect the features of multi-scales and multi-functions of landscape space from perspectives of ecosystem services. In addition, the performance of landscape space in landscape service and its efficiency are evaluated, and the comprehensive performance evaluation of landscape space is established to reflect the quality of landscape space providing corresponding ecosystem services.

Landscape ecology is the theory and method of spatial ecology based on the mosaic of landscape patch, corridor, and matrix, focusing on the spatial relationship of horizontal dimension, applying a set of methods to study the characteristics and formative processes of landscape complex at multiple scales. The paths and conditions of landscape space transformation have not effectively been solved from one scale to another in landscape ecology; meanwhile, the vertical nested process and reasoning of landscape space also have not been solved. Therefore, it could effectively support the researches on landscape pattern language in the horizontal processes.

The theory of human ecology is the key theory and method to reveal the internal mechanism between man and nature and socio-ecological conditions in local context. Local vocabularies and spatial logics had been formed in historical process, and the system of local landscape had been constructed in the process of cognition, adaptation, and transformation of nature in the specific environment. It is an essential theory to support landscape pattern language and also a fundamental theoretical basis to reveal the scaling and spatial nested mechanism, which is the theory and method to reveal the essential process of local landscape shaping.

The theory of landscape language provides a new thinking tool and path for landscape pattern language; however, landscape language is based on elements and lacks the research on spatial unit, process, and scaling of landscape. The method of combining morphology and typology in landscape is used to solve the problems of landscape morphology and organization in construction, of which the fusion and diversification are helpful to reveal landscape morphology, structure, coupling process of performance, and spatial logics.

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Chapter 2
Origin and Innovation of Landscape Pattern Language

2.1 Theoretical Context

2.1.1 Total Human Ecosystem Integrating Nature with Society

The development of ecological planning methods has gone through the process from natural ecosystem to human ecosystem and then to total human ecosystem with the targets of human settlements and focuses of landscape spaces, in which the method of suitability assessment was established mainly on ecological factors, and is the key concept of *Design with Nature* proposed by Ian McHarg in the 1960s. Then, the planning method developed to focus on the human ecosystem with the concept of *Design for Human Ecosystem* proposed by John Lyle in the 1990s, which emphasized the harmony between human and nature and the important role of landscape site and place. At the end of twentieth century, the concept of *Total Human Ecosystem* was proposed by Zev Naveh in the year of 1994, which established the unique ideas, methods, and technologies for people to recognize, utilize, and change the natural environment after a long historical process, and then formed the unique utilization and design method to shape the nature–human complex system integrally and organically.

2.1.2 Socio-Ecological Thoughts of Design with Nature

Human activities would be considered definitely to affect and interfere with the process, pattern, and interface of natural ecosystem from the thoughts of ecological planning represented by Ian McHarg's suitability assessment technology. The processes of ecological planning are always based on the positive feedback of natural environment in the framework of design with nature, on which the purpose of planning and design is to conserve the integrity of natural pattern, process, and extension

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of natural interface, while human needs are only the additional values established within the capacity of environment and ecosystem.

The uninterrupted natural ecosystem would also experience the process of degradation, withering, and even extinction due to natural succession and processes from the perspectives of John Lyle. All potential natural resources should be allocated in most suitable way to satisfy human goals and support human society through ecological planning and design which could provide the most appropriate way to create the best and sustainable habitat for the coexistence of humans and other creatures. The ideological system and planning methods on human ecosystem of John Lyle had broken through the framework of Ian McHarg and promoted the development of ecological planning toward the planning and design of total human ecosystem both in theory and practice.

2.1.3 Ecological Wisdom Bridging Science and Practice

Ecological wisdom is the ability to use ecological knowledge, principles, and laws to engage in behaviors which are beneficial to human sustainable development. It could come from the practice under the guidance of knowledge, or from the summary under the successful practice as well. It has become the important method in practical research to obtain the actionable and practical knowledge from practice. Ecological wisdom uses scientific knowledge and experience to dig out the intrinsic connotation of man–land relationships, establishes the realizable methods scientifically, and integrates the ecological relationships into practice either in design with nature or human ecosystem design.

Landscape architecture is the field of landscape engineering practice, which relies on many other disciplines such as geography, ecology, botany, behavioristics, architecture, urban planning, and esthetics. However, it focuses on the implementable and practical knowledge and skills based on researches of these scientific principles instead of scientific laws and mechanisms carried out by these disciplines, which prefers to space construction. Therefore, the wisdom of ecological practice has become one of the most important concepts of landscape architecture now.

2.2 Scale-Process-Order Supporting Spatial Logics

2.2.1 John Lyle's Ecological Thoughts and Wisdom

John Lyle believed that human ecosystem with nest structure is the unity composed of open systems with ecological orders at different scales, which contains the ongoing natural and ecological processes as links between and within systems. The key point of human ecosystem planning and design is to consciously respect, intervene, and participate in the natural and ecological process through the orderly and targeted planning and design process based on fully consideration of human factors and needs. In this way, the new ecological order in which people and environment coexist steadily would be shaped on the specific scale.

Three core ideas of John Lyle's human ecosystem design are scale and hierarchy, process and mechanism, and ecological order, which are described and interpreted in the aspects of integral characteristics, internal mechanism, and specific appearances; however, these three aspects are not three separated and juxtaposed parts of human ecosystem, through which the operating mechanisms and implemental methods of human ecosystem are constructed from macroscopic to microscopic and from extrinsic to intrinsic.

The ideological framework of John Lyle for human ecosystem design includes three core ideas, seven main standpoints, and their interactions (Fig. 2.1). The scale and hierarchy describe the main characteristics of human ecosystem from the overall view point, that is to say, the hierarchical relationships exist among ecological components which make up human ecosystem as the whole. The channels or corridors for the flows of material, culture, and energy would exist and connect between different hierarchies in human ecosystem, and each kind of components would still maintain their inner ecological specificity at the same time. John Lyle also pointed out that the explicit scope with specific or established scale is targeted with ecological planning and design.

Human ecosystem requires the support of the organized and orderly process no matter from perspectives of existing mechanism or theory of planning and design. On

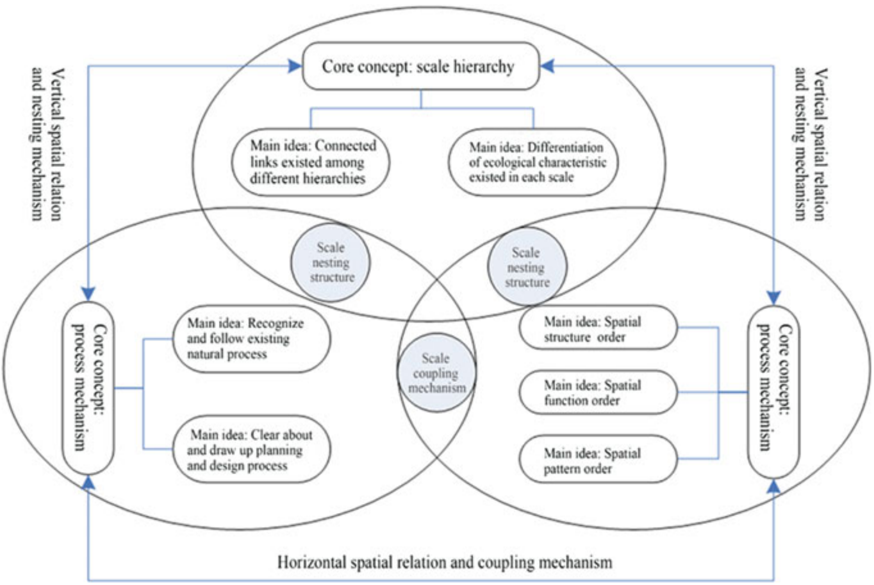

Fig. 2.1 Core ideology of John Lyle's ecological wisdom

the one hand, it means the natural and ecological processes are the internal driving forces to normal operations of human ecosystem; on the other hand, it means that the processes of planning and design set out from human needs are the significant methods of human ecosystem shaping. The ecological order describes the ecological characteristics at a certain scale from structure, function, and location, of which the significance is to clarify the reasons for stable existence and operation of human ecosystem.

The clear understanding of these three aspects also contributes to providing basic information, clarifying planning objects, and selecting analysis tools for ecological planning and design. The three core ideas are interdependent and interrelated and could interpret systematically the design ideology for human ecosystem of John Lyle. The ecological orders are considered as the expression of characteristics with scale differentiation on the horizontal dimension, which provide fundamental information and planning basis for ecological planning and design at a specific scale. The natural and ecological processes as the mechanisms of nested structure on the vertical dimension are showed as channels connecting scales and hierarchies in human ecosystem, and they are also ways to strengthen the connections between scales in ecological planning and design.

The process of planning and design intervenes and reshapes the existing orders of ecological structure through collecting, analyzing, exploring, and applying information of ecological location in terms of elements and their relationship, so that the orders of ecological function could act on normally and operate continuously under the premise of maximized human needs.

2.2.2 Nested Structure as Overall Feature

Different scales and nested relationships are the overall structural features of human ecosystem which could be regarded as the synthesis and decomposed into multiple scales. Human ecosystem exhibits different landscape patterns and ecological characteristics obviously at each scale due to the stitching effects on horizontal dimension although there is no clear boundary between various hierarchies. This provides the respective focuses for ecological planning at multiple scales so as to determine the appropriate research scope and planning features. It is nested structure on the vertical dimension that ecosystems at multiple scales are composed of the secondary sub-ecosystems and would also be part of the larger ecosystem, which finally forms the organic and unified entity.

Ecological planning at multiple scales should be considered on larger scale to avoid breaking the original key processes and connections as a result of ignoring the existing network and nested characteristics between scales. Therefore, the goals should be achieved from up to down and implemented from down to up in the planning and design of human ecosystem based on vertical relationships among scales. It means that the attributes of larger scale always dominate the directions for that of smaller one, and those of smaller scale provide the practical and operable approaches to implement for larger one.

Scale nested structure in John Lyle's human ecosystem design ideology emphasizes the scale grading, nested characteristics, and their effects to direct ecological planning and design. It makes up for the planning method of design with nature which is only applicable to landscape planning at relatively large or macroscopic scale and supplements the understanding of land properties, suitability of human activities, and restriction at the scale of region, planning unit, and even smaller scale.

2.2.3 Ecological Process as Key Force for Shaping

Human ecosystem is the synthesis of scales which could be decomposed, to which planners should identify and understand human ecological processes beyond the appearance of ecosystem, in which natural ecological processes focus on energy transfer and material exchange and socio-ecological process focus on historical culture changes and developments. Also, planners should deconstruct the organic unity of socio-ecological system through the processes of dispersing, decomposing, and analyzing and understand the formative processes and possible evolutions of human ecosystem with local, humanistic, and evolutionary characteristics under the backgrounds of geography and culture to excavate, refine, and form the inspirations of ecological planning and design.

Planners need to use various tools of design and analysis, such as sustainability comparison models, environmental impact assessment matrices, material, energy flow analysis charts, to conduct creative exploration and practice based on the analysis and application of scientific data. Meanwhile, planners should superimpose human understanding and perception onto the environment, recombine and shape the man–nature community through recognizing and experiencing the relationship between man and nature, and carry out ecological planning and design rationally and logically.

The process of design for human ecosystem proposed by John Lyle reveals that the horizontal interactions and material exchanges among various factors in ecosystem are also key forces of shaping the ecological characteristics of human ecosystem at multiple scales through the use of ecological planning methods and models. This theory complements Ian McHarg's excessive attentions to the vertical interactions and energy flows among ecological elements to a certain extent, while ignoring the horizontal interactions, exchanges, and influences among materials. In addition, this idea also emphasizes the important role of human in shaping ecosystems based on understanding of ecological process, succession, and evolution of ecosystem. Human should refine, protect, inherit, and develop the context of culture and geography through initiative participation and creation to shape total human ecosystem as the unity of nature and man.

2.2.4 Ecological Order as Guarantee for Stability

Ecological planning needs to organize and present a mass of information obtained from ecosystem in the orderly form with sufficient and internal connections, of which the key is to master the links and potential orders to unite the scattered components as an organic system and the purpose is to superimpose human factors onto natural factors in the rational and creative way of intervention to meet human needs and enable human ecosystem to operate stably with the rules and orders.

The key idea of ecological order proposed by John Lyle reveals the potential stability of human ecosystem through the modes of structural, functional, and location order. The structural order represents the abiotic elements of soil and rock, the biotic elements of producers, decomposers, and consumers. The structural order with hierarchical characteristics provides targeted analysis and planning focus for ecological planning at different scales. The functional order refers to the mutual influences and interactions among various elements, mainly in form of energy transfer and material flow in horizontal dimension, which is the reason why the structural order could be maintained at all levels, and it also provides an operational way to intervene and reshape the structural order in ecological planning. The location order describes the characteristics of the structural and functional order changing with location in human ecosystem, which are caused by the characteristics of different locations in different regions, such as topography, climate, temperature, humidity, and surface structure. Ecological patterns present the ecological structures and functional orders adaptive to each other, which are the reasons for the diverse characteristics of region in human ecosystem, and also the key approaches to shaping human ecosystem with local characteristics.

2.3 Language of Landscape: Space Order

2.3.1 Ecological Design and Cultural Adaptation Theory

The language of landscape has become an important theory and method to highlight individualization and local landscape. The method of modeling aims to seek common solutions to diverse problems, while the language of landscape emphasizes the diversity of landscape design vocabulary, locality, and diversity of spatial relationships, thus establishing design ideas of diversified local landscape. The researches on design language could be dated back to the eighteenth century, experiencing Germain Boffrand's *Livre d' Architecture*(1969), Peter Collins, Le Corbusier, Buthayna H Eilouti's *Towards a Form Processor* (2001) and C·Alexandria's *The Pattern Language*(1977), all of these had acted as the important design theories in architecture design.

The modulization and landscape language have also become one of the important fields of theoretical and practical research in landscape architecture with the development of 3S technology in the recent 30 years. *The Pattern of Landscape* by Dame Sylvia Crowe, *Landscape Ecology Principles in Landscape Architecture and Land-use Planning* by Wenche E. Dramstad, *The Language of Landscape* by Anne Whiston Spirn, *Foundation of Landscape Architecture: Integrating Form and Space Using The Language of Site Design* by Norman Booth and *Landscape: Pattern, Perception and Process* by Simon Bell, and other important books were published one after another. As the representatives of outstanding service, Simon Bell's researches on landscape pattern were inspired by the work of *The Pattern of Landscape* contributed by the British landscape architects Dan Sylvia Crowe and Mary Mitchell, American forest ecologist Jerry Franklin, American landscape ecologists Richard Forman and Michelle Gordon, as well as Ian McHarg. It absorbed the modeling method of plant community, applied the computer technology of landscape analysis and evaluation, and promoted the researches of integrated pattern which combined ecological landscape and cultural landscape organically, formed finally his own theory of landscape pattern and teaching system. The landscape language of Anne Spirn's work and the pattern language of C. Alexander acted on together to form the common foundations of landscape language, which revealed landscape space model, ecological wisdom, Anne's rich practice and travel experience, and her exploration of innovative teaching methods.

2.3.2 The Lack of Scaling Unfixing the Inner Logic

The research on Landscape Language originated early but developed slowly until the 1990s. *The Language of Landscape* of Anne W. Spirn was published in the year of 1998, became the most representative achievement in this field, and also opened up the new research field for the development of landscape architecture. *The Language of Landscape* is based on landscape architecture, landscape studies, landscape assessment, and human ecology, which discusses the modification, agreement, correspondence, subordination, coordination, and other linguistic rules of landscape and studies the basic constitution (landscape vocabulary), the order of landscape elements (spatial organization), context shaping (landscape environment), law of context (landscape grammar), and application of landscape language (pragmatics, poetics and dialectics). On the basis of theoretical research, Anne W. Spirn carried out practice researches on planning and design for a long term in MIT and teaching discussions at University of Pennsylvania through the case study of the Mill Creek.

The theoretical development of landscape language has not made the substantial progress although it is important to use the logic of language to understand the formative mechanism of landscape and establish the new ideas of landscape recognition and shaping. Landscape elements are considered as the basic components of space and basic units of landscape language, and the language of landscape emphasizes the relationships among elements instead of the relationships between landscape spaces without the system of landscape ideographic units and spatial organization units. It still lacks enough basis to establish the correct concept and accurate definition of scale and focus on the logic of single scale instead of multiple scales with nested structure and scaling mechanism of landscape space, which means that the logic and relationship of landscape space have not been established, the internal rules of landscape space have not been revealed, and essential relationships of spatial language are lacked.

2.3.3 A Tool for Research on Spatial Reasoning

Landscape pattern language uses space units as basic vocabularies instead of the way of landscape elements, which studies and describes the inner logics, functions, and performance among spatial units under the dominated scale processes, and forms the unique theory and method to reveal the mechanism and rules of landscape space. The original thinking of landscape pattern language came from the study of C. Alexander's pattern language on the rules of excellent sample spaces, Anne Spirn's landscape language on landscape space using language logic, Simon Bell's summary of spatial patterns, and John Lyle's ecological wisdom on spatial hierarchy, process, and order.

The pattern language focused on architecture and urban planning originated from the research of C·Alexander and then it became one of the important theories in the development of this discipline, in which 109 of the 253 models are related to landscape architecture, so it not only had the significant influences on architecture design and urban planning, but also became thinking source for the study on ecological planning and design. Today, it seems that the thoughts of landscape architecture reversed in pattern language have profoundly influenced landscape since its birth.

Jellicoe and Jellicoe studied the history of human environment shaping from the angle of cultural history and revealed the cultural patterns of human settlements from ancient times to the present in the book *The Landscape of Man* (1987), which are consistent with the ideas of C. Alexander. Boults (2010) and Chip Sullivan (2010) studied 46 basic principles and 84 basic design vocabularies of pattern language about landscape planning and design from perspective of landscape architecture. They revealed the important values in academy and practical significance of the essential thinking and methods of landscape design, as well as the exploration of landscape design ideas. Dramstad (1996) and others proposed 55 principles, concepts of landscape ecological planning, and conceptual patterns of ecological design with consideration of landscape patches, boundaries(borders), corridors (connectivity), and mosaics. Dube (1997) studied 48 patterns of physical landscape through the ways of sketches, photos, structural analysis, and esthetic characteristics, and he transformed each pattern to meet the demands of specific planning and design. Professor Simon Bell (1999) studied the meanings of landscape patterns and the methods to perceive them, initially discussed the topographical, ecological, and humanistic forms, and elaborated them with the methods, theories combined with examples. He believed that human is closely connected with the world where they live in; thus, human should manage natural and cultural resources better with consciousness to make them more sustainable.

Booth (2012) studied the elements of site, basic forms of spatial compositions, individual characteristics, landscape utilization, coupling processes of functions, and landscape design vocabularies and discussed the strategies of site design through integration of form and function, which have become the vital theoretical and methodological basis for landscape planning and design. Professor Yuncai WANG has successively carried out the researches on design vocabulary of landscape since 2009, such as water body, spatial interface, ecological network, landscape axis, public open space, land form. He established the logical system of landscape pattern language with spatial relationships based on the nested structure and formative mechanism at multiple scales and also explored to build the intrinsic processes of spatial relationship and locality of landscape in ecological planning and design.

The method of landscape ecological planning has experienced the process from natural, social ecosystem to total human ecosystem, during which socio-ecological factors were added more and more on natural factors gradually. The characteristics of locality, culture, continuation, and others were considered in analysis of ecosystem on the basis of naturalness, originality, and sustainability. It is the processes of integrating physical factors with human factors together that the planning and design of total human ecosystem have made great progress. The ideology of John Lyle's human ecosystem design provided a framework for description and cognition of the local and human characteristics of ecosystem through the studies of scale and hierarchy, process, and mechanism, as well as ecological rules and orders.

The methodology framework of John Lyle's provided us the paradigms of process and models of human ecosystem planning based on the rational process with design ideology of human ecosystem. And it emphasized the effects and roles of socio-ecological elements, such as the satisfaction of human needs, the participation of humanistic process, and the intervention of human factors. The methods are the complete and open systems established gradually after a long term accumulation through the studies of a mass of cases.

The landscape pattern language based on John Lyle's ecological wisdom of scale-process-order appears to be effective, which could integrate nature with socio-ecological processes into organic units of space acting as vocabularies connected with nested structure at multiple scales and transformations under the spatial mechanism. It effectively reveals the formative mechanism of total landscape from the part to the whole.

The theory and method of landscape pattern language could help to recognize landscape space and establish endemic spatial vocabulary and logic relationship, which is the guarantee for correct recognition of landscape locality and the important way for inheritance and continuation of local landscape. Designers could easily establish their personalized design system according to landscape pattern language in the process of accumulation of basic design vocabularies and spatial mechanisms. The advancement and change of design vocabularies and spatial logics with the era are the continuous and gradual processes and provide the effective paths for landscape innovations and characteristics shaping of the era.

2.4 Pattern Language and Landscape Ecology

2.4.1 Theory of Pattern Language

2.4.1.1 Influence of Pattern Language

The book *A Pattern Language* has had a wide range of influences on architecture and related fields since the publication in 1977. The American magazine *Architectural Design* declared that every library, school, environmental design organization, architect, freshman should own this book. After searching two keywords of C. Alexander and pattern Language from 1997 till now on Web of Science, it was finally retrieved that there are 20 pieces of closely related literature, 65% of which are papers about computer science, while 15% are papers on architecture. The trend is obvious with rapid increasing in the amount of research literature, but the time of publications on architecture is mainly around the year of 2000. The international interests of research on Alexander's pattern language are cooling down in the field of architecture, but his thoughts are still influential and burgeoning on computer.

The researches on pattern language in China began in the late 1980s and early 1990s, mainly of which focus on introducing the theory of Alexander's pattern language. It was found that there was just 30 papers directly studying and discussing the theory in the related fields of architecture by searching and analyzing the key words of Alexander and pattern language on CNKI. After the first climax of the theory introduction, it began 20 years later for the second climax of these researches, but just one paper discussed how to learn a lesson and construct the pattern language in Chinese environment from perspective of landscape architecture.

2.4.1.2 Development of Pattern Language Theory

The pattern language theory of C·Alexander was mainly interpreted through a series of theoretical books, in fact, the ideology could be observed throughout almost all of C. Alexander's theoretical explorations and could be traced back to his doctoral dissertation, *Notes on The Synthesis of Form* (1964), or it could be extended to the published book *The Nature of Order*. Throughout the context of Alexander's theoretical researches, it would be find that he and his research team of *The Environmental Structure Center* were assiduously trying to study the development rules of natural environment and the generation ways of city as the important living environment of human, of which the theory of pattern language was one of the main contributions as a result.

C. Alexander pointed out that it began with the search for a form suitable for context in design when considering the relationship between context and form in *Synthesis of Form.* He also proposed that the direct connection between context and form had been separated each other in the process of conscious design, and the form was designed just with the self-awareness of context by designers. As a result, it was easy to misunderstand the context, design with simplified concepts, and lack the ability to organize various forms into the entirety in order when the designers were facing the complex problems. Alexander proposed solutions to the above problems, which could be solved through decomposing the context into subsystems, finding the form for each subsystem, compositing the form by mathematical methods, and finally achieving the design goals mainly based on the rational thinking and mathematical methods. Obviously, the solutions had bred the seeds of pattern language although they still had some disadvantages, in which the concept of constructive diagram proposed by Alexander was particular the embryonic form of the theory of pattern language.

C. Alexander proposed the analyzing method called spatial pattern in the book *The City Is Not a Tree* after reviewing the mathematical methods. The theoretical thinking of pattern language was intensively illustrated in the book *The Eternal Way of Architecture* through theoretical summary and design practice although Alexander proposed the unpredictable and irritating concept of *The Quality without a Name* at the beginning of the book. He explained logically and exhaustively that everything full of vigor has the quality without a name. The patterns of constantly occurring events determine the characteristics of the environment, and those of the events are related with patterns of spaces.

It is necessary to find the active patterns in order to shape the environment lively. Alexander explained how to discover and test the active patterns and how to form the total structure of various patterns through programming language, so as to build buildings and cities where we live in. Finally, it was emphasized that *the quality without a name* could be produced only when the designers abandoned the way of pattern language. The theory of pattern language is very classic and widely accepted, which is worth noting that C. Alexander insisted to combine the theory with practice and test his theories during construction. The misunderstanding reasons might be that Alexander's theory did not create amazing architectural images which were exactly what Alexander had opposed.

Of course, C. Alexander had realized his neglects on the geometric features of spatial form. He not only put forward the concept of living structure and emphasized the focus on integrity, but also proposed 15 geometric characteristics of the total structure to further complete the theory of pattern language in his book *Essence of Order*. In short, Alexander tried to use pattern language to elaborate, name, and express the quality without a name which makes the environment full of vitality.

2.4.1.3 Main Features of Pattern Language

The theory of Alexander's pattern language born in 1960s ~1970s has distinct characteristics of the times when the contemporary western philosophy was flourishing shortly after the third technological revolution and many new theories and ideas were extremely active, including the theory of system, cybernetics, and information. The anthropology had also been accelerated the rapid development after World War II with the theory of confliction, process, neo-evolutionism, human ecology, structuralism, etc. The English teaching materials of Ferdinand de Saussure's on linguistics were also published in 1960. With the influences of the theory of system, linguistics, structuralism, etc., C. Alexander's pattern language manifested the characteristics of the era:

Synchronicity: Alexander used 7 words to describe the quality without a name he proposed; however, he always felt that it was not accurate enough when he listed the words every time. He said the last words that could help understand the quality without a name are eternity; they are free from internal contradictions and would place their site in the order which was independent of time at the moment they come out. The timeless way called by Alexander was to find those patterns which were independent of time and repeated but always different. The possible shortcoming of the pattern's synchronicity is the ignorance of historical factors.

Systematicness: C. Alexander compared the system of pattern language with that of the natural language and pointed out that pattern language was the complex system like the natural language, which was the spatial arrangement with meaningfulness of culture and finiteness in quantity and endowed us capacity to arrange space.

Integrity: The characteristics of pattern language are integral and organic just as that of the total system, which were reflected in Alexander's thoughts that the survival of pattern language absolutely depended on the degree of integrity. The complete system of language is formed by single patterns through the network structure, and the vitality of form by design is determined by the depth and completeness of spatial patterns used by designers. C. Alexander also pointed out that design is not the comprehensive process, but the gradual diversion process of the total structure.

Hierarchy: The hierarchy of pattern language is not only reflected in space at different scales, but also in different depths. As Levi Strauss pointed out in his structuralism theory, the pattern language also has the superficial and deep structures which are all established by the unconscious mechanisms or abilities of human.

2.4.2 Alexandria's Pattern Language on Landscape Architecture

The period when Alexander put forward his theory is also the important time for the development of landscape architecture in United States. The rapid development of modern industries and cities caused environmental pollution and other ecological problems. Then movements of environmental protection had emerged in United States in the 1960s. The book *Silent Spring* of Rachel Carson was published in 1962, which attracted worldwide attentions to the issues of environment. The book *Design with Nature* of Ian McHarg was published in 1969, which marked landscape architecture in United States shifting to environmental protection and ecological planning. Under the background of the era, Alexander came to the University of California at Berkeley to teach in 1963 and founded *The Environmental Structure Center* in 1967, whose theory directly influenced Lawrence Haprin, one of the leaders in landscape ecological planning in United States at that time.

After World War II, the city of California was also one of the fastest-growing cities in United States and attracted a huge number of young architects and landscape architects to start their businesses. The profession of landscape architect had just emerged when Lawrence Harprin began his practice of landscape design in San Francisco Bay in 1945, who recalled that there were few designers in this profession at that time, like well-known E. Ekebo and Thomas Church. In the 1960s, Lawrence Harprin gradually reached at a golden age of his design career and theories of landscape design; he became a good friend of Ian McHarg who was teaching at the University of Pennsylvania. They discussed the theory of ecological design and gave lectures at the University of Pennsylvania, at the same time Harprin completed the master design of the beach farmhouse in practice and formed the mature method and theory of his own. He created the term *Ecoscore* to describe and interpret the traces of natural processes. Of course, it was not a new idea originally created by Harprin, but it was different from that of McHarg and the ecologist Angus Hill who had similar ideas at the time.

The layer cake mapping of environmental resource survey and overlapped analysis method of Ian McHarg are irreplaceable and still used extensively today. In Harprin's view, the methods of McHarg could not describe correctly the dynamic natural system because they segment the dynamic and integral ecosystem artificially, and Harprin preferred to the theory of C. Alexander on the form and context, of which the illustrations of suitable forms and ideas on the relationships between context and form responding to the changes had influenced Harprin profoundly, which could be confirmed by *Notes on a Notation System* with 14 pages.

It is not difficult to find that the term *'Ecoscore'* of Harprin also has a theoretical basis from linguistics and semiotics, which is the integration of information transfer and decoding process. The essence of *'Ecoscore'* is the semiotic system which conveys, guides, or controls the factors and their combinations of spaces, time, rhythm, sequence, people, and their activities. Anne W. Spirn published her book *The Language of Landscape* (1998) 20 years later, which confirmed that the values and meanings of landscape language study in the discipline of landscape architecture.

Pattern language is the specific approach to grasping '*the quality without a name'*, which expresses the relationships among the certain correlations, problems, and solutions. In addition, the hierarchical networks are formed by the patterns through correlations, which act as the links between patterns at upper and lower scales and complements each other. It pointed out the inevitable key problems of design contradictions from perspective of pattern language, which are the principles that the potential solutions must be followed and could not be violated. The theory of pattern language is rich and flexible and could be combined with local culture and site conditions to create more specific and practical design forms from perspectives of practical applications.

The book *A Pattern Language* has three chapters of towns, buildings, and structures, which provided lots of universal guidance with inevitable principles and key proposals from planning to space design. The author believed that 10 gradations and classifications should be defined and reinterpreted to understand pattern language from perspective of landscape architecture (Table 2.1).

The total of 109 landscape patterns was selected from the 253 patterns proposed by Alexander in his book *A Pattern Language*, which were analyzed one by one and are nearly one-third of the total number of patterns (Table 2.2). Of course, it should be remembered that such selection is only for the convenience of research rather than separating deliberately.

2.4.3 Alexander's Contributions to Landscape Architecture

The value of Alexander's pattern language is first directly reflected in the system of illustrations. Alexander wrote in the preface of the reprinted book *Synthesis of Forms* in 1971 that the most important thing would be highlighting the concept of illustration when he read this book again. The constructive illustration the book mentioned above is actually the prototype of spatial pattern, which integrates the pattern of demand and the pattern of form together and means it is not only to reflect problems through using pattern, but also to express the appropriate forms to solve the problems. Alexander also believed that the duality expressed by constructive illustration is the characteristic of knowledge on form. In the preface, Alexander also pointed out that the illustration called patterns in his later works would be the key to the form creation process; therefore, the implication of Alexander's pattern originated basically from the concept of constructive illustration. It is worth noting that the so-called form here does not refer to geometric form or space image, but spatial relations which meet people's needs.

In the later discussion of pattern language, Alexander tried to express his deep and abstract thoughts in the concrete and precise way and emphasized the significance of illustration. He considered that everyone must be able to draw the patterns and also, for the same reason, everyone must name the patterns. At the same time, it elaborates 253 patterns in pattern language of architecture discovered by Alexander's team, and they were all expressed graphically, of which 109 landscape patterns were sorted out and classified. The thoughts these illustrations tried to interpret still have meanings and practical values today in many aspects, even if some patterns focus on the details. For example, the parking lot with shield expresses the idea of ecological design, the composting treatment is the pattern of domestic wastes recycling, the good materials reflect material recycling, and the jointed stone paving and soft tiles reflect

Table 2.1 Classification of Alexandria's pattern language

No	Classification of pattern	Description of pattern
1	Regional urban planning	Guidance from the perspectives of urban–rural planning, agricultural land distribution, and urban cultural heritage
2	Definition of community boundary	Maintaining community cultural integrity and sense of belonging, boundary ecology, and identification
3	Community land, function, road design	Summarizing the patterns of local cultural heritage, community ecological protection, spatial forms of community activity places, the spatial connection of streets, etc
4	Community environment and facility	Summarizing the layout of community green space, public space, and external activity facilities
5	Layout of external space	Summarizing the structural sites of outdoor space, analyzed the key point of site layout and design
6	External space detail design	Small space as typical outdoor space and with site characteristics
7	Introduce external environment into building	Analyzing how to borrow the scenery inside the building, to maintain connection with the external environment, and how the outdoor environment affects the internal space of building
8	The junction between indoor and outdoor space	Analyzing the junction closely related to the building and the external environment and explaining how to design the junction with rich levels, which integrates internal with external space
9	Garden integrated fully with nature	Analyzing the construction patterns of landscape such as economic parks and gardens, focusing on how people create comfortable spaces and fully contact nature
10	Important boundaries outdoor	Summarizing the typical engineering elements that need to be paid attention to in landscape construction, which affect the style, esthetics, comfort, and environmental quality that people could directly perceive

sustainable storm-water management, etc. The door, window, and corridor which could borrow views from outside coincide naturally with the space construction thoughts of classical Chinese gardens. These could be used as the references for the development of landscape pattern language with Chinese characteristics, just as Alexander said, these patterns could be directly applied to landscape planning and design to create design forms.

Table 2.2 Landscape pattern language summarized from Alexandra's system

Classification of patterns	No	Name of pattern	Classification of patterns	No	Name of pattern
I. Regional urban planning	1	Independent area	VI. External space detail design	110	Entrance
	2	Distribution of town		111	Semi-shaded garden
	3	Finger-like overlap between urban and rural areas		112	Entrance transition space
	4	Agricultural valley		114	Layers of external space
	5	Architectures along rural street		115	Dynamic courtyard
	6	Towns in the country		118	Roof garden
	7	Rural area		119	Arcade
	8	Mosaic of subcultural areas		120	Trails and markers
	10	The charm of city		121	The shape of path
II. Definition of community boundary	12	Community of 7000 peoples		122	Facade of building
	13	Subcultural boundary		123	Pedestrian density
	14	Recognizable neighborhood		124	Bag-shaped event venue
	15	Neighborhood boundary		125	Steps to sit on
III. Community land, function, road design	22	Area of parking lot below 9% of land		126	Scenery in the center of space
	24	Precious place	VII. Introduce external environment into building	134	Zen viewings
	25	To the water		135	Interweaving of light and dark
	30	Activity center		150	Waiting place
	31	Place for walking		192	Window to view life outside
	32	Commercial street		199	Sunny kitchen workbench
	33	Nightlife		221	Windows and doors with borrowed view
	45	Necklace-like community industry		222	Low windowsill

(continued)

Table 2.2 (continued)

Classification of patterns	No	Name of pattern	Classification of patterns	No	Name of pattern
	47	Health center		236	Large open windows
	49	Winding road in the area		238	Filtering light
	51	Green streets		239	Small pane
	52	Trail network and cars	VIII. The junction between indoor and outdoor space	158	Outdoor stairs
	53	Main doorway		160	Building edge
	55	Sidewalk higher than road		161	Sunny places
IV. Community environment, event venue, and facility design	59	Secluded area		162	Shady side
	60	Greenland near the house		163	Small enclosed outdoor space
	61	Small square		164	Windows facing the street
	62	Overlooking highland		166	Cloister
	63	Street dance		167	Six feet wide balcony
	64	Pool and creek		168	Closely connected with land
	67	Public land	IX. Garden—fully contacted with nature	169	Terrace
	68	A place to communicate with each other		170	Fruit forest
	69	Outdoor pavilions		171	Shady space under tree
	70	Cemetery		172	Wild garden
	71	Pond		173	Garden fence
	72	Local sports venue		174	Path under the shed
	73	Adventurous playground		175	Greenhouse
	74	Animal		176	Seat in the garden
	88	Street cafe		177	Vegetable garden
	92	Bus stop		178	Compost
	93	Food store	X. Outdoor details—important boundaries	207	Good material
	94	Snoozing in a public place		226	Space beside pillars

(continued)

Table 2.2 (continued)

Classification of patterns	No	Name of pattern	Classification of patterns	No	Name of pattern
V. General layout of external space	97	Parking lot with shield		241	Outdoor sits
	98	Internal traffic area		242	The stool outside
	100	Walking street		243	Low wall to sit on
	101	Street with cover		244	Canvas canopy
	102	Various entrances		245	High flower bed
	103	Small parking lot		246	Climbing plants
	104	Site refurbishment		247	Stone paving
	105	South facing outdoor space		248	Soft tiles
	106	Outdoor enclosed space		249	Decoration
				250	Warm color

2.4.4 *Insights of Alexander to Landscape Architecture*

2.4.4.1 Discovery of Pattern Language: Understanding Nature

The original meanings of Alexander's pattern language would be changed more or less in application, and there are both successful and frustrated applications and cases although it has been used in many other disciplines. The researches had concluded that the value of it shows mainly in the process of discovery rather than itself. Alexander said directly in the book *The Eternal Way of Architecture* that the quality without a name is the essential feature of nature. In terms of quality itself, Alexander said in Chap. 8 of the book that the quality would become a part of nature, like a sea wave or grass-blade, and its parts would be dominated by endless repetition and changeful movement produced by the flow of everything when a building had the vitality. The process of discovering pattern language is just the process of understanding nature and pattern language provides a convenient approach to understand nature, which is exactly the core of landscape architecture aiming to understand nature and coordinate the relationships between man and nature.

How does the pattern be discovered? Alexander did not say it explicitly at that time, but he told us that the characteristics of place are given by events which happened there and space patterns are related to event patterns. Therefore, it is the way to discover the patterns by observing recurring events which are not only social events and human activities, but also natural processes, such as sun shining on the ledge and wind blowing across the grass. It is a difficult task to discover the pattern in which the process is actually the process to find the correlations between the feature of the quality without a name and the spatial—temporal complex, and the process to grasp the essence beyond ever-changing forms through experiencing the driving forces of dissolution, and also the process to express the intuitions accurately. It must and could only be done to test whether the pattern is active with real and holistic sense.

Therefore, there is no other way to understand nature, but to observe, feel, and return to nature. Some scholars believed that Alexander's theory finally returned to a board concept and fell into a logical error, but I thought that Alexander emphasized exactly the importance of perceptual cognition. Perhaps the consistence of rational thinking and logic is very important in terms of architecture and space, but I think Alexander pointed out the only way to understand nature which here is not an ecological concept or knowledge in the book, but the real and holistic feeling of people from the angle of landscape architecture. Alexander tried to accurately express his discovery and understanding of nature using the system of pattern language with rigorous logic, and it was the inspirations that shew Alexander's ecological wisdom and thinking with rationality and sensibility.

2.4.4.2 Purpose of Pattern Language: Experiencing Nature

C. Alexander proposed the system of pattern language because of his disappointment with the education of contemporary architecture, who believed that the personal rationality and pursuit of designers to novel form are against the essence of architecture, and the purpose of pattern language is to help everyone except for planners and architects to build architectures and cities by themselves. He wrote that a city would have grown up calmly under the management, just like flowers in the garden without the help of architects and planners if you started the journey of eternity. Alexander also helped people to build houses by themselves in practice. Therefore, it is generally believed that Alexander's pattern language is a tool to promote public participation.

What Alexander was longing for is the construction process of subject-object unity, in his opinion, construction is the necessary process for building and city formation through one pattern combining with another to generate architectures, groups, and even the whole city through construction and renovation. He opposed to separating design from construction to make it independent. For landscape architecture, who designs for who is not the real relationship between human and nature, it is the experience process of integrating man and nature. Therefore, the role of landscape architects is not just a planner or designer for nature and built environment, but the experiencers who understand nature with his own real feelings by contacting with nature, observing nature, and also directors to help people understanding and participating in nature. The missions of landscape architects are respecting, coordinating and shaping the natural environment in practice, and experiencing nature through construction.

2.4.4.3 Approaches to Chinese Landscape Architecture

C. Alexander's pattern language is not only synchronic and eternal but also everchanging and different, which changes due to differences in culture and space pointed out by Alexander. He considered that every dynamic and intact society would have their own unique and clear language, each culture would have its own pattern language, and language would determine the environment quality in this cultural context. In China, the unique and diverse geographical environment and long history gave birth to its own pattern language, for example, the theory of *Fengshui* emphasized the harmony between man and nature to maintain the balance and stability by internal forces, of which the QI in *Fengshui* was similar to the vitality as Alexander said. It stated that the QI could disperse along with wind (Feng) and could be stopped by the boundary formed by water (Shui), and it should be gathered to prevent dispersing, make it dynamic without breaking the boundary, so it was called *Fengshui* in the book *Burial Scriptures* written by Pu GUO in Jin dynasty of China.

The theory of *Fengshui* also emphasized the importance of spatial pattern, from which the direct evidences whether Alexander was inspired or not could not be found but the time when he proposed the theory was also the climax for the western to study the eastern culture. It could be proved from his explanations of Chinese and Japanese cases in the book and the eastern culture images in the pattern language mentioned above. Therefore, Alexander's pattern language gives us the enlightenment that we should discover the system of pattern language suitable for the characteristics of domestic environment from the profound traditional culture, which should be re-experienced, tested, and used.

2.4.5 Expressing Horizontal Ecological Relations

2.4.5.1 Expressing the Heterogeneity of Space

Landscape ecology mainly studies the interactions between the spatial pattern, ecological processes, and their dynamic changes at macroscale and mesoscale in landscape, which was first proposed by C. Troll in Germany in 1939 and mainly studied the interaction between landscape patterns in specific regions or ecosystems, as well as their impact on ecological processes as the interdisciplinary research involving ecology, geography, and environmental science. The temporal and spatial changes in compositions of living and non-living in ecosystem had been observed by ecologists, but they did not have the technology and concepts to deal with the heterogeneity of landscape at the early stage.

The trend gradually emerged to deal heterogeneous space with identifiable units formed by group characteristics and to study on the spatial structure, time process, and ecological equilibrium of plant communities. The ecological equilibrium theory was the dominant ecological thought from 1920 to 1980s, on which *International Association for Landscape Ecology* was established in 1982. Richard T. T. Forman and Michel Gordon published their outstanding research results on landscape ecology in 1986. Its value lies not only in summarizing the basic principles of landscape ecology, but also in stimulating the interests on ecological heterogeneity of North American scientists who used to focus on human-centered scientific research in the field of human geography, landscape architecture, and urban planning, which originated from the attentions of European scientists to the heterogeneity formed in the long history of landscape transformation.

2.4.5.2 Pattern Language of Patch-Corridor-Matrix

Regional landscape could be described by the pattern language of patch-corridor-matrix according to the units of heterogeneous landscape which are the synthesis and nested mosaic with interacting patches, corridors, and matrix under certain rules in a region. The patch is a nonlinear surficial area which is different from surroundings or background in appearance. The difference between diverse patches reflects the features of size, shape, boundary, heterogeneity, complexity, etc., among which the size of the patch is the most basic and important feature to affect directly the ability of resisting disturbance, process, and function. The corridor is a narrow strip of land which is significantly different from the background on both sides, which separates different parts of landscape and connects other different parts of landscape to form an integrated entirety on the other hand. The matrix is the landscape element of basis which occupies the largest area, has the strongest connection, and plays the dominant role in landscape function. The spatial shape and characteristics of matrix depend on the distributions of patches and corridors, which largely limit the development directions of the region and the choices of management measures. The mosaic of patch-corridor-matrix is the common language to describe all landscape patterns from perspective of landscape ecology.

2.4.5.3 The Source-Sink Pattern of Landscape Process

The source-sink pattern focuses on landscape process, of which the analysis was proposed by Liding CHEN in 2003, who engages the research of landscape ecology in *the Eco-environmental Research Center*, Chinese Academy of Sciences. The key is to redefine the character of landscape types from perspectives of ecological flows and classified landscape into the source and the sink according to the role and function of landscape by ecological process. On this basis, the load ratio index of landscape space was constructed based on the source-sink process, which had been preliminarily verified and could be used to compare the advantages and disadvantages of landscape patterns of different watershed in controlling soil erosion and nutrient loss during the same period. And it could also be used to compare the effects of landscape pattern changes on soil erosion and nutrient loss in the same watershed while in different periods. At present, the concept of landscape source and sink and some corresponding evaluation methods had been applied to the evaluation of water resources conservation, soil erosion, heat island effect, and other fields of forest patterns.

2.4.5.4 Landscape Ecological Security Pattern

Landscape ecological security pattern is the spatial pattern which uses the landscape pattern of patch-corridor-matrix, combines the process of source-sink, and distinguishes the functions and roles of patches and corridors. Regardless of whether landscape is homogeneous or heterogeneous, spatial connections in landscape have different significance to the ecological processes, of which the parts, spots, and spatial relations play a key role in controlling the horizontal ecological processes of landscape and constitute the ecological security pattern of landscape.

The ecological security pattern of landscape is composed of some landscape spaces as components with the characteristics of scale, importance, priority, configuration, and function. The space of source refers to the existing habitats of native species and acts as the source of the diffusion and maintenance of species. Buffer zone means the surrounding area of the source with the relatively low resistance for species diffusion. The linkage between the sources means the low resistive channel which is most easily connected between two adjacent sources. The radiating route means the low resistive channel radiating from the source to surrounding landscape. The strategic point means the stepping stones which are key to communicating the connections between adjacent sources. The ecological security pattern of landscape determines the strategic components of landscape through the dynamics and trends of ecological processes in landscape with the obvious features of heterogeneity.

The strategic significance of the components in security pattern to control ecological process is reflected in three aspects: The active advantages mean that it has the preferential advantages for the security pattern to control the holistic or partial landscape once the components of security pattern are occupied by certain ecological processes. The advantages of spatial connection mean that it is helpful to establish spatial connections for isolated elements of landscape once the components of security pattern are occupied by ecological processes. The advantages of high efficiency mean that it controls the whole or partial landscape for ecological process to achieve the economic goals with high-efficient flows of material and energy once the components of security pattern are occupied by ecological processes. In a sense, the high-efficiency advantage is the general characteristic of security pattern, and it is also included in the active advantage and spatial connection advantage.

2.4.5.5 Typical Pattern of Landscape Ecological Space

Spatial pattern is the common feature of natural and socio-ecological space, of which the basic feature fully reflects the spatial organization and space with efficient optimization. Spatial pattern is also landscape complex reflecting the spatial laws which must be followed in ecological planning and design.

The symbiosis of three kinds of spaces must be coordinated and unified respectively for the residence and living, production, and ecological function in the planning and design of human-centered landscape, of which the basic spatial units are combined each other with different structure and approaches to form spatial patterns with the characteristics of both diversity and completeness at multiple scales.

The four indispensable patterns with top priority are summarized as the pattern of patch with large and complete natural vegetation, the pattern of vegetated streams and rivers, the pattern of connections by corridor and stepping stones, and the pattern of heterogeneity introducing small natural patches inside landscape matrix.

The pattern of aggregate-with-outlier is the effective pattern of land use diversity, which reflects the important ecological characteristics of landscape configuration, such as risk diffusion, heritage change, edge zones, corridors, large or small natural vegetation patches. It shows that the areas with crowd activity are planned along the boundary, of which land use should be relatively concentrated and small natural vegetation patches and corridors should be protected in built-up areas.

The pattern of integrity and penetration is the kind of landscape space, in which heterogeneous patches and linear channels permeate in various forms at the edges or inside to form the space pattern with both integrity and mutual permeation under the premise of conserving the integrity of large patch.

The intermeshed and extended pattern describes the growing landscape space formed in historical process with highly integration of natural environment and human society, of which the form and texture are the result of both natural and social processes and also the result of integration of natural and cultural landscape.

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Chapter 3
Landscape Unit: Base of Pattern Language

3.1 Ecological Space and Its Characteristics

3.1.1 Ontology and Ecocharacteristics of Landscape Space

3.1.1.1 Object of Pattern Language: Total Human Ecosystem

Landscape mosaic is regarded as the total human ecosystem (Naveh 1988) which is formed by co-evolution and development between man and natural environment in the long term and the main object of landscape planning and design. Man and nature are integrated with each other at a specific region on earth, and nature endows man with habitat, material, and wisdom of survival, while local people respect nature and make use of it to achieve the foundation of survival and development. Therefore, three kinds of activities of natural ecosystem, social and human system, and industrial and economic system are integrated as the organic whole in space inseparably, which constitute all the characteristics of total human ecosystem. Human activities are limited rather than unlimited to meet human needs due to the existence of natural laws and ecological capacity in landscape environment.

Total human ecosystem is formed in the processes of interaction between man and nature in the system of technology, culture and value ethics along with further understanding of environment and continuous improvement, which is the result of seeking the most suitable way for human existence and the best way to natural ecological protection, and the most harmonious and symbiosis model combining the natural ecological ethics to that of coordinating, continuous production value, and harmonious life. The ecological relationship between man and nature in landscape space is equal and adaptive to each other, which is neither human-centered humanism nor environmentalism centered on nature, but ecological value ethics coordinated by man and earth. The natural elements, ecological processes, and functions of landscape fully reflect the natural characteristics of local context, which change little in a long historical process and maintain the stability of natural ecosystem. The industrial system formed by the interactions between man and nature should be controlled

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https://doi.org/10.1007/978-981-19-6430-5_3

within the capacity of industry type, production scale, and intensity appropriate to the natural environment. Self-sufficiency is proved to be a rational behavior of protection natural ecosystem from over utilization.

After a long period of historical development, human beings have accumulated and inherited a large number of local customs and then gradually formed the unique system of local culture which is shared by people in region. Local culture is not only human culture, but also the culture of nature. The traditional total human ecosystem is the product of agricultural society, which had become the most precious culture heritage in modern society. The protection and continuation have become the theme and hard work of traditional total human ecosystem with the developing and changing of society. The large populations and consumptions, more deep interferences, modern technology, and efficiency have become the driving forces to influence the development of total human ecosystem and face the fragile natural ecosystems under the development of new technology and new concept.

3.1.1.2 Ecological Space: Carrier of Ecosystem

The ecological characteristics of landscape space are embodied in the unity of landscape elements with biological and non-biological environment, time and space of landscape process, form and function of landscape service, and subject and object of landscape perception. Landscape space is a place where carries the relationship between man and nature in the whole process of understanding, using, transforming, shaping, and establishing the harmonious and unified interactions.

The most basic ecological manifestation of landscape space is that all the living and non-living things in landscape space directly coexist in an integrating system with specific structure. Landscape process dominates the characteristics of landscape space pattern, and the unification in time and space of landscape process shapes the stability and regularity of landscape space. The diversity and integrity of landscape process lay foundations for biodiversity and relevance within landscape space. The difference of landscape is the important basis of forming the basic units of landscape, which are integrated in the process of splicing and nesting from the parts to total landscape.

There are several complete and independent subsystems at multiple levels within an ecosystem with nested structure. Landscape spaces also become the complex systems and nested bodies with dominant functions at multiple scales, among which there are features of scaling in ecological process and structure (Arganaraz and Entraigas 2014). Landscape space could be regarded as the human–natural complex composed of several relatively independent and functionally coupled spaces, in which the intricate processes lay foundations for the cognition, analysis, evaluation, and discussion of spatial reasoning due to the mosaic and nested structure of total human ecosystem. Therefore, the space of total landscape could be deconstructed through the reverse process of landscape space forming, of which the deconstruction has become an important method to recognize the flows and functions of spatial units. It has become the important sources of landscape space restructuring and shaping through the study and accumulation of a large number of spatial vocabularies in high quality.

The effects of landscape scale are the phenomena that the results of landscape space analysis would change with the size of landscape unit becoming bigger and bigger due to aggregation of basic units, also the results of landscape space analysis changes with more and more refined resolutions, or changes with longer or shorter intervals of time, which are manifested in the interactions of landscape scale, structure, and process. The scaling refers to the transforming of information between spatial scales and organizational levels, in which the process of scaling up at small scales to large scales is called upscaling, whereas scaling down is referred to as vice versa. The relevant studies have found that some principles and laws observed and studied by people at one scale are still valid and might be approximate at another scale, but some could not be transformed, it was uncertain that some information at small scale might be integrated with environment at large scale, and the information or pattern at large scale might be applied to the environment at small scale. So the disciplines of architecture, landscape architecture, geography, ecology, biological oceanography, and physics are all involved in the study of scale transformation.

The perception and ideation of landscape spaces are the important characteristics which distinguish landscape spaces from other disciplines. The composition and vocabulary, organization and sequence, characteristics, and images of landscape become the important ways and meanings of landscape space perception and expression.

3.1.2 Localization of Landscape Space Design

Landscape planning and design must focus on the personality of site where the relations are tangled between landscapes and its elements or interactions among space units. For the combination of ecological space units and its patterns, they require that spatial structure must be adapted and coordinated with the environment. Therefore, landscape design needs to be diversified, regionalized, and practiced.

Ecological space unit has the common characteristics of space, as well as its own unique characteristics and development mode. For space research, the aspects of spatial flow, intention, pattern, organization, structure, and interface are the breakthrough points of space research which could be reached accurately according to the methods and characteristics of landscape ecological design (Fig. 3.1). The research includes the dynamic change, morphological characteristic, landscape expression, spatial scale, nested structure, land mosaic, configuration, function, and interface of landscape, by which the characteristics and ecological flows could be understood deeply through the discovery of landscape feature and essential relations of ecological units to provide ideas for landscape ecological practices.

For thousands of years, the rich and colorful landscape spaces had been formed under interactions between man and nature, which are the crystallizations and essences of human ecology in total human ecosystem. With the development of

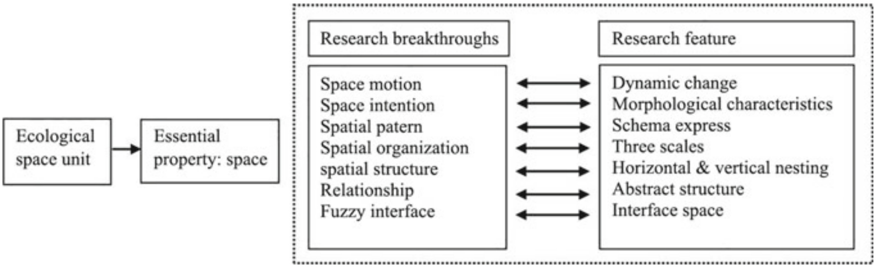


Fig. 3.1 Corresponding relation on the study of ecological space unit's feature

urbanization and industrialization, the regional landscape is facing unprecedented impacts and challenges which make people have to pay much attentions to and summarize the formative texture and morphological characteristics of regional landscape again in the process of culture convergence, landscape destruction, and local activities disappearance in one region. It is the trend to build local landscape to accord with social development through paying attentions to and understanding the types of regional landscape, as well as coordinating the needs of local economy, social activities, and other aspects.

It was well known that the methods of traditional garden design always started from the basic elements of landscape and the garden was built by simulating natural landscape, which is an effective way to explore the combinations of different elements but still lacks the improvement of systematic summary and generalization. Under the influence of traditional ideas, people paid much attentions to the compositions at the beginning, such as form of space and road of garden, instead of landscape construction of regional characteristics and role of subjectivity and regularity of space itself. In recent years, people gradually shifted the focus to construction of land texture and regional culture, and they hope to provide new way to landscape construction by constantly exploring the relationships between texture, space, and function.

It had been transformed from pure natural space originally into socio-ecological space where nature and human are united as one with the widespread acceptance and recognition of ecological space and of which the characteristics are also being recognized and obliged as basic rules by people. The ecological space carries a variety of human activities and bears the vitality of regional development. The application of ecological rules to design could promote the construction and development of regional landscape to the greatest extent through the construction of ecological planning theory.

3.1.3 Meaning and Theory of Ecological Space

Ecological space is considered as the heaven for living things to appear, raise up, and exist and the external conditions for organism to maintain its own survival and reproduction from perspectives of ecology, which is used to explain the physical states of environment where human lives in and the difference of landscape components, forms, and functions with region and time. Ecological space is the collection of all spaces for survival of living things at macrolevel, which could be composed of regional ecological spaces or their subordinate ecological spaces. Ecological spaces in landscape design include not only the green/blue spaces, such as wetlands, lakes, grasslands, reservoirs, rivers, and some special spaces as saline-alkali land, plateau, desert and sandy, but also the designed ecological spaces, such as the spaces which meet the demands of production and daily life.

The units of ecological spaces are mainly defined from spatial effects, behaviors, and functional characteristics. Spatial effects refer to interactions between biological elements and environmental elements in ecological space, which are manifested as certain spatial morphology, distribution, and scale to a certain extent. The behaviors emphasize the motivations of spatial heterogeneity which could be found through diversified ecological space units and could create conditions for the design of regional landscape characteristics. The functional characteristics emphasize the combinations of different and specific spatial textures to form the resources available to human beings, which are also the inevitable results of forming specific functions of land. Many researchers have studied the theory of ecological space, including spatial pattern, scale, mosaic dynamics and heterogeneity, and so on. At present, it is still lacking to apply these mature theories of ecological space effectively to landscape planning and design.

The ecospace theory was first derived from studies of predation dynamics by Gause (1935) and Huffaker (1958) subsequently, and then MacArthur and Wilson (1967) promoted the island biogeography which revealed not only the rapid development of spatial ecology, but also aroused a group of biologists paying attentions to spatial processes at that time. At the end of nineteenth century and beginning of twentieth century, the theory of *Garden Cities of Tomorrow* was considered conforming to the theory of ecological space and proved the rationality of ecospace theory in a certain sense. Many ideas and methods of ecological design were put forward in Ian McHarg's *Design with Nature* (McHarg 1995) which provided conditions for the cognition and development of ecological spaces in landscape; however, many scholars still had many reflections and doubts on his theory and believed that natural processes were only emphasized in the model of thousand-layer cake at vertical direction, which limited the ecological relationships within spatial units and ignored the ecological processes at horizontal direction and ecological processes among landscape units.

The relationships are emphasized in contemporary theories of landscape planning between the horizontal ecological process and landscape pattern, which study the mechanism of spatial patterns and ecological flows between ecosystems including flows of material, species, disturbance and diffusion, etc., and emphasize the control and influence of landscape pattern on process, try to maintain the health and security of landscape flows through the change of pattern, and especially emphasize the relationship between landscape pattern and the horizontal movements and flows.

3.1.4 Concept and Drivers of Ecological Space Unit

The understanding of spatial units is limited to identify the elements and interactions within space, and there are not many scholars studying the effects of ecological spaces and their formation of morphological texture on landscape construction and regional protection. Ecological spaces not only are the units composed of landscape, but also the most commonly used and studied scale type in landscape planning and design, which refer to the type of space with ecological characteristics, functions, and dynamic processes of changing and is closely related to the surroundings. There are similarities and differences among ecological spaces in type, number, spatial distribution, and connection (Bell 1999).

The ecological space units have the characteristics of dynamic change in time and space. Changes in time aim to show that the function, shape, size, and structure of ecological space change stably and dynamically in temporal process. Changes in space are intended to show the dynamic processes of type, size, and function in spatial units due to external factors or the interactions of various parts within spaces. The shape and function of space units are basically unchanged in the process of dynamic but stable changing, while the elements and their interactions in space unit change rapidly and irreversibly in the process of mutation. The interacting relationship and coupling mechanism among space units could be found through studying the changes of ecological space units in time and space (Table 3.1).

The evolution of ecological space units is the manifestation of the continuous changing process of city in the process of rapid urbanization. The research on the coupling mechanism of space is also to find better design ideas and effects, of which the interadaptation mechanism of function and structure at multiple scales is manifested as processes of the horizontal mosaics and the vertical matryoshka in protection and innovation of ecological space units.

3.1.5 Coupling of Ecological Space Units

3.1.5.1 Coupling and Integrity

The spatial heterogeneity is caused by the difference of non-biological environment and various man-made and non-human disturbance in the long-term development of landscape. It is mainly manifested as the heterogeneity and complexity of spatial distribution of various ecological spaces, which are the comprehensive manifestation

Table 3.1 Factors influencing ecological space units

Factor	Content	The relationships	Result
Natural factor	Geological hazards: floods, hurricane, tsunamis, earthquakes, etc.	Adversarial relationship	The irreversible destruction and change of ground landscape and the habitat were seriously changed, and the relatively stable relationship between the elements was broken
	Stable processes of natural dynamics: succession of plant communities, riverbank scouring, raining and snowing, formation of valley winds, etc.	Harmony and unity	A stable and harmonious ecological space unit with certain functions and characteristics
Social factor	Low impact human activities: moderate urban construction, terraces, fishery pond, policies, and regulations	Collaborative and harmonious	Within the capacity of earth environment and the internal properties of ecological space units change dynamically and stably
	Heavy impact human activities: large area of mountain excavation, lake reclamation, urban viaduct, serious impermeability	Adversarial relationship	Beyond the limits of earth environment, the elements within the ecological space unit and its nature undergo drastic changes

of spatial unit combinations and emphasize the relations of connection, quantity, and spatial distribution among ecological spatial units. The spatial heterogeneity of landscape is closely related to regional design of landscape, which directly reflects the cultural background and prospect of landscape application.

The coupling of ecological space units is the result of long-term interactions in the process of space growth, which is just the relatively stable state with the dynamic processes instead of the final state of ecological spatial patterns. It is also the relationship of multiple interactions including horizontal stitching and vertical nesting of ecological space units and means that the land forms show the interrelated and competitive relationships under the interaction of natural and artificial factors with the possibility of mutual transformation in a certain direction. The coupling actions emphasize the differences, the unique interactions, and the development modes formed under the mutual transformation and interrelation between various scales of space units, in which ecological spaces undergo the evolution process of stability, instability, and new stability, so as to realize the regionalization and characteristic of landscape space transformation (Meng 2015).

The ecological space unit is an open and complex system, which contains a variety of ecological elements, interactions, and influences. The research on integrity of

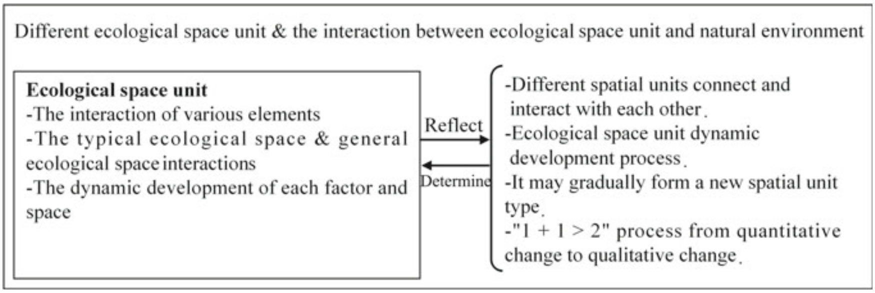


Fig. 3.2 Interaction between ecological space unit and natural environment

ecological spaces could not be simply superposed as the whole, the characteristics at certain scale of ecological spaces could be studied separately, and then the characteristics at multiple scales could be deduced to obtain the abrupt changing results of landscape. The study on the integrity of ecological space units is to find out the characteristics of activities of daily life, the conditions and possibilities of mutual transformation at different scales, and finally get the results of overall characteristics of ecological spaces from the microscopic to the macroscopic (Fig. 3.2).

3.1.5.2 Coupling Relationship of Ecological Spaces

The construction and development of ecological spaces are unified in the whole of regional ecological spaces, of which the integrity, diversity, and coupling are their basic characteristics and are unified through spatial organization of ecological spaces. The science of complexity believes that organization is the relation of relations, which could combine various relations, make the parts connected as a whole, and transform the scattered diversity into the complete and organic system. The complexity science thinks that there are coupling relationships among elements in a system referring to two or more systems interacting and influencing mutually and are the dynamic interactions of interdependence, mutual coordination, and mutual promotion between subsystems.

The integrity and diversity of ecological spaces in region are unified in spatial organization, while the complexity science holds that any forms of organization do not exist fixedly but always change from the thoughts of dynamics. Under the guidance of this idea, the study of ecological space has been shifted to the questions of stability to study the spatial organization and interaction among ecological spaces. It is necessary to explore the interactions among the horizontal and vertical structure, space pattern, and the coupling relationship existing in dimensions of time and space (Fig. 3.3).

For the stability of horizontal and vertical structure of ecological spaces, the formation of structure is the result of function coupling in a system with negative feedback from perspectives of the science of complexity, of which the essence is the

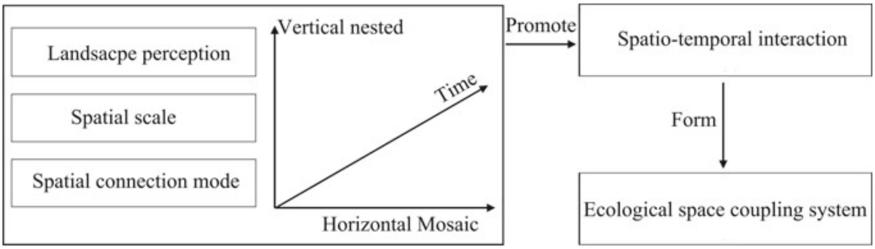


Fig. 3.3 Relationship of coupling ecosystem

different growth modes of human living spaces and their impacts on the ecological spaces in the dynamic process rather than the static existence.

The coupling is not the final result of ecological spaces but the various relationships between ecological spaces which interact and influence each other. The coupling relationship needs to emphasize the difference of ecological spaces and the harmonious state formed by interaction and coexistence.

The purpose of the study is to emphasize the design of space types suitable for local residents according to the characteristics of ecological spaces. The growth effects are mainly reflected in the horizontal stitching and vertical nesting dimensions of ecological spaces, as well as in the morphological structure, similarity, and difference at multiple scales.

3.1.6 Scale Theory of Ecological Spaces

Scale refers to the unit of space or time measurement in the study of landscape or its phenomenon and refers to the scope involved in space and time and the frequency of the phenomenon or process occurrence. The former defined the scale from perspective of researcher, while the latter defined the scale according to the characteristics of process or phenomenon. Scales could be simply classified as spatial and temporal scales (Wu et al. 2014). The vertical nested structure of ecological spaces is mainly manifested in landscape construction processes at multiple scales, which is the important feature of transformation and cohesion between landscapes. Scaling is an important feature of scale, which includes the transformation of scaling up and scaling down and refers to the process of extending information and knowledge obtained at one scale to other scales, or exploring the cross-scale characteristics of ecological structure and function through multiple scales research.

There are various spatial scales in region and landscape spaces with a system of natural hierarchy. The functional units at low-level would be abstracted out of space at high-level, and many similar types of units are gradually merged into the area of functional unit at high level. The concept of scale should be emphasized and aimed at the corresponding hierarchy of region when the recombination of regional spaces is studied and the scale theory is helpful to accurately grasp the special problems to

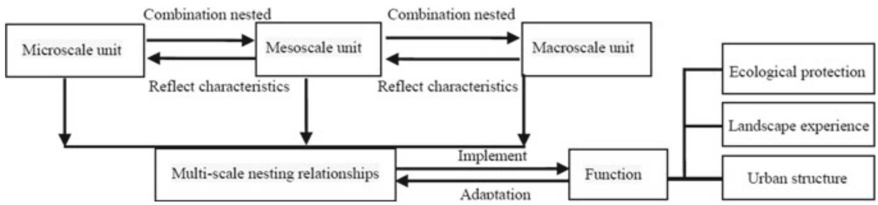


Fig. 3.4 Research hierarchies related with landscape space

be solved at multiple scales in the study of spatial structure recombination in region (Fig. 3.4).

Scale refers to the resolution of space and time of the object or process, of which spatial scale refers to spatial resolution of the studied area or the minimum unit of information or mapping, and the time scale is the interval between its dynamic changes. Landscape pattern and heterogeneity would change according to time and space scale, so the restriction of scale must be taken into account in landscape spatial analysis, and the conclusions obtained by spatial analysis at one scale could not be applied to another directly (Chen et al. 2002). The larger the space scale, the longer the time for evolution and change. The obvious landscape changes could only be detected at the small scale in the short period, but there is no fundamental change at large scale.

The scale effect shows that there are various types of patches in landscape, and landscape diversity index decreases with gradual increase of patch area. The scale of landscape ecology research basically corresponds to the scope of mesoscale, which is from several square kilometers to several hundred square kilometers, from several years to several hundred years. The large scale mainly reflects the variation of macro-climate, the mesoscale mainly reflects the variation of surface structure, and the small scale mainly reflects the variation of soil, vegetation, and microclimate. Due to the existence of effect at multiple scales, the geographical elements have the property of fundamental changings in spatial distribution. The study could be further carried out only by grasping the key problems at the specific spatial scale.

3.2 Classification of Ecological Space

3.2.1 Definition of Ecological Space

The main directions for the study of ecological spaces firstly are to explore the connotation and understand the importance of ecological space for landscape construction. Secondly, the research of ecological space analyzes the characteristics of ecological space units with various functions, forms, and their relations and laws. Thirdly, it is to establish the alternative systems of ecological space planning through the analyzing of spatial organization modes. Finally, the widely accepted and most suitable system

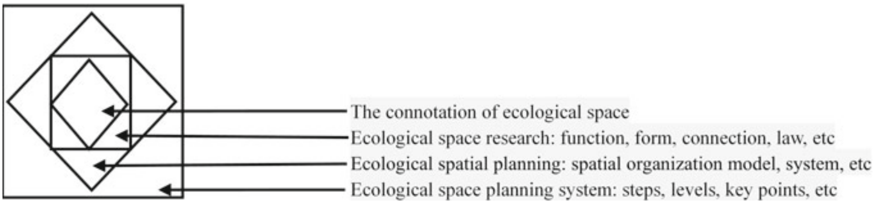


Fig. 3.5 Relationship between scale and function of landscape space

would be constructed through the complete steps, multiple levels, key points, and related planning and design contents of landscape ecological spaces (Fig. 3.5).

Ecological space units refer to the types of landscape with its own ecological characteristics and functions and have obvious differences and close relations with the surrounding spaces in terms of functions, composition, and forms. The research of ecological space units mainly focuses on landscape design at mesoscale. The space units are commonly classified as the basic unit, aggregated unit, and holistic unit, and the law of landscape design is further summarized by analyzing the interaction and correlation at these three scales.

3.2.2 Classification and Characteristics of Ecospace Unit

Landscape is a complex system composed of organic connection of landscape elements. Ecological spaces are the important parts of landscape space, which emphasize more on the interactions and connections of landscape. The main functions are to form the types of spaces with specific characteristics and development needs of the sites. The combination rules and modes of ecological space units could control the functions and characteristics of landscape space, which affect the communications and exchanging processes of material, energy, and other information.

Landscape elements of waterbody, plant, landform, architecture, and road are the basic composites to distinguish the types of landscape space, which reflect the basic spatial characteristics and regional characteristics of landscape. The features of landscape elements are different in form, function, and heterogeneity. Ecological space units emphasize the forms, distribution modes, and organization types of space compound by landscape elements at specific scale.

Aggregated spaces refer to spatial units which could best reflect the interior characteristics or functions of ecological space with a larger area and more types of elements on mesoscale compared with the basic units. Because the aggregated units generally contain much more types of space with obvious characteristic of heterogeneity and complex functions and forms, the subregional characteristics of site could be better represented, but the basic units could show the characteristics of site better at microscale. Aggregated units emphasize landscape functions at mesoscale,

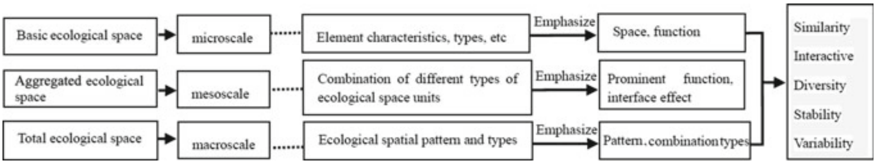


Fig. 3.6 Three-level scale analysis of ecological space units

influences of dynamic actions on holistic units, and impacts on interfaces with other aggregated units.

Ecological units emphasize the characteristics of landscape at mesoscale, which are the reflections of comprehensive results under the actions of landscape functions or elements, and also emphasize the connecting directions and ways between different space units. The design and application of interfaces between spatial units are the emphases in the study of ecological spatial units. The holistic units emphasize the combinations and connecting modes of spatial units, the combination types between spatial units, and the modes interacting with the surrounding ecological space units at multiple levels.

The basic unit, aggregated unit, and holistic unit are three different scales of the research on ecological spaces, which represent various spatial characteristics and orders of each scale. The basic unit is the type of space size connecting all elements at microscale, while the holistic unit is the type connecting at macroscale and forming regional ecological space, although ecological space units on mesoscale are divided into three small scales based on the scope of mesoscale, which emphasize the form, function, interface, spatial interaction, and so on (Fig. 3.6).

The similarity of landscape indicates that the same or similar elements at multiple scales are connected together in the same way to form the total features with functions and effects at corresponding scales. The reciprocity highlights the properties of scale, which means the possibility of scaling up and scaling down. The diversity is mainly reflected in the diverse types, combinations, and functions of the aggregated units. The stability and variability are mainly used to describe the changes over time at large scale or mesoscale of ecological space, of which the type, scope, scale, and combination mode are always changing in dynamic way, although the whole system is still in work maintaining the original functions and attributes in relatively stability.

3.2.3 Classification of Basic Ecological Space Units

3.2.3.1 Cognitive Framework of Basic Ecological Space Units

The basic space units are used to describe basic compositions of ecological space, which are the basic parts with independence of landscape functions at mesoscale and macroscale. Its classification system is established based on the distinguishing of the

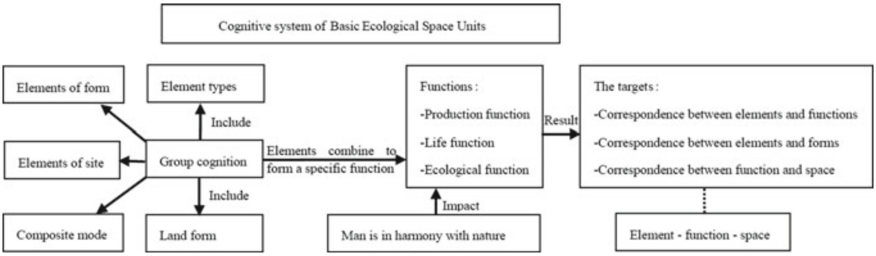


Fig. 3.7 Cognitive system of basic ecological space units

natural and human elements, in which natural elements include plant communities, mountains, lakes, and rivers, while human elements include cultivated lands, gardens, fishery ponds, and their combination modes. The basic ecological space units are mainly landscape environment in which we live and work and also are the spaces which were felt most strongly and truly. The basic ecological space units mainly emphasize the similarities and differences of element types and spatial characteristics and the connections between forms of element and functions through the analysis of element types, forms, and other aspects. The cognitive framework of basic ecological space units is as follows (Fig. 3.7).

3.2.3.2 Elements of Basic Ecological Space Units

The relationships between elements, functions, and spatial reasoning are the focus of landscape space research at basic level of ecological space. There are five types of functions, such as storage areas, buffer spaces, shelter belts, ecological conservation, and construction areas according to types of natural and human factors of element type, location, shape, and combination mode (Table 3.2). Meanwhile, there are three types of combinations, such as the combination of cultivated land with terrain or waterbody, the combination of road with settlement or cultivated land or vegetation, and the combination of water with vegetation or terrain or settlement (Table 3.3).

The ecological space units are statistically analyzed in terms of elements types, forms, spatial types, functions, and relationships according to the classification standards of natural and human elements (Table 3.4). Landscape elements are main factors which would form specific functions, of which the forms are the manifestations of function enhancement. It would be conducive to enhance understanding of spatial functions through focusing on the form of element combinations. Various types of element are interdependent and organized naturally to form the relatively stable space with specific characteristics in the long-term process. The same elements in different places would form various forms of spaces adapting to the context and diverse functions.

Table 3.2 Functions of basic ecological space units

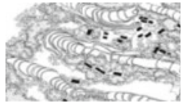
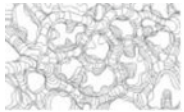
Function types	Implication	Form
Storage area	A water area with regulated and controlled water volume to ensure ecological safety	Pie—line—mesh combination mode
Buffer space	The ecological space with form of strip or pie different from the bilateral landscape	Strip + pie combination mode
Shelter belt	A linear space composed of forest groups with windbreaks, sand fixation, and microclimate regulation of living environment	Strip—pie combination mode
Ecological conservation	Ecological spaces such as water or vegetation zones that regulate climate and maintain water and environmental stability	Pie—strip—mesh combination mode
Construction area	The space which human beings constructed to satisfy the needed for production and life	Scattered—strip—pie combination mode

3.2.3.3 Function of Basic Ecological Space Units

The clusters of landscape elements contained in basic ecological space units are the right spaces in which we perceive life, make friends, play, and produce in our daily life. People create wealth with their hands and also change the surrounding environment, accept, and perceive the gifts given by nature. All our behaviors and activities could be considered to be realized relatively in these kinds of spaces at microscale.

The spaces we live in are formed through joining together of common elements such as vegetation, water body, road, building, and terrain, which meet the needs of these diverse mosaics with different locations and climate environments, create good conditions for local people to get along better with nature. Landscape cognition at this level would help better understand the relationships between spaces and functions in terms of spatial behavior orientation, explore the active effects of spatial elements and functions enhanced with form, and provide the databases and possibilities for future planning and design of regional landscape. The orientation of spatial functions could encourage participants to carry out presetting behaviors and activities and encourage us to provide the possibility of the ideas about basic ecological space units through the understanding of spatial form.

Table 3.3 Landscape element combination mode of basic ecological space unit

Element group type	Composite type	Form	Features	Typical Pattern
Cultivated land/landform/watershed combination	Splicing type	Finger T type Intersection	Comply with the terrain, connect the water source, and use the land to create rich production space	
	Monomer repeating type	Fingerprint repetition, terraced repetition	While the cultivated land conforms to the terrain and topography, the vein is prominent and the zoning is obvious	
	Surrounded type	Rings with multilayer	It helps to form a relatively closed space, retaining water and nutrients, while helping farmers to cultivate	
Road-settlement/plantation/plant combination	Wrapped type	Linear	The road between settlements is helpful for people to reach the destination quickly and form a more convenient traffic environment	

(continued)

Table 3.3 (continued)

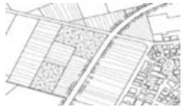
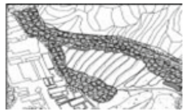
Element group type	Composite type	Form	Features	Typical Pattern
	Linear intermeshed type	T type Linear	Road and cultivated land form a linear intermeshed space, which is conducive to farming activities of people and reach the destination quickly, while square fields are convenient for farming and management	
	Wrapped/intermeshed/interval/interval and intermeshed type	T type Linear	Under the influence of topography and environment, the road and vegetation form spatial relationships, such as interval type and intermeshed type, thus forming diverse road spaces	

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Table 3.3 (continued)

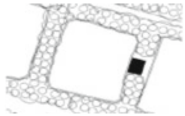
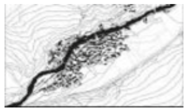
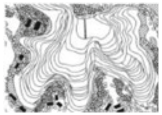
Element group type	Composite type	Form	Features	Typical Pattern
Waterscape/plant/terrain/settlement combination	Surrounded type	Patch Annular	On the one hand, vegetation surrounding water protects the water environment and provides a relatively stable microclimate; on the other hand, it forms a more comfortable farming and production environment	
	Blend type	Linear	The waterscape extends along the terrain and topography, forming an environment where mountains and rivers uphold each other	
	Wrapped type	Patch Linear	The settlements are distributed linearly or horizontally along the water area, forming a production and living space centered on water. Living in accordance with the water provides great convenience for people to produce and living	

Table 3.4 Relationship between landscape element, function, and space

Element type			Form	Land type	Typical Pattern	Spatial Type	Spatial Function	Element, Function, Spatial Relations
Natural elements	Plant	Drought resistant	Scattered Strip Belt	Arid desert		Semi-open or enclosed spaces	Protection and conservation functions; ecological beautification function	Elements are the basis for forming space and producing certain functions; Different elements have different functions; the form of elements also varies with the function; The space is the necessary way to realize the function. Only by forming a certain space could certain function be realized; The function is the final result, the space is formed by the element combination, and the space produces the final expression of the effect
		Cold resistant	Patch	Highland				
		Hygrophilous	Belt Blocky	Watershed				
	Mountain	Hill	Ridge Belt	–		Semi-open spaces	Various elements acting as bases	
		Basin	Strip Belt					

(continued)

Table 3.4 (continued)

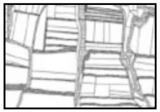
Element type			Form	Land type	Typical Pattern	Spatial Type	Spatial Function	Element, Function, Spatial Relations
	Water	Lake	Patch	Flat		Open spaces	Saving water resources, ecological conservation	
		River	Liner Strip/belt	Hill, plain				
		Watershed	Network	Plain				
Human elements	Residential building		Scattered Belt Patch	Flat Sloping fields		Semi-open spaces	Residential space	
	Farmland	Farmland	Belt Annular Network	Flat Sloping fields		Open space	Production space	
		Dry farmland	Blocky Belt Annular	Flat Sloping fields				

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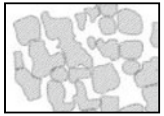
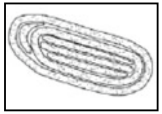
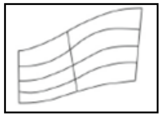
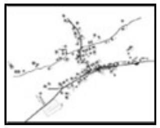
Table 3.4 (continued)

Element type			Form	Land type	Typical Pattern	Spatial Type	Spatial Function	Element, Function, Spatial Relations
		Fishpond	Patch Branched	Rivers and lakes, farmland, base ponds, etc				
	Gardens	Tea garden	Annular Blocky Network	Flat Sloping fields		Open space	Production space	
		Orchard	Belt Network	Flat Sloping fields				
	Road		Liner	Anywhere		Semi-open or enclosed space	Connectivity space	

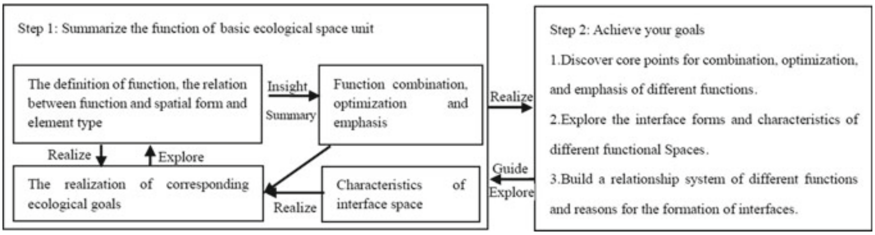


Fig. 3.8 Framework of aggregated ecological space unit

3.2.4 Classification of Aggregated Ecological Space Units

3.2.4.1 Framework of Aggregated Ecological Space Units

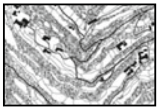
Aggregated ecological space is the type of landscape space unit with one or several functions formed by repeated and superimposed combinations on the basic units, which is larger than the unit of basic ecological space and smaller than the unit of overall ecological space, of which the scale is easy to be slightly overlooked by people. The research focuses on the extraction of main spaces and improvement of spatial interfaces; therefore, the multi-functional combinations and interfaces effect of ecological space are mainly highlighted at this scale. It would be effective on innovative ideas and conditions for ecological space planning to study the relations of spatial interfaces at small scale and analyze the characteristics of interfaces with groups of different elements (Fig. 3.8).

3.2.4.2 Classification of Aggregated Ecological Space Units

The basic ecological space units are combined in pairs to form the functional combinations according to integrating functional systems and characteristics of spatial interfaces, which include six major functional combinations and ten subordinate combinations. For example, the spaces aggregated with constructed area and ecological conservation consist of three small functional combinations, such as constructed space and water space, constructed and woodland space I, and constructed and woodland space II. These spatial interfaces are coagulants for the intersection and fusion of spaces and are also the sites of many important human activities. The interfaces of aggregated ecological spaces are usually formed by two or more intersecting spatial units of landscape, which are spaces with various elements and dominated linear spaces, and supplemented by the punctiform colonies or small patches (Table 3.5).

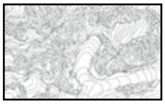
The main functions of aggregated ecological space units are determined through clustering the groups of basic units with similar geographical location or adjacent location into similar groups to form the block with relatively comprehensive and

Table 3.5 Classification of function and interface feature of aggregated units

Functional combination type		Interface space	Interface characteristics	Example
Residence, production, and ecological conservation	Residence and production space and water space	Intermesh between water and cultivate field	The interface is mainly an interlaced form of water and land, which blends with each other and retreats and advances, which is typical landscape in the south region of the Yangtze River, China	 Jiangsu
	Residence, production, and woodland space I	House along with the woods	Both the building and trees are parallel to the contour line, and trees provide a good shelter and protection space for the building. The two are interdependent, the building and the field are protected by trees, and the tree space is enriched by the presence of the building and cultivate field, which is typical landscape in the mountainous area, Sichuan, China	 Sichuan
	Residence, production, and woodland space II	House separated from woods	Trees are densely distributed parallel to the contour lines, houses, and farmland mostly exist in areas with relatively gentle terrain, forming an interactive and isolated relations between the woodlands and the living and production spaces. The interface is relatively clear, and the interface relationship is progressive and recessive, which is typical landscape in the alpine region of Chongqing, China	 Chongqing

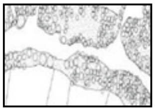
(continued)

Table 3.5 (continued)

Functional combination type		Interface space	Interface characteristics	Example
Shelterbelt, residence, and production	Waterside protection, residence, and production	Trees parallel to the water shoreline	Shelterbelt land is parallel to water shoreline, forming the mode of outsourcing living and production space, which is typical landscape in south region of the Yangtze River and coastal region of Guangdong, China	 Guangdong
	Alpine protection, residence, and production	Trees crossing cultivate fields	The tree cluster extends along the ridge and valley, the farmland, living space, and shelterbelt are interlaced to form a multi-level integrated space type, which is typical landscape in the mountain area	 Chongqing
Storage and regulation areas, residence, and production	River and paddy field, residence, and production	River and cultivate field coexist in harmony	Rivers and paddy fields blend with each other, and there is no clear boundary between them. The function of river regulation and storage could be strong with the help of paddy fields, and the water source and construction of paddy fields could also be realized through rivers	 Wuhu, Anhui Province
	Central lake district, residence, and production	Lake and residence with spatial relation of near and away	There are many tidal flats and wetlands around the central lake area, which are not suitable for building houses or developing dryland farmland. However, there would be a symbiotic relationship between them, in which one moves in and the other moves out	 Zhejiang Province

(continued)

Table 3.5 (continued)

Functional combination type		Interface space	Interface characteristics	Example
Storage and regulation areas and shelterbelt		Water and trees embraced each other	Form a type of relationship between lakes surrounded by channels and trees surrounded by water	 Zhejiang Province
Storage and regulation areas and ecosystem conservation	Central lake district and wetland space	Multiple plants coexisting and fusion	The interface is composed of a variety of aquatic and semiterrestrial plants, which is the transition zone between water and land	 Zhejiang Province
Ecosystem conservation and shelterbelt	Wetland space and shelterbelt	Fusion in space gradually	From the wetland space to shelterbelt space, the species diversity is more and more varied, the wetland plants are gradually reduced, and the shelterbelt plants are gradually increased	 Zhejiang Province

perfect functions, which are those with large area connecting the surrounding subsystems quickly in the block or related closely to the basic ecological space units nearby (Fig. 3.9).

The spatial interfaces are the important parts of aggregated ecological space units, of which three types of fusion, connection and separation could be identified by summarizing and studying the relations of interfaces with different functions in different regions. The interfaces with different elements vary greatly in scale, element type, and morphology, and these differences are finally reflected obviously in the functions of spatial interfaces (Table 3.6).

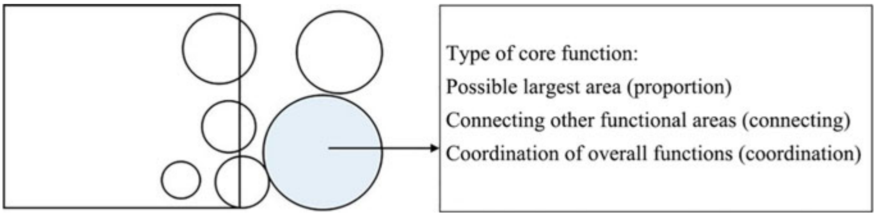


Fig. 3.9 Identification of core function

Table 3.6 Corresponding relations between type and function of interface

Interface classification		Element type	Interface function
Intermeshed	Finger-like intermeshed and raised	Mountain and field, Water and wetlands, Water and farmland, Land and water, etc.	Creates a critical space
Conterminous	Relatively smooth interface	Roads and farmland, tributaries and farmland, mountains and tributaries, etc.	A sign of relative functional separation
Separation	Wrapped but with separation relationship	Roads and settlements, shelterbelt and water, etc.	A relation without direct connection

3.2.4.3 Function of Aggregated Ecological Space Units

The aggregated ecological space units are the transition parts of the basic ecological space units and the holistic ecological space units and also the important ways for us to analyze the core functions of landscape. The basic unit is the space scale which could be perceived directly in daily life. The holistic unit is the space scale which could capture the uniqueness of landscape quickly with a view of looking down from the air. The aggregated unit is the space with dominant and systematical features of landscape instead of certain minor or unimportant activities and functions. It was found that important activities are closely related to the edge area where many behaviors take place, but the activities in turn could be led to other areas through the function of corridor acted as the edge area. Therefore, the aggregated units are the indispensable parts of ecological spaces and the important parts focusing to understand ecological spaces at multiple scales. In aspect of spatial behavior orientation, the aggregated ecological space unit also emphasizes the embodiment of key functions of region and the exploration and utilization of boundary environment, which is very helpful to summarize and discover the laws of human behaviors and implement landscape planning and design of functional areas.

3.2.5 Classification of Holistic Ecological Space Unit

3.2.5.1 Cognition of Holistic Ecological Space Units

The graphical features of landscape are mainly derived from the interactions between different things in nature and the influences of human behaviors over time, of which the classification mainly depends on natural factors, such as elevation, water system, hydrologic and morphological characteristics, and regional characteristics and human

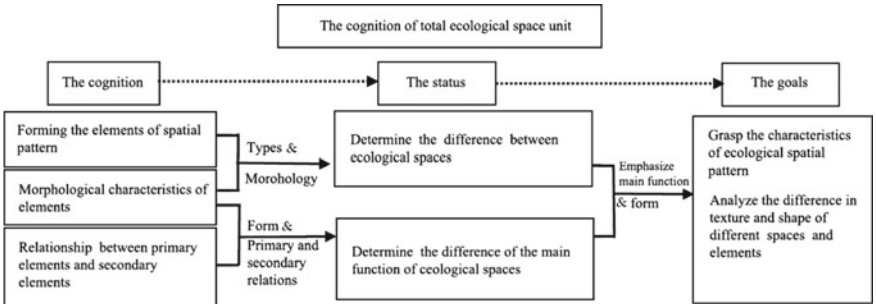


Fig. 3.10 Cognition of holistic ecological space unit

factors such as architecture, road network, irrigation system, cultivated lands, and so on.

Holistic ecological space refers to the total characteristics of cities or landscapes perceived by people with a bird's eye view, who ignore the specific functions of spaces and the characteristics of interfaces, and pay more attentions to overall characteristics of space at holistic scale, such as patterns of road networks, water systems, and mountain configuration. Therefore, the classification of holistic units mainly emphasizes the form and type of space with high level of priority to total landscape and grasps the overall pattern, distribution, and relations among landscape elements (Fig. 3.10).

3.2.5.2 Classification of Holistic Ecological Space Units

The classification and analysis of spatial pattern are the focus of planning and design at the overall level, which could be divided into four types of landscape according to the group of elements, such as waterscape, mountain and hill, ecological network in the plain and the geomorphic and landscaping transition, and seven types of element morphology groups, such as plane, strip, block, ridge, scattered dot, network, and crisscross, as well as three types of spatial patterns, such as dispersion, combination, and extension (Tables 3.7 and 3.8).

Through the vectorization analysis of ecological space maps in different regions, the pattern analysis on natural landscape elements and human landscape elements could summarize the characteristics at macroscale (Tables 3.9 and 3.10). Spatial pattern is greatly different due to element types and presents the characteristics of relative regionalization with culture and climatic conditions. The interaction modes and functions of same element are also different due to different forms, in which there are dominant elements, spatial types, and multiple functions. The forms and patterns of group are also similar in units of space with same elements of composition.

Table 3.7 Configuration of holistic ecological space unit

Pattern form	Implication	Classification
Dispersion	It refers to the random or regular distribution pattern of major element groups according to natural conditions such as topography and water system	Patch randomly distributed
		Patch regularly distributed
Combination	Refers to the main element types to classify the production, living, and ecological space which are regularly distributed and constitute a relatively stable pattern of landscape	Fenster combination
		Dendritic combination
		Ring banded combination
Extension	Refers to the extended development mode formed in the integration process of elements with banded forms, such as water system, road network, and farmland, so as to expand their influence scope	Curve extension
		Symmetrical extension
		Radiation extension

3.2.5.3 Function of Holistic Ecological Space Unit

The charm and function of holistic ecological space unit might not be really perceived in daily life in terms of function and significance of space. The air we breathe, the grass, and flowers around us are the integral parts of the whole and the basis for stable existence and dynamic changing of ecosystem.

The four holistic units of water landscape, mountain and hill, ecological network in the plain, and the geomorphic and landscape transition have their own functions and are basic components of residents dwelling, production, ecological, and transition spaces. Waterscape space plays an important role in saving water resources and regulating atmospheric humidity. The mountains and hills are very common landscape all over the world and have strong effects to human settlement, where activities related to human settlement are basically concentrated to form the locality of spatial pattern and cultural characteristics.

Ecological network in the plain is the system of typical spaces recording the processes and forming the diverse landscape in the eastern coastal areas. Water system is often regularly distributed and interacted with roads and human settlements to form the patterns of abundant seafood and rice. Topographical transition is the spatial interfaces where different types of spaces blend with each other with very high species richness and the relatively stable patterns of interfaces, which could also form different types of spatial activities on both sides of the interfaces.

In terms of spatial behaviors, it would help to know the forms, characteristics, and elements distribution of landscape and help to cherish the present ecological spaces and to understand and control the development trends of ecological spaces from a macroscopic perspective through understanding the characteristic of holistic ecological space with different functions. It could provide materials and conditions for ecological and regional design and reconstruction of total landscape.

Table 3.8 Corresponding relations between element types and configuration

Category name	Groups and classification of elements		Group type of element morphology	Corresponding spatial pattern morphology	
Waterscape	Natural elements	Water area in center	Patch	Dispersion, combination	With large water surface as the dominance and some small watershed scattered around, which combined together
		Branch of the river	Extended strip (main body of water extending outward)	Dispersion	Extending directly outward along terrain, etc
		Protective species	Attaching strip (attaching main water area)	Combination	On both sides of the water is a symmetrical strip distribution
		Wetland and tidal flat	Attached block (attached to main water area)	Combination	Distributed in blocks on both sides of the water
	Human elements	Residential building	Scattered	Extension	Construction according to appropriate characteristics of site
		Paddy field	Patch	Dispersion	Distributed in patch shape on the water surface
Mountain and hill	Natural elements	Mountain and hill	Strip, ridged	Extension	Long and narrow space
		Waterscape tree network	Random network (forming random channel network according to the terrain)	Extension	According to the terrain, channel distribution randomly

(continued)

Table 3.8 (continued)

Category name	Groups and classification of elements		Group type of element morphology	Corresponding spatial pattern morphology	
	Human elements	Residential building	Attached scattered (random distribution of attached terrain)	Dispersion	Depending on the terrain, the unsuitable land for farming is selected for building construction
		Farmland (terraced fields)	Stripe (conform to topography)	Combination	Homeopathic development, parallel to the contour line
Plain and network	Natural elements	Water area	Regular network	Combination	A relative uniform of space
		Tree group	Patch	Combination	The tree clusters as patches are relatively random and uniform
	Human elements	Road	Relatively regular network	Combination	Roads, farmland, and residential buildings are intersected by network
		Residential building	Patch, strip/belt, scattered	Extension, combination	Patch on a large scale and local scattered distribution pattern
		Farmland	Patch, strip/belt	Combination	Farmland and roads, residential buildings and other regular distribution combination
Landform interface	Natural elements	Water and land	Natural interface (tidal flats, wetlands, etc.)	Combination	Wetland, tidal flat, watershed, land stratified combination

(continued)

Table 3.8 (continued)

Category name	Groups and classification of elements		Group type of element morphology	Corresponding spatial pattern morphology	
		Mountain and plain	Natural interface, such as cluster of trees	Combination	The mountain meets the plain smoothly
	Human elements	Forest and farmland	Interlaced (natural fusion)	Extension	The mosaics, in which a staggered and a large range of natural surfaces are formed in the process of gradual fusion
		City and country	The urban–rural staggered integration zone (farmland, forest, etc.)	Combination	The city as the center of combination with multiple rings surrounded

3.3 Horizontal Mosaic of Ecological Space Units

3.3.1 Concept of Horizontal Mosaic of Spaces

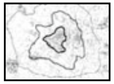
The relationship between spatial units is an important content to understand spatial structures in landscape architecture, which should be defined clearly and definitely. The horizontal mosaic refers to the connections of structure and functions of space units in the system of ecological spaces at same level which limits strictly the exploration of interactions between spatial units. However, the relationship between spatial units is mainly juxtaposed or intersected instead of inclusive relation. The mosaic here refers to the structural relationship of spatial units, which refers to relationship between spatial units with different functions formed in long-term coordination between man and nature (Fig. 3.11). The connections between ecological spaces are equal and symmetrical without the difference of the primary and secondary. A pattern of coordination would be formed by coordinating and integrating spaces with different functions constantly when spatial units interact and connect each other. The interfaces in horizontal mosaic are mostly tangible and act as corridors and barriers with complex structure of ecological space, in which there are abundant spatial activities.

The horizontal mosaic was used to describe the structural characteristics of ecological community in early stage, mainly to describe the ecological characteristics, and

Table 3.9 Patterns of natural landscape elements

Elements pattern		Natural element				
Natural element		Forest, oasis in desert	Terraces, waters, etc		Water bifurcation, small basin in mountain	
Spatial pattern	Name	Dispersion	Combination		Extension	
	Characteristic	Scattered distribution patch influenced by topography	The natural terrain and water system are used to divide the space, forming a combination pattern with natural space as the main part and human activity space as the auxiliary scattered among them		Highlights the characteristics of water extension, and natural environment and human living space are also distributed continuously	
	Subgroup	Patch dispersion randomly	Trellis composite	Dendritic composite	Curve extension	Stripe extension
Typical cases	Site	Maduo County, Guoluo Tibetan Autonomous Prefecture, Qinghai Province	Hejiang County, Luzhou, Sichuan Province	Fengcheng City, Yichun, Jiangxi Province	Wuning County, Jiujiang, Jiangxi Province	Yudu County, Ganzhou City, Jiangxi Province
	Image					
	Features	Oases in the desert are randomly distributed, and its form is related to natural topography	Terraces in grid texture, the production spaces locate in ecological space, morphology is influenced by topography	Dendritic water system divides natural spaces and forms a large area of living and production space, morphology is influenced by topography	The curved river stretches, which is influenced by topography	Water system, forest belt, and human settlement zone are symmetrically distributed on both sides of water system

Table 3.10 Patterns of human landscape elements

Elements pattern		Human element				
Human element		Farmland, small area of water, settlement space	Farmland, settlement space, fishery pond, road network		Water system, road network	
Spatial pattern	Name	Dispersion	Combination		Extension	
	Characteristic	The matrix is relatively homogeneous, and the individual plaques are evenly dispersed	One dominant function, others like living space distributed regularly in them		Human living space as the central, it radiates all kinds of space outwards	
	Subgroup	Patch dispersion randomly	Patch dispersion randomly	Trellis composite	Ring combination	Radiation extension
Typical cases	Site	Wuzhong, Suzhou, Jiangsu Province	Hejiang County, Luzhou, Sichuan Province	Guoyang County, Haozhou, Anhui Province	Jurong City, Zhenjiang City, Jiangsu Province	Yudu County, Ganzhou, Jiangxi Province
	Image					
	Features	Water space and human living space with a pattern of large aggregation and small dispersion. Water surface morphology is influenced by the interaction between human and nature	Human settlements are scattered in texture of farmland regularly, the form of human settlement is influenced by climate, terrain and farmland	Road network in rectangular lattice shape, and residential space is distributed in them, morphology is influenced by topography	Ring structure of living and planting space, of which the form is influenced by topography and urban sprawl	Residential space as center, the periphery radiates out gradually as planting spaces and connects to the center. The morphology is greatly affected by the terrain

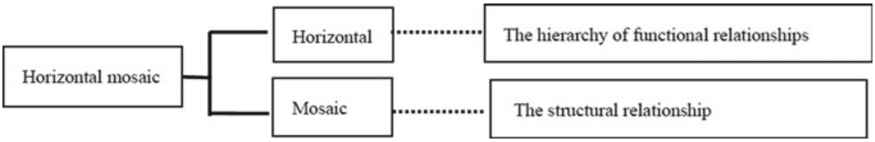


Fig. 3.11 Concept analysis of horizontal mosaics

emphasize the planning layout and relationship of biological community, which is still in the exploration stage now in landscape planning and design. In *Landscape Ecology: Pattern, Process, Scale and Hierarchy*, Prof. Jianguo WU put forward that the horizontal structure refers to the number, characteristics, and interactions of integral elements at the same level, and the decomposability of the horizontal structure is due to the differences in strength of interactions within and between subsystems corresponding to the level. He tried to explain the relations of horizontal coupling in terms of *'Loose Horizontal Coupling'*, here *'Loose'* means decomposability and *'Coupling'* means resistance to decomposition and emphasizes the decomposability of complex systems.

Prof. Yuncai Wang tried to apply the horizontal characteristics of mosaic to landscape design, who mentioned in the book *Principles of Landscape Ecological Planning* that the planning of landscape mosaic is firstly to shape the horizontal pattern of spatial mosaic through allocating patches, corridors, and matrix of regional landscape. The second is to construct the framework of corridor networks in region, for example, the water systems are very common and important in regional planning, so it is the right way to build the networks through adding various functional spaces as landscape patches on the basis of the network of waterscape tree embedded on earth dependent on the context of landscape matrix.

3.3.2 Integrity and Coupling of Horizontal Mosaic

Landscape shows the high complexity both in time and space as the mosaic of patches, corridors, and matrix, which shows the diversification of functional space on the one hand and emphasizes the complexity of spatial fusion forms and functional expressions on the other hand. It refers to the influence of the number, relationship, and pattern of spatial units at different levels in system of ecological spaces because the complexity of system is often related to the number of components and relationship between components and observers (Wu 2004). The horizontal mosaic is mainly manifested in two aspects which are the integrity of space and their coupling relationships.

The understanding of landscape emphasizes the perspectives of analytical and reductive cognition in the process of landscape formation and evolution, which are both the abstraction and separation of total ecological spaces and processes in the process of restoration and analysis and would cause the whole systems to lose their original relations and attributes partly and lack of the accurate and complete understanding of the whole. The real integrity should be ambiguous, diverse, and indefinite because of the uncertainty of integrity which is influenced by the difficulties of boundary determination of the whole system and the integrity of one system being part of another larger system (Zhao 2007). Tao Jin believed that the edification of holistic philosophy is based on the following two basic premises: Firstly, any phenomena are based on conditions, which are called the conditionality of things, and the generalized laws of causality are the necessary and sufficient conditions for the recognition of a phenomenon and its existence. Secondly, any kinds of existence are surrounded by internal and external uncertain interferences, which are called the uncertainty of the real world.

The integrity of horizontal mosaic of ecological space unit is used to describe the formation of functions and spatial structure of residents living and production spaces through the fusion of man and nature in the long-term development, which is mainly embodied in connection, functional combination, functional connection, and fusion of shape and texture, and is an important field of landscape space researches. The horizontal mosaic mainly aims to grasp spatial function and structure and form the spatial modes with certain functions through connection, fusion, and innovation of blocks at each level. Therefore, two background factors of formative conditions and external interferences are mainly emphasized in the study of integrity of horizontal mosaic in the system of ecological units. As an important carrier to express the function and form of landscape space, the integrity plays an important role in the formative mechanism and function expression of spaces (Table 3.11).

The unit of ecological space is a complex coupling system which is mutually coupled and restricted by natural background, cultural context, function, form, and elements. The coupling relationship in horizontal mosaic mainly emphasizes the relationship between integrity and stability of landscape, of which the essence is the growth mode of ecological space.

3.3.3 Horizontal Mosaic of Ecological Space Units

According to the complexity of horizontal mosaic of landscape, three principles of cognition mainly include the criteria of dynamic cognitive planning, criteria of problem-oriented cognitive planning, and criteria of integrated cognitive planning, which would clarify the cognitive processes and key points of landscape horizontal mosaic.

Ecological space unit is a dynamic, open, and complex ecosystem with the characteristics of openness, complexity, diversity, and integration in landscape design. The establishment of dynamic cognitive planning criteria is a stable system at macroscale and a dynamic system at mesoscale or microscale based on the dynamic evolution and stability of ecological space.

Table 3.11 Characteristics of ecological space units at three scales

Scales	Formation condition (stability)	External disturbance (dynamic changing)	Integrity	Spatial pattern
Holistic ecological space unit	Atmosphere, temperature, and humidity conditions Many people interact with nature in long-term activities	Irregular natural phenomenon: earthquake, tsunami, etc. Disordered development: breaking of natural context, fire, etc.	Spatial integration without disaster Functional integration of living space Regional continuity Matching ability of environmental conditions	Dispersion Combination Extension
Aggregated ecological space unit	Differentiation of space types Space function consistent with natural form	Disordered construction The occurrence of natural disasters	Diversified integration of space types Diversified integration of spatial connection Diversified integration of space composite forms	Combination of residence, production, ecological conservation, and storage and regulation space
Basic ecological space units	The mutual need of function and form Elements adapt to natural phenomena	Man-made destruction The occurrence of natural disasters	Elements, form, and functions corresponding to each other Diversification of elements combination pattern	Scattered, patch, strip, and belt

Through the comparative analysis of ecological spaces, the living environment is facing the phenomena of regional character disappearance, ecological space fragmentation, and spatial connection randomness and instability. It could help to better understand the connecting mode and systematical steady of ecological space through analyzing the excellent modes of landscape horizontal mosaic with problem-oriented cognition.

It is obviously for ecological space with the development trend of integrity from perspective of macroscale, of which the establishment could also promote the construction of spatial units and improve their functions. The horizontal mosaic emphasizes the establishment and construction of the relatively perfect system of landscape units through the connection of spaces and integration of functions.

The horizontal mosaic of ecological space follows the planning processes under the guidance of three principles: firstly, analyzing the conditions of horizontal mosaic at three levels of holistic, aggregated, and basic ecological units based on the stratified cognition of elements and space functions; secondly, the determination of key problems needs to be solved of the horizontal mosaic at each level; and finally, implementing the optimizing and adaptive design of ecological spaces to establish overall spatial patterns of landscape. The connections between different levels could be controlled to create an integrated spatial hierarchy through the establishment of horizontal mosaic.

It is to use the philosophy of complexity science, holistic thought of region and theory of ecology for planning and design of ecological space to rediscover, recognize and rebuild the spaces of residents living and production, to summarize and restore the spaces of nature with beautiful landscape, to implement the sustainable proposals of regional development, and to provide the most suitable settlements for residents on the basis of minimized disturbance to eco-environment. The horizontal mosaic could help to understand, improve, and design the types and connections of ecological spaces so as to find the effective modes of space design, which are suitable for and adaptive to the rapid development of urbanization and industrialization in China. However, the horizontal mosaic is only the part of landscape patterns, and it could be better understood the construction of ecological spaces only with the help of vertical nested structure and other theories.

3.4 Vertical Nested Structure of Ecological Unit

3.4.1 Vertical Nesting of Ecological Space

The vertical nesting of ecological units refers to the similarity of landscape in form, function, interface, connection, element type, and other aspects at multiple scales formed gradually in the process of evolution. Here the word of *'Vertical'* refers to the relationship between different scales, and the word of *'Nesting'* refers to the same or different relationship of landscape in terms of features and connectivity between different levels. The features at one scale could be used to deduce the features at another scale through the nesting theory and then guide the practices of landscape design. The concept of vertical nesting of ecological spaces could be summarized as two aspects: One is the cognition, definition, and understanding of spatial scales, and the other is the correlation degree of ecological units at multiple scales.

Firstly, the recognition, definition, and understanding of spatial scale would have more significant contributions to the construction of ecological units. Spatial scale refers to the extent or resolution of ecological space which carries a lot of information such as landscape functions, users, and element forms. The functions and performance of landscape basic space, aggregated space, and holistic space are somewhat emphasized the difference corresponding to three scales based on the previous analysis, but essentially they all shape the environment of human settlement from macro to microlevels.

Secondly, it may have the functions of scaling up and scaling down for an ecological unit in the hierarchy system, and the derivation method between scales is the focus of our research. Scaling up refers to the method to roughly deduce the features of landscape functions, forms, human activities, and other aspects at a high or large scale by summarizing the relevant characteristics of landscape at a low or small scale. Scaling down is the opposite process of scaling up, which refers to the method of roughly introducing the characteristics of landscape at low or small scale by summarizing the characteristics of landscape pattern at large or high scale.

The theory of vertical nesting has made a preliminary progress, and scholars have carried out many in-depth studies on scale and applied the theory of scale into practice. In the book *Landscape Ecology: Pattern, Process, Scale and Hierarchy*, prof. Wu proposed that vertical structure refers to the number, characteristics, and interacting relationships across levels in a hierarchical system. The nested interfaces may be invisible, and the relationships between two adjacent levels are asymmetric, e.g., the features at higher level always impose restrictions on those at lower level, which provide dynamic mechanisms for the features at higher level. In the book *Principle of Landscape Ecological Planning*, prof. Wang mentioned that scale analysis and scale effect are of great significance to landscape ecology, which are generally the formative processes of spatial patterns at large scale by recombining the spatial patterns at small scale (Wang 2017). In the book *Regional Spatial Structure Reorganization: Theory and Empirical Research,* Xiuying Chen discussed the characteristics and emphases of landscape at multiple scales in time and space, who proposed that landscape pattern and its heterogeneity are dynamic in accordance with the changes at temporal and spatial scales, so landscape spaces must be considered strictly in the analysis of scales (Chen 2005). Most scholars studied the difference of landscape at a specific scale or at different scales from perspective of comparison, but there are still few researches on the similarities and differences between scales and their essential linkage across scales, which are still in the process of exploration.

3.4.2 Coordinating Growth and Stability of Ecospace Unit

The units of ecological space are supported and depended on each other at three levels, in which there are landscape patterns of collaborative development among spaces and the relationships of interdependence and cooperation among levels. Synergy is the coordinated, cooperative, or synchronous joint actions and collective behaviors of subsystems in a system, which is the intrinsic expression of the integrity and correlation in system (Zhao 2007). The spatial, temporal, and functional structures are formed through coordination at macroscale, and connections are formed from small scale to large scale and from individuals to groups in subsystem (Table 3.12). Various types of ecological space are formed gradually in the process of continuous integration between man and nature. The living spaces of residents are mostly in the state of relative balance and steady, and the modes of actions getting along with the surroundings are relatively fixed. Therefore, it could be better to adapt to the

Table 3.12 Functions and coordinating growth ecological space units at scales

Spatial level	Function	Interaction
Holistic ecological space unit	Controlling and restriction	It plays a controlling and restricting role in aggregated ecological space unit and basic ecological space unit and is in a leading position in the whole system
Aggregated ecological space unit	Coordination and continuation	Analyzing the element function of basic ecological space unit to form systematic function spaces The foundation for the formation of patterns of the total ecological space unit
Basic ecological space unit	Foundations and promotion	The basis for the formation of aggregated ecological space unit and the total ecological space unit and promoting the realization of spatial functions to a certain extent

natural evolution and reach a long-term sustainable development through studying the stability of ecological spaces and applying it to landscape design practice. It is to analyze and summarize the functions and connecting modes at multiple levels through the study of nested structure in order to recognize the vertical patterns of ecological space units.

3.4.3 Scale Process of Ecological Space Unit

Scaling refers to the translations of information at different spatial and temporal scales or organizational levels (Edward et al. 1992, Van Gardingen et al. 1998; Wu 1999, 2004, 2006), which could be further measured into two processes of scaling up and scaling down. Scaling up or upscaling refers to the translations of information from a small scale to landscape at a large scale, while scaling down or downscaling refers to the translations of information from a large scale to landscape at a small scale. The possible information which could be transferred between scales is the type of elements, the form of space, the way of spatial connection, the mode of space combination, and the function of space, which plays an important role at different scales of space. In the process of scaling, information has a strong dependence on the system, and some information would change greatly due to the changes of scale, or even completely disappear at some scales, while some information has a weak dependence on scale and would not change greatly with the change of scale, so it could exist in landscape spaces stably at multiple scales. The information with strong scale dependence generally would not have the characteristics of scaling, while the information with weak scale dependence would have extensive functions of scaling, so it could be widely used in planning and design and becomes the pattern vocabulary with the most universal characteristics. Therefore, the scale process of ecological space units could not only recognize logical relationships of landscape nested structure vertically, but also the applicable scales of landscape patterns.

3.4.4 Mechanism of Vertical Nesting of Ecospace Unit

The decomposition of a system is the prerequisite for applications of hierarchy theory, and the criteria used to decompose the complex systems often include the velocity of process, the boundary, and surface characteristics manifested in structure and function (Chen 2005). In other words, the decomposability is the prerequisite for interconnections and interactions of ecological space units among three levels.

The system of ecological space units is always in the process of dynamic evolution and succession, in which all spaces have the processes corresponding to the dynamic changing at the large, medium, and small scales. The stability of ecosystem would decrease gradually from macroscale to microscale.

The functions and features of ecological space always act as the role of directionality in the hierarchy system, but the importance is different corresponding to their level in system, of which some are decreasing from macroscale to microscale, some are increasing, and some remain the same. For example, the importance of element types would decrease gradually with the gradual increase of scale, and it would increase gradually for the importance of spatial pattern formed by element groups, while the spatial function occupies an important position in each layer, and the importance remains basically unchanged (Fig. 3.12).

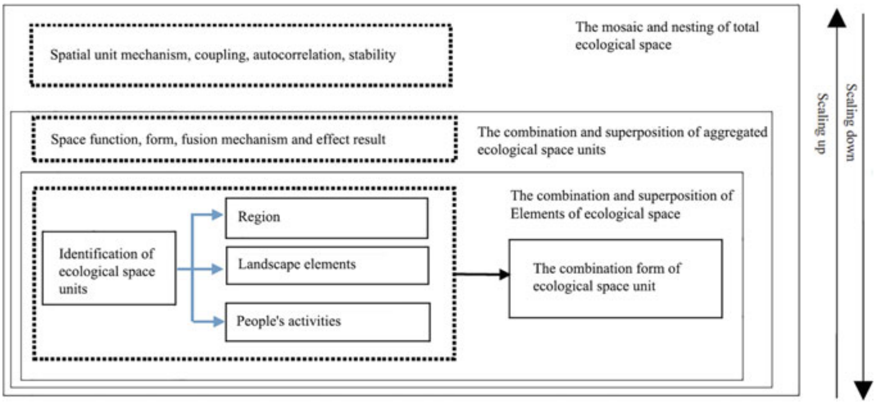


Fig. 3.12 Key expressions of ecological space units at different levels

The planning processes directed by vertical nesting of ecological space are as follows: Basic cognitions in hierarchy are implemented at three levels, summary and analysis of function, form and connection, determination of the characteristics of element group or functional group, and optimization of ecological space design. The vertical nesting is helpful to control the spatial similarities and differences between groups with same elements and functional groups at different levels in order to create the hierarchy system of integrated spaces.

In recent years, the researches on vertical nesting of space had been improved greatly and made a big step forward, in which the overall characteristics of scale, the connection, and difference of ecological space units were studied systematically in detail. The vertical nesting of ecological space is guided by the principles of spatial decomposition and orientations of development based on the complex system and summarized the characteristics of people's living and production spaces using the thoughts of integration. The vertical nesting could help designers to improve the spatial elements at different levels and finally form the patterns of coordinated and stable evolution at microscale in detail and macroscale in integrity.

3.5 Ecological Space Unit and Zoning

3.5.1 Relationship Between Spatial Units and Ecological Zoning

Ecological zoning refers to the integrity of regional functions from perspective of the system rather than the geographic division based on the homogeneity of morphology from perspective of horizontal structure, which is the determination of regional ecosystems at different levels and is of great significance to regional planning and construction. It is usually formulated by analyzing the spatial differentiation rules of regional ecological characteristics, ecosystem services, and ecological sensitivity on the basis of ecological investigation and then determining the dominant ecological functions of different regional units.

Ecological zoning could be the thematic regionalization of single ecological factor, or thematic regionalization of multiple factors, or the comprehensive regionalization determined by systematic functions, in which some zoning aims at certain objects, such as crop production or biodiversity conservation. Ecological zoning mainly depends on the spatial difference of ecosystem under interaction of ecological factors, which is the inevitable results of regional differentiation. Therefore, ecological zoning is the result of revealing the objective laws of natural ecosystem on the surface of earth within ecological region, which is emphasizing the commonality of ecological characteristics, but it would emphasize the difference of ecological characteristics out of ecological region.

Ecological space unit refers to the whole space with certain independence and integrity. From the perspective of context, the spatial unit could be either the unit

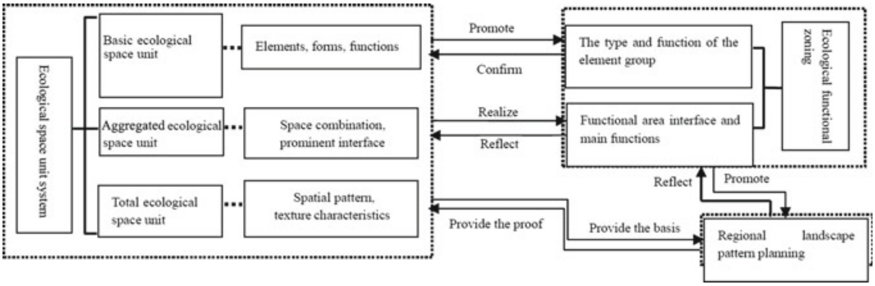


Fig. 3.13 Relationship between ecological unit and ecological function zoning

with single factor or the unit with multiple factors, which could also be classified functionally into space units of production, culture, and eco-environment. On the one hand, the ecological unit depends on the environmental conditions itself, and on the other hand, it depends on people's perception of space. The division of spatial units is both objective and subjective, which is the symbiosis of spatial independence and integrity instead of the difference and commonality, but it is the difference and commonality that give birth to the unit of landscape space and the spatial unit is not the product of ecological zoning. The system of ecological space units and the division of ecological functions are interdependent and mutually promoted, which ensures the progress of regional construction to a certain extent and creates conditions for the construction of harmonious and stable landscape in region (Fig. 3.13).

3.5.2 Symbiosis Between Spatial Unit and Ecological Zoning

Both spatial unit and ecological zoning are coexisting in our cognition system of landscape environment. The cognition of spatial units needs a unified standard for the division of spatial units, and ecological zoning also needs a unified standard and system with the orientation of specific goals. Spatial unit and ecological zoning are only the different cognitive systems to recognize landscape environment.

The cognitions of site background and ecological space are the foundations of ecological space units, which summarize systematically the element types, groups and forms, explore the relations of ecological space units, morphological characteristics, and patterns at multiple scales, implement the ecological functions zoning and ecological patterns planning of the site, and finally realize the system of ecological spaces with regional characteristics and landscape integration (Table 3.13).

Table 3.13 Coexistence between ecological units and function zoning

Name	Status and function in regional ecology	Interrelation
Ecological spatial units	The foundation and basis of cognition and seeking the way to regional construction Creating conditions for the division of functional areas and pattern planning	Ecological space unit system is the basis and guarantee to establish The mesoscale and microscale are the basis of ecological function zoning, and the macroscale could guarantee the implementation of regional landscape planning
Ecological function zoning	An effective way to provide appropriate functional space for people	The reflections of ecological space unit system applied to landscape design Promoting the implementation of regional landscape pattern planning
Regional landscape pattern	The senior level of planning which controls the direction of the whole area development	Regional landscape pattern planning directs and controls the zoning of ecological function from a macroscopic perspective

3.6 Spatial Performance Based on Ecosystem Services

3.6.1 Spatial Performance as the Basis for Sample Selection

Landscape architecture is an evidence-based major and discipline, which needs sufficient and reliable scientific basis to evaluate the current situation of landscape and guide the sustainable development in future. At present, it has attracted more and more attentions of scholars and designers to evaluate landscape performance. In 2010, the Landscape Architecture Foundation (LAF) proposed *Landscape Performance Series* (LPS) in order to promote quantitative landscape researches and sustainable design practices. The 2014 annual conference hosted by *Chinese Educators Council in Landscape Architecture* devoted a subtopic to landscape performance research, which is of great significance to study the performance evaluation of landscape space, and also helpful for designers to confirm the values of space, find the problems of space, promote the approaches to development and protect the totality of landscape space.

Through the literature research on landscape performance and practice research on related spatial evaluation, it is found that the system of landscape performance currently used for quantitative evaluation of built environment including landscaping, architectural, urban, and ecological spaces cannot be directly used in performance research of landscape spaces with the characteristics at multiple scales and multiple functions (An et al. 2013). Therefore, it is the lack of performance quantification and evaluation system that could not reflect the spatial characteristics and systematic integrity of landscape space. At the same time, the construction of an effective evaluation system needs theories which could integrate scale characteristics of landscape space with characteristics of multiple functions and establish the corresponding indicators to measure landscape performance. In view of the situations of landscape architecture and other disciplines all over the world, the theory of ecosystem services is considered as an effective theoretical basis for the evaluation of landscape spatial performance (An 2013).

The measurable indicators of landscape performance could reflect the characteristics and functions of landscape space at multiple scales from perspectives of ecosystem services. The performance of landscape space must be evaluated quantitatively in eco-environment, economic production, human culture, and other aspects by using the comprehensive indexes which could reflect the current quality and capability of landscape space to provide corresponding ecosystem services and try to answer the question of 'what kind of space is a good space of landscape?'. The theory of ecosystem services is considered as a bridge in this research between landscape spatial characteristics, functions, and performance evaluation indexes on the basis of summarizing the research results of ecosystem service and landscape service (Costanza et al. 1997). On the one hand, the diversified services of ecosystem could reflect directly the scale characteristics and multi-functions of landscape space at multiple scales. On the other hand, the direct or indirect values of ecosystem services could be quantified by corresponding indicators of landscape performance.

3.6.2 Diversity of Spatial Performance Evaluation

The term of performance was derived from the science of management and is used to express the effective outputs at multiple levels of various activities carried out by individuals or organizations to achieve the goals. Performance evaluation is the comprehensive evaluation of the achievements according to predetermined objectives with the system of evaluation methods, quantitative indicators, and evaluation standards. In the field of planning and design, the earliest assessment of performance began with the publication of the book *Measuring Municipal Activities: A Survey of Suggested Criteria for Appraising Administration* (C.E. Ridley, H.A. Simon) in 1938, since then, performance evaluation had been applied in the researches of architecture design, urban and rural planning, transportation management, and landscape studies.

3.6.2.1 The Efficiency of Overall Landscape or Element

Landscape performance is the theory and method to assess the achieving goals, sustainable effectiveness, and efficiency measurement in practices of landscape architecture, of which the target is to measure the quality of landscape planning and design projects, and to quantitatively evaluate the environmental, social, and economic benefits of projects. It helps to express clearly the values of sustainable design and the reliability of design decisions in landscape architecture and finally realize effectively the preset sustainable goals through landscape performance evaluation, in which the sustainability was set clearly as the main goals of design and planning intervention. Therefore, the sustainable features in landscape planning and design projects are the key strategies of landscape performance evaluation.

What should be evaluated? The question of landscape performance evaluation is to express unique feature of landscape sustainable characteristics which are critical to the categorization of landscape performance. However, the sites of various design projects have their own unique property under the comprehensive influences of many factors, such as geography, social economy, and local environment, as a result, there is no uniform standard for classification and measurement of landscape performance. Landscape performance evaluation needs to be paid more attentions to the main problems and solutions in each project and developed the classifications target-oriented and measurement methods for each project. In order to promote the quantification of landscape performance, LAF launched the *Case Study Investigation* (CSI) in 2010, which revealed the benefit indicators and quantification methods of landscape performance by displaying the measurement methods of various sustainable characteristics through nearly 100 cases.

The successful cases of evaluation practice have emerged constantly despite the big challenges of performance quantification and evaluation of landscape, for example, Prof. Bo Yang et al. evaluated landscape performance of the *Dawn Community* in Southern Jordan of Utah State by sorting out and analyzing the sustainable features of the site (2013) amd the Woodlands (2019). Nan Sun et al. made quantitative analysis of the performance of *Beijing Olympic Forest Park* and *Tangshan Nanhu Eco-City Central Park* based on the theory and method of landscape performance (Sun et al. 2012). From the perspective of social benefits, Bo Yang and his research team selected 19 indicators to evaluate three residential landscape projects in Pitkin County, Colorado, USA (Yang and Li 2013, Yang et al. 2013). The research of Texas A & M University investigated the overall landscape performance of the community *Cross Creek Ranch* with wetland treatment system and natural landscape and obtained finally the results of quantified benefits (Li et al. 2013). The research team of the University of Texas at Arlington analyzed the social values of urban landscape by studying the landscape performance of two typical projects in Texas, USA (Taner 2016). Landscape performances were evaluated through these case studies with both qualitative and quantitative methods, such as basic statistics, modeling, monitoring, post-use evaluation, and other methods appropriate to the identified performance categories with the advantages of systematization, preciseness, and quantification.

3.6.2.2 Energy Saving and Sustainability of Green Building

When performance is applied to measure the spatial differentiation, it is called spatial performance which means the results and goals achieved by organizing spaces, is the effective outputs of spaces in a certain period, and reflects the quantity, quality, and efficiency of spaces used. In the field of planning and design, the evaluation of performance had been applied earlier in the quantitative researches and scientific evaluations of space types, such as architecture, urban design, and traffic network. The performance of buildings is often used to describe the effects of architecture, especially in terms of comfortableness and energy conservation. Compared with landscape performance, the evaluation method and system of building performance are relatively perfect and mature. In 2001, *The U.S. Green Building Council* (USGBC) released the performance-based green evaluation system which is *Leadership in Energy and Environmental Design* (LEED), to respond to the low impact needs of the 1990s and promote the development of environmental-friendly green buildings. LEED focuses on environmental performance rather than economic and social aspects in setting performance indicators of building construction.

3.6.2.3 Spatial Structure and Mode Efficiency of Urban Space

It takes the elements of urban space as the object to evaluate the performance of urban space and judges the rationality of the utilization of urban space by analyzing whether the elements are organized efficiently in space. The comprehensive benefits of urban space could be improved only by meeting the increasing needs to the greatest extent and allocating various resources of space reasonably. The index classification of urban space performance evaluation is more complicated than that of landscape performance because of the multiple attributes of urban space. *The United Nations Commission on Sustainable Development* (UNCSD) constructed the index system of urban sustainable development from four dimensions of economy, society, environment, and institution and finally determined the key indexes of spatial performance evaluation for 58 cities. In China, the study of urban space performance evaluation mainly focused on three aspects of space carrier, constituent elements, and operating mechanism and constructed a system including five dimensions of society, economy, environment, space, and institution to evaluate the performance of urban space, by which the fields of economic activities, resources utilization, environment protection, spatial morphology and structure, infrastructure construction, and social development are evaluated systematically, and the indexes of each specific level are selected with different emphases. The evaluation indexes of urban space performance could enhance the measurement of spatial attributes and urban functions compared with landscape performance.

3.6.2.4 Biodiversity and Improvement of Ecosystem

Ecological performance refers to the harmonious conditions of environment where the creatures live in and which determines the evolution directions of ecosystem. The interactions between spatial patterns and ecological processes of environment elements in landscape space are the main mechanisms to control and influence ecological performance. At present, researches on ecological performance always focus on the effects of urban land using, urban and rural space regeneration, artificial landscape construction, natural space conservation, and others. In general, the objects of ecological performance research and evaluation are natural or human ecosystem, in which as one of the important elements of ecosystem, the ecological performance could be affected by human behaviors and their relationships with other organisms. In the *Method of Constructing Network of Green Infrastructure Based on Ecological Performance of Space Utilization*, An Chao et al. (2013) analyzed the ecological performance from evaluation of sensitive areas, ecological patches, corridors, and minimal path simulations, and on this basis, he proposed a method to construct the network of green infrastructure. The ecological performance emphasizes the concerns of human activities and historical sites as representatives of human ecology compared with the evaluation of landscape performance.

3.6.2.5 Spatial Structure and Organization Efficiency

The premise of performance research is to clearly define the connotation of research object and its characteristics. From a perspective of physical space, landscape space is the complete environment which exists within the specific geographical area and is the nested complex with multiple scales. Landscape space is composed of landscape elements of different types and functions, but it is not only the simple accumulation of elements, but the organic and integrity formed with internal logics. From perspectives of social and cultural attributes, landscape space is the place of human activity formed by the harmonious coexistence between man and nature with functions of social, cultural, and spiritual value.

The multi-scale, multi-dimensional, and multi-functional characteristics of landscape space endow great significance to the study of landscape performance. The multi-scale features determine the breadth of landscape space research and help to realize the sustainable development and protection of landscape space at all scales. The multi-functional characteristics mean that the research needs to seek the broadest performance category as far as possible, which could expand the index system of landscape performance evaluation and promote the development of landscape performance quantification and evaluation research.

What is a good landscape? The lack of universal evaluation system makes the cognition of landscape space just stay at the level of perception, which is not conducive to people's cognition and inheritance of excellent landscape spaces. The studies on landscape performance always were limited at small scale projects. Moreover, the quantification and evaluation of landscape performance focus on the sustainable characteristics of a certain or several landscape elements in landscape projects, which could not conduct quantitative evaluation of the integrated characteristics and internal mechanisms of landscape space.

The construction of spatial performance index systems, such as architectural construction and urban space shaping, is based on the characteristics and functions of various spatial types, of which the results cannot be directly applied to the performance research of landscape space with uniqueness feature, place, and functions. Although the study of ecological performance is helpful to quantify and evaluate the ecological functions of landscape space, the multi-functional characteristics make it unable to represent the complete and comprehensive performance. Therefore, it is the lack of performance quantification and evaluation system that the evaluation could not reflect the spatial characteristics and system integrity of landscape space. Landscape performance evaluation lacks the stable value orientation and pertinence, which has become the big problem in spatial evaluation of landscape architecture.

3.6.3 Ecosystem Service Providing an Effective Approach

3.6.3.1 Ecosystem Services and Landscape Services

Since the mid of 1990s, the researches on ecosystem services have been widely noticed and rapidly developed in the fields of concept, classification, formative mechanism, value measurement, and its evaluation methods. The definition and classification of ecosystem services have not been unified completely because the products of ecosystem service are both having interests of the public and the private, as well as the characteristics of dynamics and complexity. Ecosystem services refer to the products, resources, and environment provided by natural ecosystem and the species which support and satisfy the needs for human survival and development. They mainly include the provision of food, resources for economic utilization, natural environment for ecological security and human health, and ecological functions such as climate regulation, disaster mitigation, and self-healing of the environment, as well as meeting the spiritual and cultural needs of human.

As a hotspot of ecosystem service research, landscape service is considered as a special perspective of ecosystem service, which followed the system of ecosystem services evaluation in the early stage. In order to improve the classification of landscape services index, study the correlation between elements of regional landscape, and better describe the characteristics of landscape elements and versatility, Groot et al. (2010) put forward a classification system of landscape provision, regulation, habitat, and cultural service, which is different from that of ecosystem service. In addition, the characteristics of landscape spatial elements in a specific area also affect the classification of landscape service and evaluation index. Fagerholm et al. (2012) classified landscape services into tangible products and intangible cultural values, among which ornamental plant resources, geological resources, spiritual, and religious values were selected as important indicators when he studied the landscape services of the Angukha Island in Zanzibar Islands of northeastern Tanzania.

Ecosystem services are more being focused on the values and ecological functions of the components and interactions between the physical and chemical processes (Bai et al. 2011). Landscape services emphasize more on the analysis and evaluation of functions and services provided by natural ecosystem to human beings from perspectives of landscape spatial elements and the needs of human society, which could highlight the importance of landscape spatial patterns, the comprehensive results of service, and the intuitive perceptions of product by consumers. In the evaluation of ecosystem services, the intangible social and cultural values are often ignored or there are difficulties in measuring social and economic benefits, but landscape services could include all services provided by landscape, which makes them possible to evaluate and quantify ecosystem in terms of social, artistic, cultural, historical, spiritual, and religious values. In a word, landscape service studies can compensate for some of the limitations of ecosystem service assessments, and the concept of landscape service provides a new direction for sustainable development from a perspective of landscape ecology. However, both ecosystem services and landscape services focus on human dimensions of ecosystems and emphasize the links between ecosystems and human values as an effective way to strengthen the links between ecosystems and human well-being.

3.6.3.2 Characteristics and Functions of Landscape Space

The study of landscape space from perspective of ecosystem services could reflect the scales and multi-functional characteristics of landscape space. First of all, the spatial characteristics of ecosystem services at multiple scales could reflect the scales and their relations of landscape spaces. The services could be provided by ecosystem at all scales, and their formations should be depended on the structure and processes of ecosystem at the specific spatial–temporal scale, on which ecosystem services could fully express their dominant roles and effects of ecological space. Ecosystem services provided by landscape space would have different landscape performance with the change of temporal and spatial scales, for example, the cultural services provided by landscape space could change from the global scale (>1,000,000 km^2) to provincial scale (10,000–1,000,000 km^2), county scale (1–10,000 km^2), and then to site scale (<1 km^2). As the scale of landscape space becomes smaller, the cultural services of landscape space are reflected differently in providing the regional cultural patterns at national level, inheriting historical culture at regional level, and providing cultural landscape heritage at local level, as well as providing cultural perception of the site by stakeholders with different culture backgrounds.

The characteristics of landscape spatial elements could well be reflected through ecosystem services at different temporal and spatial scales, and they would help to understand the impacts of spatial distributions of human activities on landscape pattern and process. The diversity of ecosystem services could reflect the versatility of landscape spaces, which depends on the material basis of landscape with multiple functions and could be classified into production, regulation, maintenance of ecological structure, processing habitat, and information (Costanza 2008). It is beneficial to enhance the understanding and application of multiple functions of landscape space through combining the diversity of ecosystem services.

3.6.3.3 Quantitative Evaluation with Landscape Spatial Indexes

The purpose of quantifying and evaluating ecosystem services is to confirm the status and values of ecosystem, which is conducive to the development and protection of ecosystem. The determination of ecosystem service types and the establishment of evaluation index system are the basis and premise for the value evaluation and application of ecosystem service. Luo et al. (2015) classified the index system of LAF into environmental, economic, and social indexes of landscape performance, by which they believed that ecosystem services could be evaluated systematically with the change of landscape. Under the framework of landscape performance, the provision, regulation, and support services of ecosystem could be measured by indexes of environmental performance, which should be added to the measurement metrics of ecosystem services, such as climate regulation, hot-island mitigation, wind speed reduction, human disease controlling, storm, and waterlogging prevention. The cultural services of ecosystem can be measured through the indexes of social performance combined with indexes of tourism attraction, inspiration stimulation, and social relations. In conclusion, the indicators of landscape space performance provide a quantitative approach to the values generated by ecosystem services, which can evaluate ecosystem services and reflect the quality and functions of landscape space.

In a word, the function and value of landscape space need to be evaluated and quantified as the total human ecosystem provides a variety of ecosystem services. On the one hand, ecosystem services are feasible to be measured by performance indexes; on the other hand, they could reflect the characteristics and functions of landscape space. Therefore, ecosystem services could be used as the bridge among scales, multiple functional characteristics of landscape space, and corresponding indexes of landscape performance. The ecosystem service type of landscape space could be used as reference for the classification of landscape space performance evaluation index.

3.6.4 Evaluation Framework Based on Ecosystem Service

3.6.4.1 Framework of Landscape Spatial Performance Evaluation

According to the theory of total human ecosystem and framework of C-3P system, the analysis and evaluation of landscape space can be implemented from four dimensions which are component, pattern, process, and perception. The component is the material basis of landscape space and total human ecosystem. Spatial pattern is the expression of landscape function, characteristic, and evolution over time. Spatial process is the way to realize sustainable development of landscape space and the continuance of total human ecosystem. Landscape perception is the result of cognition to context and shaping of landscape space with orientation to human needs. Under the actions of these four dimensions with internal logic, the features and functions of landscape space could be presented, and diverse ecosystem services could be provided for human beings. The analysis of ecosystem services in different spatial dimensions is a helpful approach to define landscape spatial diversification, so as to

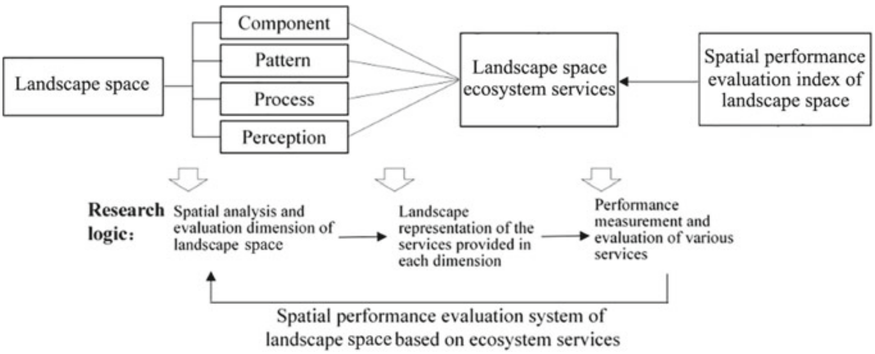


Fig. 3.14 Evaluation of landscape performance based on ecosystem services

determine the specific research object of landscape spatial performance quantification and evaluation and select the corresponding evaluation index and measurement method.

The logic for construction of landscape performance evaluation indexes is as follows: Firstly, landscape space is decomposed into four analysis and evaluation dimensions of component, pattern, process, and perception, on which ecosystem services provided by landscape space are classified. Secondly, the specific performance and ecosystem services in each dimension are analyzed, and the evaluation criterion of each dimension for each service is constructed. Finally, landscape spatial performance is classified according to ecosystem services, and specific performance indexes are selected according to each evaluation criterion to evaluate the comprehensive performance of the four spatial dimensions in the process of providing various ecosystem services. Ecosystem services could be used as bridges to build the evaluation index system of landscape performance through above approaches (Fig. 3.14).

3.6.4.2 Classification of Landscape Services

The classification of ecosystem services provided by landscape space is not only the summary of diversified functions of landscape, but also the premise of building landscape space performance evaluation system. At present, most scholars classified ecosystem services according to ecological attributes of ecosystem components, structures, and processes, such as classification of regulating, supporting, provisioning, and cultural services proposed by MEA (Millennium Ecosystem Assessment), which helped to reflect the impacts of ecosystem changes on human well-being except of changes on social and economic environments. This research classifies ecosystem services especially landscape service based on human needs for landscape space.

According to the theories on human needs of Abraham H. Maslow (1959), Clayton Alderfer (1969), combined with the relationships between human needs and landscape services provided by landscape space, this research believes that human needs for landscape space could be summarized into security, materials, and spiritual needs. Correspondingly, ecosystem services provided by landscape space can be classified into ecological security, material products, and cultural services. Ecological security services meet the needs of safety for a healthy and stable environment. Material product services satisfy the material demands of human for abundant and sufficient products. Landscape culture service meets the spiritual demands of human for beautiful and unique landscape culture.

The above three types of ecosystem services are reflected by four dimensions of landscape space, which are the characteristics of components, pattern, process, and landscape perception, and by which the total human ecosystem is constituted comprehensively with inner logics. Landscape space is regarded as an organic whole, of which ecosystem services are comprehensively evaluated through the assessment of landscape performance and ecosystem service values (Table 3.14).

Ecological security service provided by landscape space reflects the supporting and regulating functions of ecosystem, which mainly refers to the maintenance of ecological security such as natural environment and biological resources. In landscape space, the components with continuity on spatial–temporal process are key factors to form material space with consistent appearance and inner stability, which could provide specific services to form ecological corridors and provide perfect facilities (Liu and Yu 2013). At the same time, it could maintain the stability of habitats, avoid the isolation and fragmentation of landscape spaces, and provide specific services of habitats conservation, such as the animal and plant habitats, as well as human settlements. The stable spatial processes could support or regulate functions of ecosystem in changing environment, which enhance the resilience of landscape space to mitigate the external disturbance and provide services, such as climate, atmospheric, water, soil, and natural disaster regulation. From the perspective of building harmonious environment, landscape perception with security would strengthen the maintenance of physical senses, console the psychological feelings and mental health, and prevent and control human diseases.

The production service provided by landscape space reflects the support and supply function of ecosystem, which mainly refers to the supply of basic material products and space resources needed by human production and daily life. In landscape space, the components with high productive capacity are main bodies from which people obtain material products and economic sources. The specific services include output of living materials such as grain, fruits, and vegetables and production materials such as wood, rubber, fiber, and other raw materials. The diverse spatial patterns provide rich spaces and environmental resources for human activities, among them the spaces provide services of biodiversity protection and space resources, such as the production, living, ecological spaces, and environmental resources, such as water, soil, forest, and energy. The sustainable space processes can ensure the continuous outputs or circulations of various resources, which provide services of nutrient cycling, energy flow, waste treatment, and economic growth. Various

Table 3.14 Ecosystem services of landscape space and its evaluation criteria

Landscape space ecosystem services			Evaluation criteria
The primary classification	The secondary classification	Specification of ecological services	
Ecological security services	Constituting physical space	Forming the ecological corridor and providing the consummation facility system	Continuity of landscape element
	Maintaining stable habitat	Protecting the habitat	Integrity of pattern
	Supporting operation and acting	Regulation services of climate, air, water and soil, natural disaster	Process stability
	Creating a harmonious environment	Maintaining people's physical and mental health, prevention, and control of human diseases	Perception safety
Material product service	Material product output	Subsistence export (grain, vegetables, fruits, etc.)	Output material product
	Providing space and environment resources	Biodiversity conservation, provision of space resources	Providing space resources
	Supporting continuous output of resources	Nutrient cycling, energy flow, waste disposal, economic growth	Process sustainability
	Providing livable living conditions	Maintaining interpersonal relations and stabilizing social relations	Satisfaction of perception
Landscape culture service	Expressing regional cultural characteristics	Maintaining historical or cultural scenes, preserving historical sites and relics, inheritance of folkways and religion	Authenticity of elements
	The unique value of space	Protecting land use mechanism and presenting aesthetic characteristics	Identifiability of pattern
	Developing according to local conditions	Creating opportunities for leisure and recreation, scientific research and education, providing opportunities for public participation	Locality of process

(continued)

Table 3.14 (continued)

Landscape space ecosystem services			Evaluation criteria
The primary classification	The secondary classification	Specification of ecological services	
	Shaping local cultural image	Developing a sense of belonging, a sense of place	Identity of perception

services provided by ecosystem could reflect the livability of landscape space, which include maintaining interpersonal relations and stabilizing social relations.

Landscape culture services provided by landscape space reflect the cultural functions of ecosystem, which mainly refers to the non-material benefits which human beings get from ecosystem due to its unique composition and structure. In landscape space, the components which represent authentically the characteristics of regional culture are the important carrier of inheriting culture landscape and main targets of conservation, which provide services of maintaining historical or cultural scenes, preserving historical sites and relics and inheriting folk customs and religions. Secondly, landscape paces with identifiable patterns are endowed with unique values, such as protected, artistic, and cultural values, which provided specific services of land use protection and aesthetic characteristics presentation. Spatial processes have the distinct characteristic of locality under the driving forces of culture, society, economy, and technology with regional features, which could provide local and targeted supports and promotions for development of landscape space in different areas according to local conditions and provide services of opportunities for leisure and recreation, scientific research, and education, as well as opportunities for public participation. The images of local culture created by landscape space conforms to the understanding and cognition of local residents, which are the premise of effective inheritance of landscape culture and provide the services of forming the sense of belonging and cultivating the sense of place.

3.6.4.3 Landscape Space Performance Evaluation Index

Based on three types of landscape services and referring to classification of landscape performance indexes by LAF, this research classified the performance of landscape space into eco-environment influence, economic production, and human and cultural performance. Inspired by existing references and contributions of space performance research, such as landscape, urban space, construction, and ecological spaces, the evaluation indexes of landscape space performance are established based on the typical indicators reflecting the characteristics and functions of landscape space combined with conclusions of the specific ecosystem services. In this way, the performance of landscape space analysis is more reasonable and comprehensive, which corresponds to the evaluation index describing and measuring its characteristics, and the indexes were considered the feasibility of research and the availability of data. Finally, the indexes of landscape space performance evaluation with high feasibility of operation have been built and include 33 indexes, belonging to 12 sublevels and three categories (Table 3.15).

Ecological performance is used to measure the capacity of natural spaces providing the chances of coexistence between man and nature, from which man could benefit from the effects of environmental maintenance, governance, and ecosystem sustainability (Dong 1999). The continuity of elements is reflected through evaluation of elements connectivity and the perfection degree of facilities. The evaluation of landscape fragmentation and intensification of residential construction space could reflect the integrity of landscape patterns. The stability of process could be reflected by quality of environmental systems and resources such as air, water, and soil and the benefits of improving microclimate and disaster prevention and reduction. The security evaluation of natural and living environment could reflect the perception of safety together.

Economic production performance is used to measure the capacity and their effects of human production behaviors and living spaces, which is the benefits man could be provided from land use, resource supply, productive output, and ecosystem health. In the index system, the yield of food crops and raw materials reflects the productive capacity of landscape, and the indexes of biodiversity, ecological spatial diversity, and resource abundance reflect the diversity of landscape pattern. The indexes of material cycling, sewage, and waste disposal rate, employment growth rate, and GDP growth rate reflect the sustainability of process and the indexes of economic income, living environment, and social relationship reflect the satisfaction degree of people and harmony of society.

Culture performance is used to measure the places where human could benefit the values of artistic aesthetics, history, leisure and tourism, education, scientific research, local sense of belonging, and other intangible values. The utilization rate of local materials, integrity of historical buildings, originality of historical sites, and traditionality of customs are indexes to measure and evaluate the authenticity of components and landscape. The typicality of settlements and coordination of traditional agriculture could shape the recognizability of landscape patterns. The indexes of tourism and recreation benefits, education and research benefits, and participation of local residents could reflect the locality of processes, of which landscape perception could be evaluated through the survey on landscape personality and cultural resonance.

Landscape spaces at various scales are facing unprecedented pressures and threats today, so it is particularly important to implement practices of sustainable planning and design and to protect and improve the quality of landscape space. The evidence-based research and design methods of landscape architecture have become one of the main approaches to accelerate the scientific development in order to evaluate effectively the quality, efficiency, and possibility of landscape space at present and in future. The systematic, rigorous, and quantifiable landscape performance provides the quantitative evaluation methods and tools for the evidence-based study (Liu 2005, 2014; Fan and Zhuang 2014).

Table 3.15 Index system of landscape space performance evaluation

The goal	Rule	Index	Definition of Indicator
Environmental and ecological performance	Component connectivity	The connectivity of components The perfection of the facilities	The connectivity of ecological and heritage corridors The perfection of green infrastructure and public supporting facilities
	Pattern integrity	Degree of fragmentation Degree of network Degree of intensification	The degree of fragmentation of patch pattern The degree of network of patch pattern The degree of intensification of construction spaces such as cities and towns
	Process stability	Quality of resource and environment Microclimate improvement Disaster prevention and mitigation	Air quality, water quality, soil quality, etc. Regulation of landscape space for wind speed, temperature, humidity Sand control, flood and drought mitigation, rainwater management, etc.
	Perception safety	Safety of natural environment Safety of living environment	Climate suitability, air quality Human disease outbreak rate, settlement defensiveness, and disaster prevention capacity
Economic production performance	Components capacity	Food crop yield Raw material output	The output of various grains, vegetables, fruits, etc. The output of various raw materials for production
	Patterns diversity	Biodiversity index Ecological spatial diversity index Abundance of natural resource	The number of plants and animals in landscape space Human and natural ecological space diversity index The richness of landscape and environmental resources in landscape space

(continued)

Table 3.15 (continued)

The goal	Rule	Index	Definition of Indicator
	Process sustainability	Material circulation and fixed benefits Sewage and waste disposal rate Growth rate of employment Year-on-year GDP growth rate	Carbon fixation and oxygen production, water conservation, soil fixation and fertilizer, nutrient element circulation, and other benefits Sewage treatment rate, solid waste treatment, and recycling rate Creating employment opportunities for human beings Percentage of the gross product of landscape space increased year on year
	Perception satisfaction	Economic income satisfaction Living environment satisfaction Social relationship satisfaction	Income gap between residents and the average income level of residents Tidiness and convenience of landscape space Providing opportunities for people to communicate and interact
Human culture performance	Components authenticity	Utilization rate of local materials Historic building integrity Degree of restoration of historical scenes Retention degree of traditional customs	Total amount of local materials used in the construction process Overall retention degree of traditional architecture and the intact degree of traditional architectural details The extent of preservation, restoration, and restoration of historical sites and relics The extent to which local festivals and customs, artistic skills, and folk customs are preserved
	Pattern identifiability	The typicality of building settlements Traditional agricultural coordination degree	The uniqueness and typicality of spatial form of settlement patches in landscape space The coordination degree of traditional agricultural land pattern and surrounding land

(continued)

Table 3.15 (continued)

The goal	Rule	Index	Definition of Indicator
	Process locality	Tourism and recreation benefits Education and research benefits Local residents participation degree	The benefits of landscape space as a tourist destination and leisure place Landscape space as a scientific research object, education base, and other benefits Awareness of environmental protection, the degree of participation in improving the quality of landscape space
	Perception identity	Beauty identity Cultural image identity	Aesthetic degree of landscape space The degree of harmony between landscape space and local culture

However, the system of landscape spaces not only includes the spaces different from small and medium-sized spaces to spaces with large area or at larger scale, such as regional landscape and the watershed, but also can be different from their scopes, such as spaces of natural landscape and cultural landscape. Therefore, the existing landscape performance evaluation cannot directly evaluate the performance of landscape space with multiple scales and various types. In order to narrow this gap, the theory of ecosystem service is considered as a theoretical basis to reflect the characteristics of landscape spaces at multiple scales and with multiple functions and act as a bridge connecting the characteristics of landscape space with multiple functions and the indexes of performance evaluation.

Firstly, ecosystem services provided by landscape space are successively classified into services of ecological security, material product, and social culture based on the security, material, and spiritual human needs for landscape space. Secondly, the evaluation criteria mainly include the continuity, capacity, and authenticity of components, the integrity, diversity, and identifiability of pattern, the stability, sustainability, and locality of process, the security, satisfaction, and coherence of perception through the analysis of landscape space components, pattern, process, and perception. Finally, landscape performance is classified into environmental and ecological performance, economic production performance, and cultural performance, of which the evaluations are conducted through the method of *Analytic Hierarchy Process (AHP)*. According to three types of performance and 12 evaluation criteria of ecosystem services, the system including 33 indexes of specific performance is qualified, and the comprehensive performance evaluation index system is constructed with pertinence and operability based on ecosystem services.

This research is only the discussion and attempt to establish the system of comprehensive performance evaluation index for landscape space from perspectives of ecosystem services. However, there are still many challenges in the quantitative and analytical research of landscape architecture, for example, the research on landscape performance is still in its infancy stage, and the experience of quantifying environmental, economic, and social benefits is limited. Secondly, some types of ecosystem services, such as cultural services and regulating services, are difficult to be directly perceived by people, so they are difficult to accurately describe and quantify them, which lead to the finiteness of evaluation indexes because of inconformity with the classification criteria, as a result, the possibility of double counting is inevitable in the process of quantitative research on landscape performance and ecosystem services. Additionally, the regional changes of landscape spaces and intervention, interference of human activities, would bring challenges and difficulties to the universality of ecosystem service metrics, which provide the breakthrough directions and research focuses for future evidence-based research in the field of landscape architecture.

3.7 Verification of Ecological Space Unit

3.7.1 Identification and Classification of Ecospace Unit

The system of ecological space units aims to protect the original and diverse natural spaces and cultural activities through case study of the Nanyi Lake, Anhui Province in China based on the planning of regional landscape. The construction of landscape should be integrated systematically from basic ecological spaces to aggregated ecological spaces and holistic ecological spaces according to landscape cognition of hierarchy, classification, and interrelation, as well as organization mode of ecological units. It could be accelerated to realize the construction of beautiful urban–rural landscape and the integrated regional landscape through creating suitable spaces of production, living, and ecological conservation under the process of rapid urbanization.

3.7.1.1 Holistic Ecological Space Units

The natural and human components are richly in planning area around the Nanyi Lake, which mainly include the mountain, hill, highland, flatlands, and central lake as typical components at the scale of holistic ecological unit. The mountains are concentrated in the southeast and northwest adjacent to central lake area with small percentage of the total area. The highland is mainly distributed around the mountain area, mostly in north and south of the central lake area, and occupies small proportion. Hilly land takes up a large proportion, which locates around the central lake. Flatlands are in and between hilly lands, playing a role of geomorphologic transition. The

Table 3.16 Spatial patterns of landscape around the Nanyi Lake

Element		Spatial pattern	Subgroup	Characterization	Cluster of element form
Physical features	Mountain area	Dispersion	Random distribution	Mountain patches are scattered in the region	Linear, patch
	Lowland area	Extension	Ridged extension	Extending along the ridgeline to the lake	Patch, scattered extension
	Hilly area	Combination	Dendritic combination	Hills mingled with river tributaries and the plains	Patch
	Highland	Extension	Scattered extension	Extending along the ridgeline to the lake	Patch, finger-like extension
	Lake area	Combination	Central water and dendritic channels combination	Consisting of the central lake and a branched river	Patch, linear, network
Human elements	Relics and landscape	Dispersion	Random distribution	Uniformly distribution in the site, different types of relics, and physical landscape are affected by topography and landform	Scattered
	Residential area	Dispersion	Random distribution	Distribution location is greatly affected by topography and water system	Patch, scattered

following table shows the statistical classification and morphological summary of natural and cultural elements in the site (Table 3.16). Furthermore, the morphological characteristics of five types of elements are determined at a macroscopic scale and by which the eco-environment could be controlled and conserved.

3.7.1.2 Aggregated Ecological Space Units

The complex of landscape around the Nanyi Lake can be classified into six main types and ten subdivisions with consideration of the basic functions and interface models of the site and the classification of function complex in the cognitive system

Table 3.17 Spatial interfaces and functions of landscape around the Nanyi Lake

Interface classification		Element of connecting space	Interface function
Intermeshed	Finger-like intermeshed and humped	Mountain and field, water and wetlands, water and farmland, land and water, etc.	Creating a critical space
Conterminous	Relatively smooth interface	Roads and farmland, tributaries and farmland, mountains and tributaries, etc.	A sign of relative functional separation
Separation	Wrapped relationship with separation	Roads and settlements, shelterbelt and water, etc.	Relation between things but without direct connection

of aggregated ecological space units. The system can reflect the basic characters of landscape within the site comprehensively, and the understanding of ecological functions of the site is conducive to zoning and arrangement activities adapting to landscape context and landscape pattern (Table 3.16).

Three basic interface spaces of the site, including fusion, connection, and separation, can be identified obviously, which are the basis for the evolution of various types of activities, as well as the interfaces for distinguishing different activities (Table 3.17).

Through the summary of interface spaces and determination of combined functions in aggregated space units, we could better understand the characteristics of local natural conditions and optimize the configurations according to the characteristics of site in the process of scenic spot design, so as to create the most appropriate landscape experience environment with the most appropriate interface spaces and spatial relationships.

3.7.1.3 Basic Ecological Space Units

According to the classification of component combinations in system of basic ecological space units, there are also three types of component groups around the area of Nanyi Lake, which are the combination of cultivated land and water area, the combination of road-settlement, cultivated land and vegetation, and the combination of waterbody, vegetation, and terrain or settlement. These three categories of component groups form the basic types of spatial units and basic spatial types of integrated spaces (Table 3.18). The site is grasped and recognized through the cognition of three levels of ecological space units, which means the cognition and positioning of holistic landscape pattern, the cognition and utilization of interface spaces, and the function and morphology cognition of landscape space at small scale (Table 3.19).

Table 3.18 Function and interface feature of landscape site around Nanyi Lake

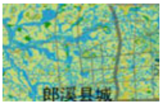
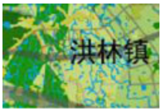
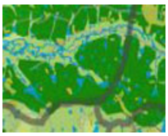
Functional combination		Interface space	Interface characteristics	Example
Residence, production and Ecological conservation	Residence, production space and waterscape	Water and cultivate field	The interface is mainly an interlaced form of water and land, which blends with each other and retreats and advances	
	Residence, production and woodland space I	House parallel to woods	Both buildings and trees are parallel to the contour line, and trees provide a good shelter and protection space for buildings. The two are interdependent, buildings and the field are protected by trees, and trees spaces are enriched by the presence of buildings and fields	
	Residence, production and woodland space II	House separated from woods	Trees are densely distributed parallel to the contour lines, while the houses and farmland mostly exist in areas with relatively gentle terrain, forming an interactive and isolated space between the woodland, the living and production space. The interface is relatively clear, and the interface relationship is progressive and recessive	
Shelterbelt, Residence and production	Waterside protection, residence and production	Trees parallel to the water shoreline	Shelterbelt land is parallel to water shoreline, forming the mode of outsourcing living and production space	

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Table 3.18 (continued)

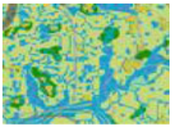
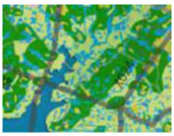
Functional combination		Interface space	Interface characteristics	Example
	Alpine protection, residence and production	Trees crossing fields	The tree cluster extends along the ridge and valley, and the rest part is farmland. The farmland, living space and shelterbelt are interlaced to form a multi-level integrated space	
Storage and regulation areas, Residence and production	River and paddy field, residence and production	River and field fusion in harmony	Rivers and paddy fields blend with each other, and there is no clear boundary between them. The function of river regulation and storage could be strong with the help of paddy fields, and the water source and construction of paddy fields could also be realized through rivers	
	Central Lake district, residence and production	Lake and residence adjacency	There are many tidal flats and wetlands around the central lake, which are not suitable for building houses or developing dryland farmland. However, there would be a symbiotic relationship between them, in which one moves in and the other moves out	
Storage and regulation areas, and Shelterbelt		Water body and trees embrace each other	The relationship between lakes surrounded by water, and trees surrounded by water	

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Table 3.18 (continued)

Functional combination		Interface space	Interface characteristics	Example
Storage and regulation areas, and ecosystem conservation	Central lake district and wetland space	Multiple plants community intermeshed	The interface is composed of a variety of aquatic and semiterrestrial plants, which is the transition zone between water and land	
Ecosystem conservation and Shelterbelt	Wetland space and shelterbelt	Ablative gradually	From the wetland space to the shelterbelt space, the species diversity is more and more varied, the wetland plants are gradually reduced, and the shelterbelt plants are gradually increased	

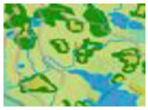
3.7.2 Division of Ecological Space Units

According to the cognition and classification of ecological space units on three levels and basic compositions and characteristics of different landscape units, this research proposed the appropriate planning measures to meet the goals of macroscope ecological planning, and at the same time, on the maximum extent to maintain regional ecological network and the characteristics of circular distribution. In terms of ecological integrity, it emphasizes the preservation and reflection of regional characteristics at macroscale to improve the connection mode between space units at mesoscale and ensure the relative stability of eco-environment at microscale. In terms of regional landscape characteristics, it emphasizes that regional texture and characteristics should be reflected at macroscopic and mesoscale.

The regional amorous feelings were reflected by making use of regional indicative plants or building regional indicative small spaces at microscale. Ecological space units are connected through space coupling on horizontal dimension according to the connection of tourism functions so as to form a relatively complete space system. Therefore, landscape spaces around the Nanyi Lake were divided into units of water body, water storage and regulation space, watershed intersection, small mountainous, hilly spaces, landform transition unit I, landform transition unit II, landform transition unit III, waterscape network in mountainous area, waterscape network in plain area, and regular network landscape in plain area according to the standards and guidance. There are 11 types of landscape units (Fig. 3.15; Table 3.20).

The macroscopic ecological location of the planned area is transformed from an ecological node to a strategic ecological hub in the evolution of historical water environment. At the early stage, the Nanyi Lake was just part of the ancient Danyang

Table 3.19 Elements, forms and functions of landscape site around Nanyi Lake

Element group	Composite type	Form	Features	Typical pattern
Cultivated land-landform/watershed combination	Splicing	Finger like	Comply with the terrain, connect the water source, and use the land to create rich production spaces	
	Monomer repetition	Fingerprint repetition, Terraced repetition	While the cultivated land conforms to the terrain and topography, the vein is prominent and the zoning is obvious	
Road-settlement/plantation/Plant combination	Wrapped	Linear	The road between settlements is helpful for people to reach the destination quickly and form a more convenient traffic environment	
	Intermeshed with linear space	T type Linear	Road and cultivated land form a linear intermeshed structure, which is conducive to people's farming activities and reach the destination quickly, while square fields are convenient for farming and management	

(continued)

Table 3.19 (continued)

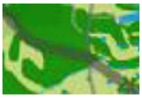
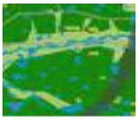
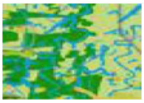
Element group	Composite type	Form	Features	Typical pattern
	Wrapped	Linear Patch	Under the influence of topography and surrounding environment, the road and vegetation form special relationships, such as interval and intermeshed space, thus forming rich and diverse road spaces	
Water body–plant /terrain/settlement combination	Surrounded in ring	Patch Annular	Vegetation surrounding water protects the water environment and provides a relatively stable microclimate, which forms a more comfortable farming and production environment	
	Blending	Linear	The waterbody extends along the terrain and topography, forming the environment where mountains and rivers support each other	

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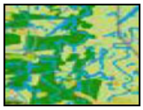
Table 3.19 (continued)

Element group	Composite type	Form	Features	Typical pattern
	Wrapped	Patch Linear	The settlements are distributed linearly or horizontally along the water area, forming a production and living space centered on water. Living in accordance with the water provides great convenience for people to produce and live	

Lake and was the auxiliary water regulation and storage system for the maintenance of ecological security. The area of ancient Danyang Lake decreased sharply with more and more construction of polders, and the ecological regulation and storage functions of Danyang Lake decrease greatly. It is the main reason that most of water flows in the upper reaches of Shuiyang River need to be regulated and stored by Nanyi Lake, so the change of water environment and internal ecological process would lead to the overall transformation of ecological location of the area around Nanyi Lake. The macrogoal of ecological planning is to build a total landscape pattern with security of water system, which can strongly support the ecological positioning of strategic hubs. Specifically, it minimizes the impact of surface runoff except for rivers on regional water system storage in terms of water volume.

Through the division and planning of landscape spatial units, the results of planning were compared before and after (Table 3.21).

3.7.3 Zoning of Ecological Functions

This planning divided the whole area into six ecological functional zones which are the core ecological area of waterbody, core ecological area of terrestrial ecosystem, ecological optimization area, ecological transition area, ecological coordination area, and residential construction area. Each ecological area presents the characteristics of circular distribution with the Nanyi Lake as the center. With the increase of

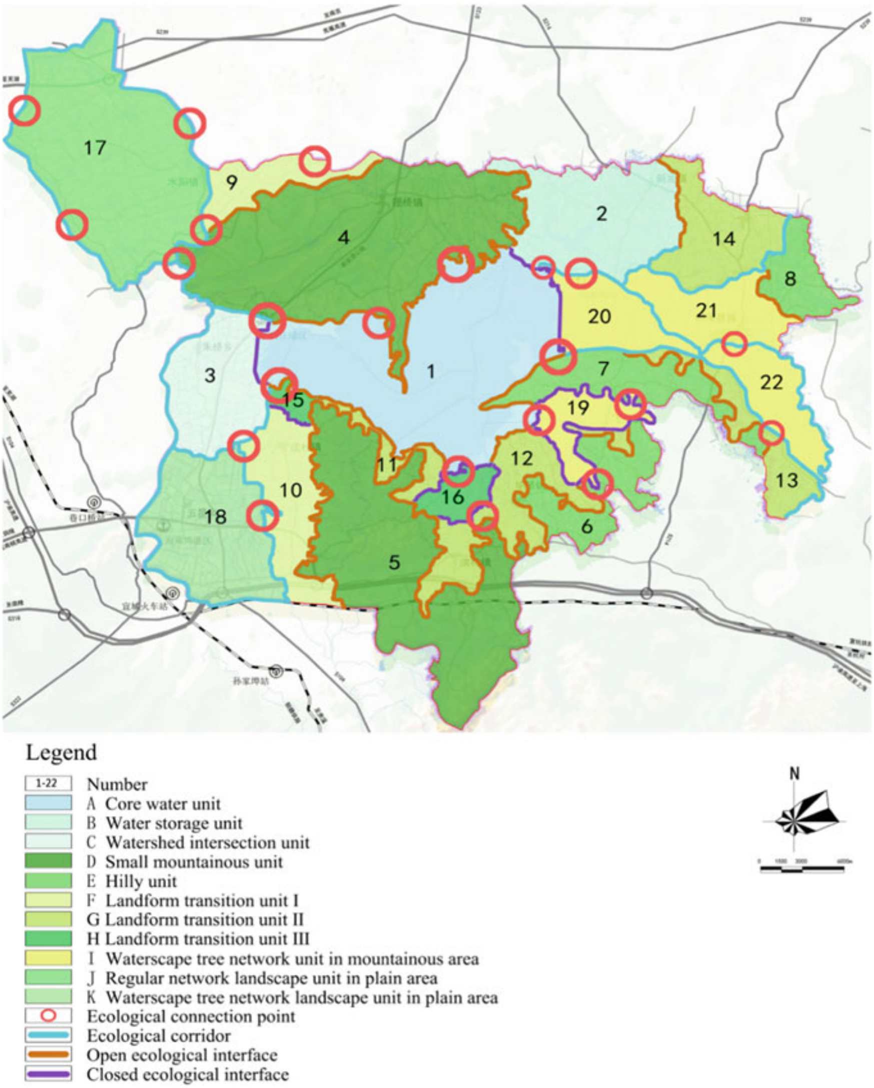


Fig. 3.15 Distribution of holistic landscape space units

spatial distance away from the center of lake, it shows a trend of offset from each other in scale and construction intensity in ecological space and construction space (Fig. 3.16).

The core ecological function area of waterbody: All water area of the Nanyi Lake, where surface elevation is less than or equal to 8.6 m, and the surroundings of natural or artificial tidal flats, wetlands, and other spaces which are maintained and supplemented due to the needs of environmental protection. The total area of

Table 3.20 Characteristics and functions of landscape unit

Landscape unit	Basic composition and characteristics	Status in regional ecological pattern	Key points of ecological planning
1. Main unit of waterbody: Landscape unit is dominated by the main waterbody of Nanyi Lake	It mainly includes the main waterbody of Nanyi Lake and the surrounding tidal flats, wetlands, potholes, and polders with the elevation below 13.5 m	It is the core of regional ecological pattern, the sink of ecological process in the Nanyi Lake Basin, and one of the sources of ecological process in the Shuiyangjiang River Basin	1. Scale and layout of Shuikou wetland 2. Ecological reconstruction of polder in the areas around Nanyi Lake 3. Planning of ecological buffer space around the lake 4. Ecological connection with the surrounding ecological spaces
2. Water storage unit: Landscape unit mainly centered on the south lake and the surrounding wetlands	Hilly terrain, good vegetation coverage, and developed farmland water network provide advantages for the stability of internal ecosystem of landscape unit, which is further strengthened by the construction of the sluice	It is relatively independent in the holistic pattern, and the change of topography, geomorphic features and connections with the water system of Nanyi Lake make it a special ecological buffer space in regional ecological pattern	1. Planning of ecological buffer spaces around the lake 2. Integration of core ecological function space in the north and construction of network pattern of agricultural production space in the south 3. Strengthen the integration pattern with Nanyi Lake
3. Watershed intersection unit: Zhuqiao polder landscape	The agricultural production landscape in the polder area of the plain, with Zhuqiao polder as the core, has formed the similar grid landscape texture	Semi-artificial independent landscape ecological space, which mainly has negative impact on regional ecological system. Landscape unit was a strategic ecological space before the construction of the polder, but with the construction of the polder, the ecological space in the unit has been compressed and its original ecological functions have basically disappeared	1. Maintaining and continuing the cultural and ecological context 2. The construction of the network ecological pattern 3. Ecological treatment of ecological connection space which is mainly realized by increasing the construction density of farmland forest network and expanding the scale of conservation potholes
4. Low mountainous unit: Five dragons—Changshan landscape	The existence of mountain range is one of the prerequisites for the formation of the Nanyi Lake, the southwest–northeast direction of mountain range is also the watershed of precipitation in the unit, and good vegetation coverage makes it become a high-quality ecological space	Landscape unit is the northern barrier of regional ecological pattern and one of the sources of regional ecological process. Its ability of ecological conservation and habitat provision is second only to the Nanyi Lake and Dangnan Lake landscape units	1. Defining its control and protection boundary as ecological space 2. Strengthen the integrated ecological pattern with the Nanyi Lake through ecological buffer spaces and corridors

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Table 3.20 (continued)

<table>
<tr><th>Landscape unit</th><th>Basic composition and characteristics</th><th>Status in regional ecological pattern</th><th>Key points of ecological planning</th></tr>
<tr><td>5. Low mountainous unit:
Magu Mountain Landscape</td><td>The unit is the watershed of the area, complementing the Nanyi Lake basin via the Sha River on the east side through the earth's surface. Runoff complements the Shuiyang River Basin on the west side, and good vegetation coverage makes it a high-quality ecological space</td><td>Landscape unit is the southern barrier of regional ecological pattern and one of the sources of regional ecological process</td><td></td></tr>
<tr><td>6. Low hilly unit I</td><td>It mainly locates in the relatively high hilly terrain area in the southeast of the planning area, which is an important water storage space in Shahe River Basin</td><td rowspan="3">Landscape unit is basically the same as that of Magu Mountain in the composition of regional ecological pattern, which is the regional ecological pattern of the southern barrier. However, due to the large amount of agricultural and forestry production space, the fragmentation of ecological space is relatively high, and the corresponding ability to provide habitat space is limited</td><td rowspan="3">1. Integrate the core ecological space with relatively high terrain to strengthen its functions of soil, water, and surface runoff conservation
2. Carry out ecological transformation on the existing water system and strengthen the connection between the water system and the surrounding core ecological space through the connection of the facilities and ecological space in corridors</td></tr>
<tr><td>7. Low hilly unit II</td><td>With Fushou Island as the core, it is an important water storage space in the basin of Shahe River and the Huxungchuan River</td></tr>
<tr><td>8. Low hilly unit III</td><td>It takes Longxu Lake Reservoir as the key area of low hilly landscape unit</td></tr>
<tr><td>9. Landform transition unit I-01</td><td>It includes Weidong Polder and the relatively flat terrain area in the southwest</td><td>Landscape unit is an important buffer space of regional ecological pattern and is the strategic ecological space in the regional ecological pattern</td><td rowspan="2">1. Strengthen the ecological connection of the catchment of the surrounding mountains by means of ecological buffer space
2. Effectively retain surface runoff by setting low-level ecological corridors parallel to the trend of surrounding main rivers and mountain
3. Comb the forest networks and irrigation ditches in the field, integrate them in the form of network, and strengthen the treatment capacity of sewage produced by purifying agriculture and related industries</td></tr>
<tr><td>10. Landform transition unit I-02</td><td>Landscape unit locates between the small mountain landscape of Magu Mountain and the polder area of the plain. The current situation is mainly agricultural production space with slightly undulating topography</td><td>Landscape unit is the general buffer space of regional ecological pattern. The area is less affected by hydrological changes, and the water network density is much less than that of the western polder area</td></tr>
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Table 3.20 (continued)

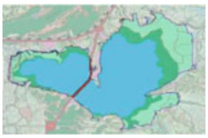
Landscape unit	Basic composition and characteristics	Status in regional ecological pattern	Key points of ecological planning
11. Landform transition unit II-01	Contains the mountain and water transition area from Wucun to Sihe Polder	Landscape unit is the general buffer space of regional ecological pattern. It is less affected by hydrological changes, and its ecological conditions are stable and good, which is suitable for human settlement activities	1. Strengthen the ecological connection with mountain and lake landscape units through the setting of ecological buffer space around the lake and the mountain 2. Through the setting of low-level corridors between mountain and lake landscape units, of which the pattern construction is improved
12. Landform transition unit II-02	It mainly includes the Shahe River Basin between Sihe Polder and Tuanjie Polder	Landscape unit is buffer space of regional ecological pattern, which is an important ecological buffer space for controlling the amount of cement and sand, ensuring water quality and storage	
13. Landform transition unit II-03	The transition area between the south side of the upper reaches of the New Langchuan River and the hilly landscape unit with Fushou Island as the key area	Landscape unit is an important buffer space of regional ecological pattern	1. Organize the existing low-grade water system intersecting with the surrounding main rivers, connect and supplement potholes through corridors, and improve the overall water storage capacity of landscape unit 2. Relying on the existing ecological space, the stepping stone system is used to strengthen the construction of the open ecological interface
14. Landform transition unit II-04	It mainly contains the hilly catchments between the upper reaches of the Zhongqiao River, Dangnan Lake, and Longxu Lake Reservoir. It mainly contains the hilly catchments between the upper reaches of Zhongqiao River, Dangnan Lake, and Longxu Lake Reservoir	The Zhongqiao River is a complement of the Langchuan River and also a seasonal river. The unit is relatively independent on space, rich in potholes and vegetation coverage, and has the characteristics of network, and the ecological quality and stability is high	
15. Landform transition unit III-01	It mainly includes wetland, tidal flat, and some polder areas at the entrance of the Shuangqiao River	Landscape unit is an important ecological buffer space in regional ecological system, and its upstream is the main agricultural activity space. The existence of this landscape unit is very important to reduce the negative impact of agricultural production on the lake area	Enhance the ecological self-purification ability of landscape units through the network integration of ecological space in existing polder areas and the ecological transformation of some polder areas
16. Landform transition unit III-02	It mainly includes wetlands, tidal flats, and some polder areas at the entrance of the Shahe River	Landscape unit is an important ecological buffer space in regional ecological system and the inlet of the Shahe River Basin. The existence of this space is very important for the regulation of hydrological environment and sediment retention	

(continued)

Table 3.20 (continued)

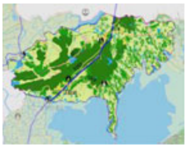
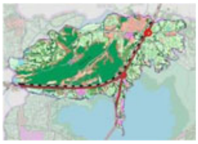
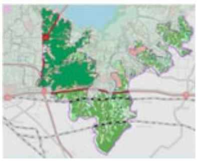
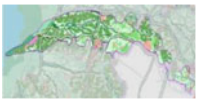
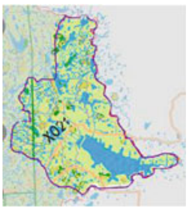
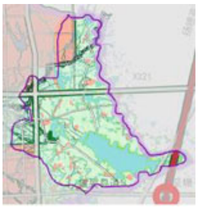
Landscape unit	Basic composition and characteristics	Status in regional ecological pattern	Key points of ecological planning
17. Regular network landscape unit in Plain area: Jinbao Polder landscape unit	With Jinbao Polder as the main part of the seminatural landscape unit, it presents obvious characteristics of regular network form	As a general part of regional ecological system, landscape unit is relatively independent in space, and its overall impact on regional ecological system is reflected as a negative disturbance	1. Maintaining and continuing the cultural and ecological context 2. The construction of the ecological network pattern 3. The treatment of ecological connection space is mainly through increasing the construction density of farmland–forest network and expanding the scale of conservation potholes
18. Waterbody network landscape unit in plain area: Wuxing and Shuangqiao	The seminatural landscape with Wuxing and Shuangqiao, which has the obvious characteristics of waterscape network		
19. Waterbody network unit in mountainous area: Xingfu Polder	With Xingfu Polder as the main part of the seminatural landscape unit		
20. Waterscape tree network unit in mountainous area: Diyi Polder landscape unit	It is a seminatural landscape unit mainly composed of the Diyi Polder		
21. Waterscape network unit in mountainous area: Nanfeng Polder landscape unit	With Nanfeng Polder as the main part of the seminatural landscape unit		
22. Waterscape tree network unit in mountainous area: Yuejin-Tuanjie Polder landscape unit	With Yuejin-Tuanjie Polder as the main part of the seminatural landscape unit, it presents obvious characteristics of waterscape tree network form		

Table 3.21 Comparison between the existing and planning of regional landscape

Landscape unit	Existing condition	Planning proposal	Key points of ecological planning
Landscape unit 1			1. Scale and layout of the Shuikou wetland 2. Ecological reconstruction of polder areas around the Nanyi Lake 3. Planning of ecological buffer spaces around the lake 4. Ecological connection with the surrounding ecological spaces

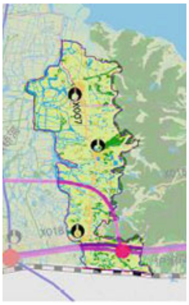
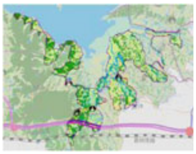
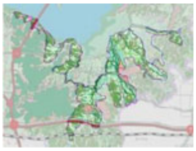
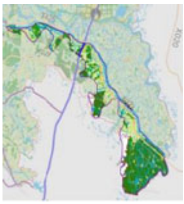
(continued)

Table 3.21 (continued)

Landscape unit	Existing condition	Planning proposal	Key points of ecological planning
Landscape unit 2			1. Planning of ecological buffer spaces around the lake 2. Integration of core ecological function spaces in the north and construction of network pattern of agricultural production spaces in the south 3. Strengthen the integrated pattern
Landscape unit 3 and 18			1. Maintaining and continuing the cultural and ecological context 2. The construction of the ecological network pattern 3. Ecological treatment of external connection spaces
Landscape unit 4			1. Defining its control and protection boundary as ecological space 2. Strengthen the integrated ecological pattern with Nanyi Lake through ecological buffer spaces and corridors
Landscape unit 5			1. Defining its control and protection boundary as ecological spaces 2. Strengthen the integrated ecological pattern with Nanyi Lake through ecological buffer space and corridors
Landscape unit 7			1. Integrate the core ecological space with relatively high terrain to strengthen its functions of soil and water conservation and land conservation 2. Ecological transformation of the existing water system 3. Use corridors or stepping stones to strengthen the construction of open ecological interfaces around landscape units
Landscape unit 8			

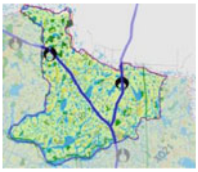
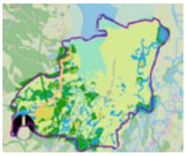
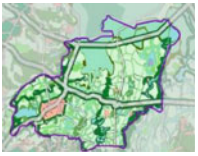
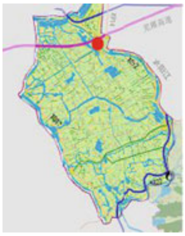
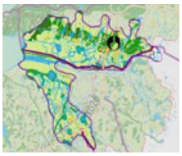
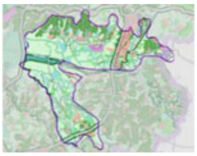
(continued)

Table 3.21 (continued)

Landscape unit	Existing condition	Planning proposal	Key points of ecological planning
Landscape unit 9			1. Strengthen the surrounding mountains by means of ecological buffer spaces 2. Effectively retain surface runoff by setting low-level ecological corridors parallel to the trend of surrounding main rivers and mountains 3. Comb the existing forest networks and irrigation ditches in the field
Landscape unit 10			1. Strengthen the surrounding mountains by means of ecological buffer spaces 2. Effectively retain surface runoff by setting low-level ecological corridors parallel to the trend of surrounding main rivers and mountains 3. Comb the existing forest networks and irrigation ditches in the field and integrate them through networking
Landscape unit 11 and 12			1. Strengthen the ecological connection with mountain and lake through the setting of ecological buffer spaces around the lake and the mountain 2. Through the setting of low-level corridors between mountain and lake, the internal pattern construction of landscape units is improved
Landscape unit 13			1. Strengthen the ecological connection with mountain and lake through the setting of ecological buffer space around the lake and the mountain 2. Through the setting of low-level corridors between mountain and lake, the internal pattern construction of landscape units is improved

(continued)

Table 3.21 (continued)

Landscape unit	Existing condition	Planning proposal	Key points of ecological planning
Landscape unit 14			1. Organize the existing low-grade water system and improve the overall water storage capacity of the landscape unit by means of corridors and adding potholes 2. Use stepping stone system to strengthen the construction of open ecological interface around landscape units
Landscape unit 15			1. Organize the existing low-grade water system and improve the overall water storage capacity of the landscape unit by means of corridors and adding potholes 2. Use stepping stone system to strengthen the construction of open ecological interface around landscape units
Landscape unit 16			1. Maintaining and continuing the cultural and ecological context 2. The construction of the ecological network pattern 3. Ecological treatment of external ecological connection space. It is mainly through increasing the density of farmland and forest network construction and expanding the scale of conservation potholes
Landscape unit 17			1. Maintaining and continuing the cultural and ecological context 2. The construction of the ecological network pattern 3. Ecological treatment of ecological connection space. It is mainly through increasing the density of farmland and forest network construction and expanding the scales of conservation potholes
Landscape unit 19			

(continued)

Table 3.21 (continued)

Landscape unit	Existing condition	Planning proposal	Key points of ecological planning
Landscape unit 20, 21 and 22			

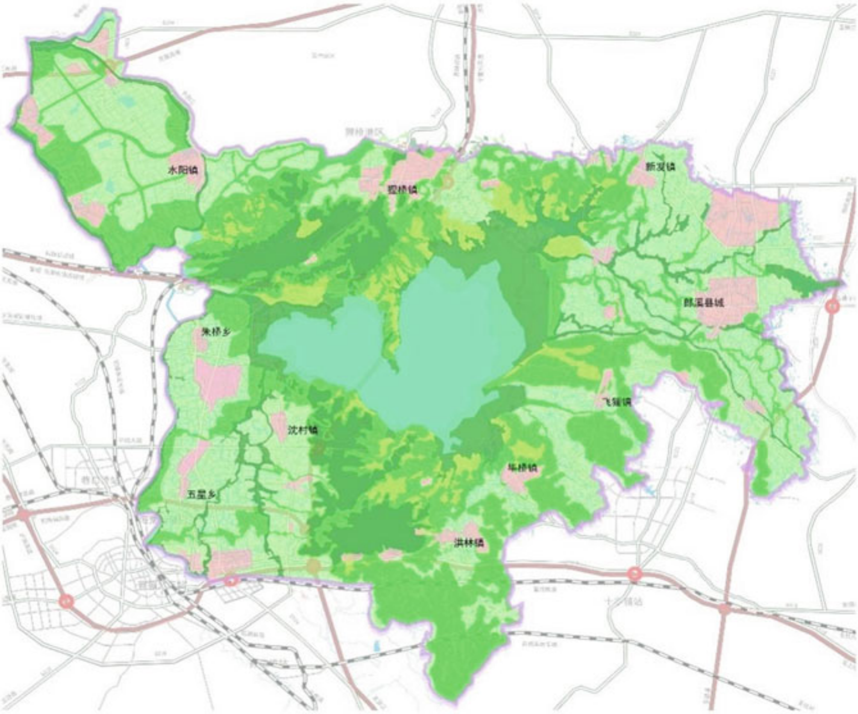


Fig. 3.16 Overall mapping of ecological function zoning

the core ecological function area of lake is 140.61 km^2, accounting for 9.48% of the total area of planning. The proportion of the planned wetland area is controlled at 10–15% with consideration the harmonious relationship between landscape quality and ecological environment. All forms of fishery production and aquaculture are prohibited in the core ecological function area of water, and the existing fishery production and operation facilities and activities should be gradually cleared away from the water area and the ecological function area. The villages in this region should be removed out and restored ecologically step by step. Wetlands construction should

Table 3.22 Percentage of ecological function zoning in overall landscape

Name	Area (km^2)	Percentage (%)
Waterbody ecological area	140.61	9.48
Terrestrial ecological area	244.43	16.48
Ecological optimization area	65.11	4.39
Ecological transition area	405.65	27.35
Ecological coordination area	511.70	34.50
Residential construction area	115.68	7.80
Total	1483.18	100

be focused on at the entrance of water flowing in or out, and wetland spaces should be set with domestic sewage of residential areas, agricultural production sewage, and aquaculture sewage at corresponding scale without affecting the normal hydrological regulation and storage function and making full use of the wetland tidal flats (Table 3.22).

The core ecological area of terrestrial ecosystem: the spaces with water sources, wetlands, and polders along waterfront of lake, aggregated forest lands, lands with steep slope and highlands, and main ecological corridors dependent on rivers, of which the Wulong, Magu mountains, and the Dangnan Lake are main ecological patches and polders around the lake, all spaces of mudflats, wetlands, and forest belts are connected in circular structure. The total area is 244.43 km^2 accounting for 16.48% of the total area. Ecological improvement of industry should be carried out in polder areas around the Nanyi Lake to reduce or eliminate water pollutions by aquaculture. Meanwhile, the policy of *'Returning polder areas to lake'* should be carried out in some polder areas, in which the functional replacement of fisheries around the peninsula of Nanmu Zui and Dangnan Lake was made into an integrated space with aquaculture and strong ecological functions. The belt with width of 50–100 m outside of the polders is demarcated as a zone of ecological buffer and built as parts of ecological spaces around the lake together with the modified polder area. The area connecting the Dangnan Lake and the Nanyi Lake would be transformed into a compound space with functions of ecological agriculture, wetland tourism, water regulation, and water quality purification through planting wetland community with economic value, dredging lakebed, and improving the overall landscape. The main ecological areas of the Magu and Wulong mountains, the ecological forests and non-commercial forests should be protected strictly, and economic forests should be carried out in a scientific way of logging and utilization. The habitat restoration of damaged mountains shall be carried out through ecological restoration technology with the orientation of nature-based solution (NBS). The residential areas should reduce the negative disturbance to environment by moving out gradually and combining with ecological transformation. At the same time, all forms of new and expanded construction activities should be prohibited except for major traffic facilities, municipal public facilities, tourism facilities, and natural parks.

Ecological optimization area: The spaces with better eco-environment conditions can accommodate a range of scales and intensity of human settlement constructions without affecting ecological quality after landscape planning and integration, which locates at the area between the core ecological function area and the ecological transition area, mainly along the south and north edge of the Nanyi Lake. The area is 65.11 km^2 accounting for 4.39% of the total area and of which it is suggested that the area should be no less than 60% of total area of ecological space. Based on the premise, the connectivity should be fully considered between internal and external ecological spaces, the corridors should be implemented in ecological security pattern at various scales, and the quality and quantity of landscape should be guaranteed from the dual perspectives. The principles of overall concentration and internal dispersion should be followed in new constructions, and the combination with ecological elements should be considered to reduce the negative impacts on environment. It is suggested that the floor area ratio of new construction projects should be controlled within 0.6–0.8 and the rate of green space should be no less than 40% in the planning. The residential areas should be strictly controlled in terms of their new construction and expansion size, in which some residential areas can be merged in a timely and appropriate manner through combination with new rural community construction and new projects within the region.

Ecological transition zone: Spaces including the core ecological function area, ecological buffer, secondary ecological corridor, and some ecological function space in ecological security pattern can be regarded as the strategic spaces in the planning area. On the one hand, it integrates the fragmented spaces systematically by means of zoning; on the other hand, it also limits the intensity of construction activities which just approve the modes of low-density construction. The total area is 405.65 km^2 accounting for 27.35% of the planned area, which should be no less than 80% of ecological space after planning. The constructions with large scale should be prohibited, moderate expansion of existing settlements is allowed, and transformation of rural settlements in the form of '*Beautiful villages*' and '*Ecological villages*' is encouraged. It is claimed clearly in ecological transition zone to make full use of landscape resources and protect the ecological context of '*Blue-green complex*', promote ecological transformation of traditional agriculture and aquaculture, and reduce the negative interference of industrial development. The scale of residential areas should be strictly controlled in planning, and the agriculture and domestic sewage should be treated through increasing the density of forest networks in farmland for polder area with high density of water system and river flowing out.

Ecological coordination area: Spaces were mainly cultivated as basic farmlands and polder areas, which locate at the periphery of human settlement construction area and are the important compositions of the mutual relationship between coordinated construction spaces and ecological spaces in this region. The total area is 511.70 km^2 accounting for 34.5% of the planning area. A network of forests coexisting with water systems and roads in farmland can be built through vertical greening with crops. They are the typical areas of traditional settlements and the important cultural landscapes representing the harmonious relationship of man–land for a long time, in which the important and native socio-ecological landscapes need to be protected through the planning. On the basis of basic farmland and landscape texture protection, it is allowed to increase the appropriate scale of construction spaces in an intensive way and of which the specific location should be determined through comprehensive analysis in combination with conditions such as public service facilities and traffic location.

Residential construction area: Spaces suitable for construction of centralized residential settlement with large area on the premise of ensuring regional ecological security and landscape quality, which locate outside the ecological transition zone and surrounded by the ecological coordination zone. The residential construction area is mostly planned based on existing residential construction spaces with large area, which is surrounded by areas with low ecological risk as potential expansion spaces for future needs (Gao and Wang 2016). The total area is 115.68 km^2 accounting for 7.8% of the total planning area. The land with large size for new construction during the planning period must be controlled within the scope of residential construction area. The external ecosystems should be fully considered to connect with internal ecosystems in the residential construction area and protect ecological corridors and functional patches of all levels by means of green spaces construction at the same time.

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Chapter 4
Landscape Space C-3P Analysis

4.1 Landscape Space C-3P Analysis

4.1.1 Content of Landscape Space C-3P System

The C-3P framework refers to cognition and analysis of the components, pattern, and process of landscape space at a certain scale, as well as landscape perception which was cognized comprehensively and totally on other three dimensions (Shen and Wang 2017; Bell 1999). The system establishes a comprehensive and systematic framework on spatial analysis of regional landscape with multi-scales and multi-dimensional characteristics (lyle 1999). The characteristics and their concrete embodiments of landscape space at different scales are also different and vary obviously due to the difference in composition, structure, and function of landscape. The connotation of analysis and cognition of landscape space at certain scale based on C-3P analysis system are as follows:

Based on identifying the consistence and spatial logics of landscape, the system could be used to distinguish space units from overall environment and clarify the correlations between landscape units through decomposing, naming their components, and then classify space units by the characteristics such as quantity, shape, and distribution. The spatial processes and connections were analyzed to maintain the establishment, spatial combination, and the stability of ecological relationships among various components in landscape space. It is necessary to perceive and evaluate the phenomenon and inner processes of landscape space from perspectives of esthetics, psychology, ecology, sociology, and other disciplines (Stephenson 2008), so as to build a rich, three-dimensional, and comprehensive experiences and understanding of landscape space at multiple scales.

Based on the above viewpoints and the characteristics of scaling and nested structure of landscape space, the C-3P analysis was established to adapt to the multiple scales of the holistic, aggregated, and basic landscape space. The four cognitive dimensions in the C-3P analysis of landscape spaces and their relationships are shown in Fig. 4.1.

Y. Wang, *Landscape Pattern Language*, EcoWISE,
https://doi.org/10.1007/978-981-19-6430-5_4

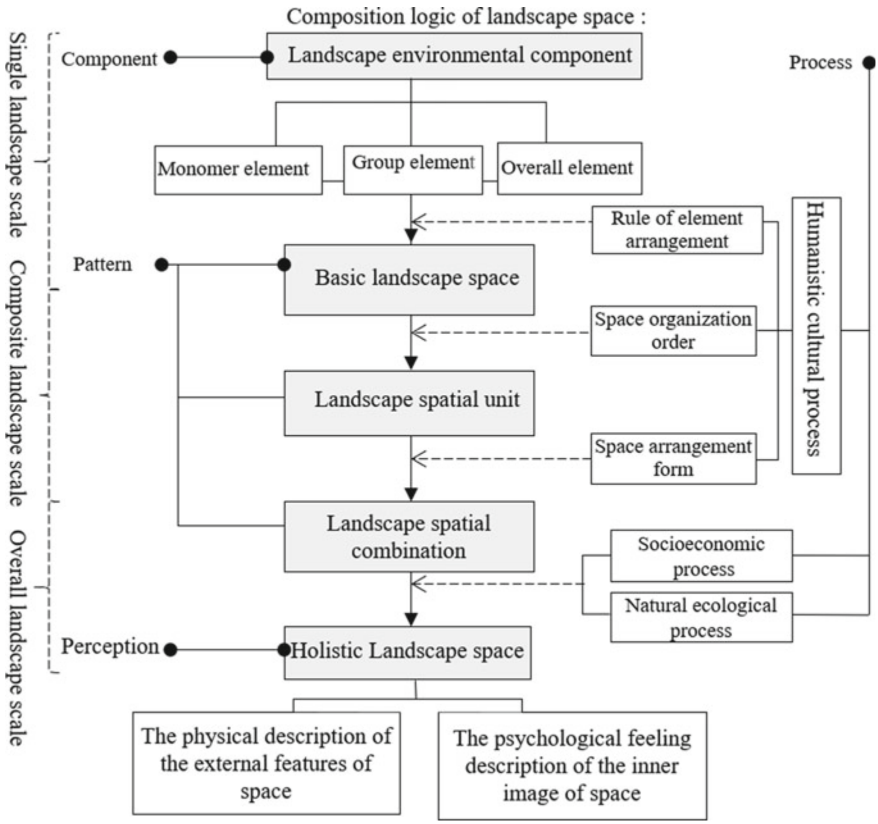

Fig. 4.1 C-3P analysis of landscape space

4.1.2 Significance of Landscape Space C-3P Analysis

Ecology, culture, and art are three important aspects of landscape space in which ecological feature is one of the landscape context, source of landscape service, limitation of human utilization, and niche of creature of landscape resources. The cognition, analysis, and evaluation of landscape space dependent on ecological feature would be of great significance to landscape planning and design, for which so does the establishment of landscape space C-3P analysis framework.

The system describes the characteristics of landscape space from four dimensions which provide a strong basis for cognition and understanding of ecological space and key tools for ecological planning and design. The system provides behavioral guidelines for planners to observe and collect data, information, and features of landscape space and highlights the framework of landscape planning and design. Planners can objectively recognize and evaluate the characteristics of landscape space at different scales in the process of planning and design with help of the framework.

The framework could help planners to establish an ecological design approach to sculpturing and measuring spatial component, pattern, process, and perception of landscape project and encourage planner and designer implement local design with the goals of natural and cultural protection detailed from the master planning, detailed planning, site design, and other practices by specific scales of planning and design.

4.1.3 Structural Logic of Landscape Space C-3P Analysis

The C-3P system is conducive to landscape planners to cognize landscape space systematically and comprehensively, which is also the basis and premise of planning and design with an angle of ecosystem and ecological logic.

The first is the cognition of landscape components and spatial pattern (Fig. 4.2). As for landscape components distributed as point-like and spatial pattern aggregated as a block, the cognition and research of their features such as shape, proportion, type, distribution, and spatial relation are mainly carried out on the vertical and horizontal dimensions through visualization methods such as map, planar graph, and remote sensing image. Landscape space as the mosaics is gradually formed on horizontal dimension with the change of extent and resolution from mono-element, group elements to homogeneous patches. Landscape pattern with nested structure is integrated on vertical dimension with change of depth and hierarchy from basic space, aggregated space to holistic space. Landscape pattern is described in static and individual state from basic space to total landscape and is presented in a fixed and specific way in a system from two dimensions corresponding to a scale.

The second is the cognition of spatial processes which mostly exists invisibly inside the environment and is more like the dynamic, developing, continuous, and abstract mechanism (Fig. 4.3). The formative mechanism needs to be traced in the environment in which landscape was formed at the previous dimension in the process of spatial cognition, and the dynamic changes of spatial pattern should be identified to understand the formative mechanism of existing landscape pattern at different time and spatial scale from the sequence of static pattern. The future development and change of spatial pattern could be simulated through analyzing the dynamic evolution of relations among factors in different stages from the mature and stable existing relations.

The final step of landscape spatial analysis is landscape perception on spatial patterns, which is the highest level of cognitions in landscape (Fig. 4.4). One reason is that the subjective expressions of landscape space are adopted with physical and psychological factors in the process of cognition, in which ecological spaces are replicated subjectively by using various sensors from perspective of observers (Kaplan and Kaplan 2008). The other reason is that landscape perception is considered as the comprehensive and integral cognition of landscape component, pattern, and process, which is not only an esthetic evaluation of space from perspective of visual esthetics and behavioral psychology, but also an overall understanding and experiencing the

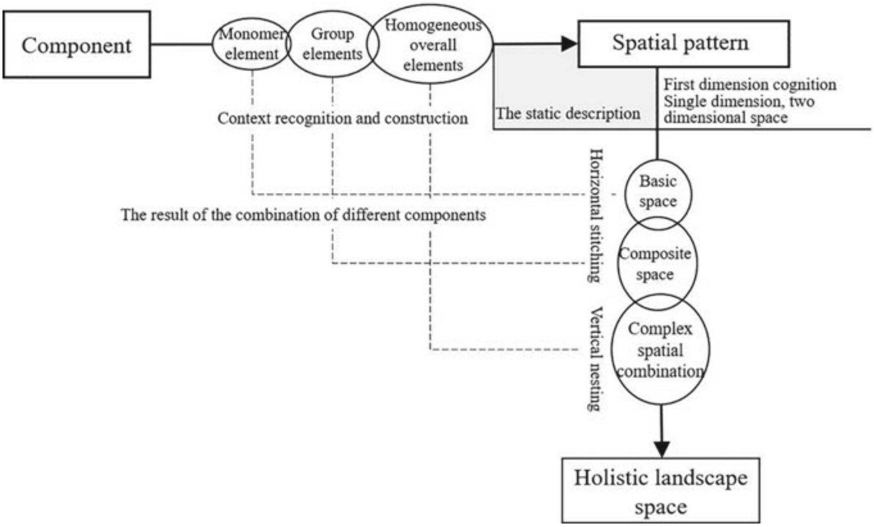

Fig. 4.2 Static description of landscape component and spatial pattern

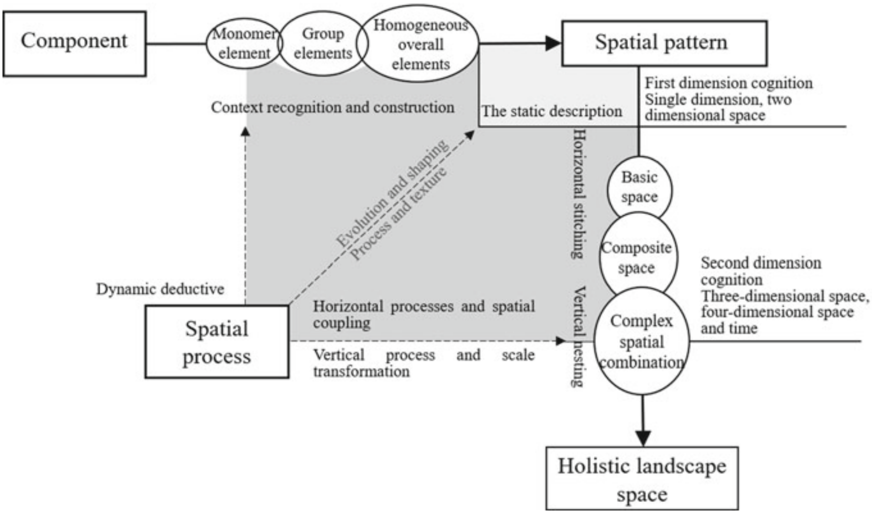

Fig. 4.3 Dynamic deduction of holistic space following spatial process

inner mechanism of space from perspective of ecology, sociology, environmental science, and other natural and human disciplines. The cultural factors are injected into the cognizing and understanding of landscape space on the base of the material world and physical landscape.

The C-3P framework established a complete process of cognition from the flat world to the community integrating appearance and internal essences together and

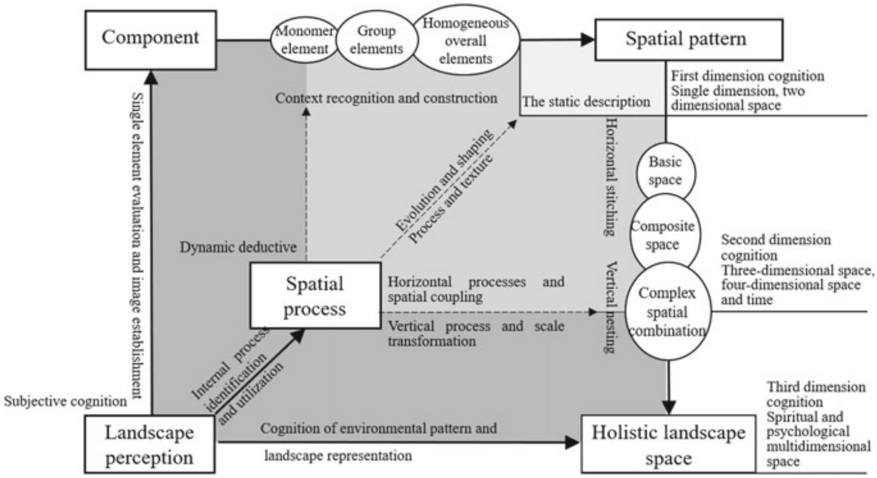

Fig. 4.4 Subjective cognition of landscape perception to the holistic space

to the cognition, analysis, and evaluation combining subjective feelings on multi-source data in the process of landscape space cognition from two dimensions and three dimensions to four dimensions with time and five dimensions with psychological factors. Therefore, the structural logic of landscape C-3P analysis presents a framework with multiple dimensions, multiple levels, multiple angles, and multiple scales (Fig. 4.4).

4.1.4 Landscape Space C-3P Analysis Framework

The research of landscape space always focuses on the feature cognition and function evaluation of three subsystems of landscape and the protection mechanism and development strategy of landscape on various spatial attributes at different scales.

The interactions among landscape component, pattern, process, and perception should be emphasized systematically in the application research of C-3P overall framework. These relationships maintain the stability and integrity of the whole system and integrate three main functions of landscape together, which include ecological security service, material production service, and landscape cultural service. Based on the theory of *Total Human Ecosystem* and the characteristics of landscape spaces at multiple scales, which are regarded as the organic whole formed by the coupling of three kinds of subsystem (Kienast et al. 2009). The component, pattern, process, and perception in the framework are all equivalent in total human ecosystem of landscape space and cannot be studied separately (Fig. 4.5).

At present, most of the analysis and evaluation researches on landscape space in China are focused on the investigation and evaluation on factors of current situation

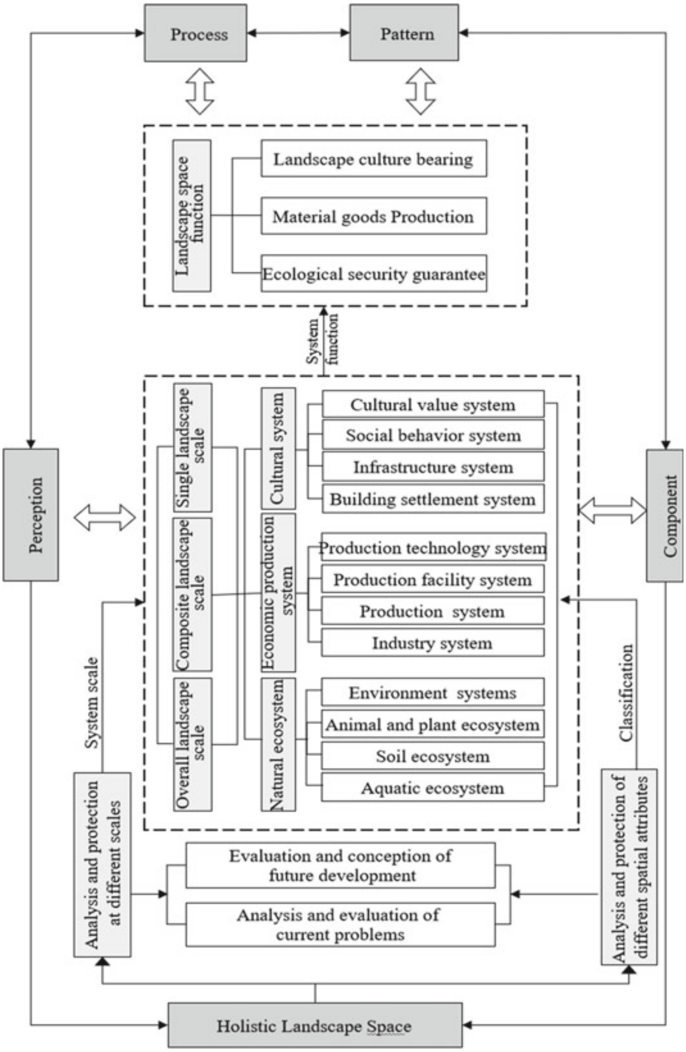

Fig. 4.5 Research framework of landscape space analysis based on C-3P theory

(Shen 2009; Shi-l 2015), the relations between landscape pattern and process, and landscape perception, but most of them ignore the deep internal connections and characteristics of landscape spaces at multiple scales, which are considered as the essential features of total human ecosystem (Wang 2014). Here, the C-3P system is used to conduct a comprehensive analysis of current situations and existing problems of landscape space at multiple levels through the study of interactions among landscape component, pattern, process, and perception at three scales. And finally, the aim is to obtain the optimization and protection strategies of landscape space at multiple scales from multiple angles.

4.2 Landscape Component: Context Dependence

4.2.1 Classification and Characteristics of Landscape Components

Components of landscape space could be classified into three systems which include many specific types of elements as natural elements, economic and production elements, and cultural and human elements.

Natural elements are the components of ecosystem including climate and environment elements of the whole region as well as waters, animals, plants, and landforms which constitute the environmental background of landscape space (Table 4.1). The structure and functional connectivity of natural elements in the spatial–temporal process and changes are the key stabilizers to guarantee the external unity and internal balance of the holistic landscape space (Dong 1999).

Economic and yielding elements are components of production system including factors of land form and factors of production facilities from perspective of material world, as well as factors of non-material industry and technical factors (Table 4.1). It is in the stable and healthy environment that enough materials and services could be provided by landscape (Ouyang et al. 1999). The health of economic factors is the pillar and power to promote the development of space.

Cultural and human elements are components of human system including traditional building, settlement, street, infrastructure, and some spatial elements, as well as social behaviors and culture elements (Table 4.1). Too much influence and impact of construction and artificializing environment were brought to landscape space in the process of rapid urbanization and invasion of tourists, which greatly weaken the traditional characteristics and cultural connotation of landscape space locality. Cultural elements are the real resources to understand the past and production of human beings, nationalities, and cultures (Lopez and Gwartney 2010). The reliability and authenticity of cultural elements are the necessary conditions to preserve and inherit landscape personality (Fig. 4.6).

4.2.2 Scale Analysis of Landscape Components

It is the components recognition at scales that landscape components can be observed and identified scientifically with different resolutions and landscape grains. The degree of involvement in the details of components in cognitive process is the main reason of the different ways of components division with different grains, which

Table 4.1 Classification of landscape space components

Item	Natural elements			Economic elements		Cultural elements		
Material element	Topographic and geomorphic	Animal and plant element	Natural water element	Land form element	Production facility element	Building settlement element	Infrastructure element	Environmental element
	Soil Rock Hills Valley The sands The slope Platform, etc.	The forest, The farming, Fengshui forest, Animal habitat, etc.	River, Lakes, Pond, Wetland, Stream, etc.	Arable land, Garden, Fishery ponds, etc.	The reservoir, The canal, The water tank, Irrigation channel, Water wheel, etc.	Traditional local-style, Dwelling houses, Temple, Ancestral hall, Memorial arch, The academy, The teahouse, The tower, etc.	Road, Dock, Wells, Water port, Nozzle, Bridge, etc.	Park, Square, Green space, The bazaar, Neighborhood, Garden, etc.
Non-material elements	Climatic and environmental elements			Industrial system element	Technical element	social behavior element	cultural element	

(continued)

Table 4.1 (continued)

Item	Natural elements	Economic elements		Cultural elements	
	Wind speed, Precipitation, Temperature, Sunshine time, etc.	Tea industry, Fruit industry, Forestry, Animal husbandry, Fishery, Handicraft industry, Tourism, Agriculture, etc.	Production of energy, Production technology, Farming mode, etc.	Mode of transport, Folk costumes, The festival ceremony, Traditional skills, Traditional etiquette, etc.	Human settlement culture, Historical culture, Industrial culture, Spiritual culture, etc.
Ky feature	Keep strong unity and continuity in the constant change of time and space.	Keep high level of health in terms of exporting or transforming into means of life and production, as well as bringing employment and security opportunities to local residents.		Represent high reliability and authenticity in reflecting the living and production conditions of human beings in specific regions, nationalities, and cultures.	

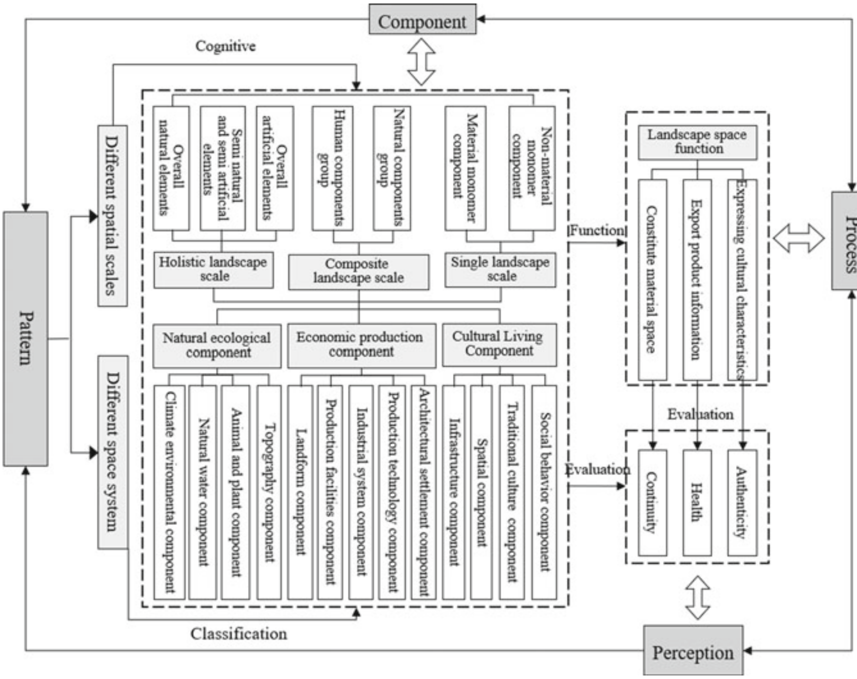

Fig. 4.6 Framework of landscape components analysis

would help to obtain targeted information at various scales of regional landscape, and further form the identification and analysis of spatial patterns corresponding to scales (Table 4.2).

The fineness of elements cognition Is generally the coarsest, and the resolution is also the lowest at the scale of holistic landscape. It could be classified into natural, semi-natural, semi-artificial, and artificial landscape elements according to the naturalness of components. The natural elements of landscape include ecological spaces, such as forests and mountains, which are composed of plants, water, soil, and other biological and abiotic elements. Semi-natural and semi-artificial elements both include natural spaces, farmland, cultivated land, and other limited man-made elements, in which the percentage of propensity to nature or to man-made landscape is different. The artificial elements refer to the living space where mainly composed of buildings, facilities, and roads, such as ancient towns, modern towns and villages, settlements, and other man-made elements. It is analyzing the external effects of homogeneous elements as a total system on the environment and the characteristics in the environment based on the overall characteristics of elements that the spatial patterns and their relations can be managed in the space system of regional landscape.

The main purposes of recognizing a”d an’lyzing elements in holistic landscape are to grasp the relationship and spatial pattern between artificial and natural component in regional landscape from a macroperspective and to have a preliminary concept

Table 4.2 Cognition and analysis of landscape components at three scales

Scale	Fineness	Basis	Result	Type	Analysis Points	Objects	Purposes
Holistic landscape scale	Rough and low resolution	Nature of components	Homogeneous	Natural space	1. Homogeneous characteristics of space: nature, function, extent, edge shape, patch shape. 2. Homogeneous characteristics of space in the environment: spatial proportion, location, and distribution.	Natural space: woodland, mountain, meadow, lake, river.	1. Grasp the relationship of pattern between artificial and natural component. 2. Form an overall concept of landscape spatial structure.
				Semi-natural and semi-artificial space		Semi-natural production space: pasture, farmland, cultivated land.	
				Artificial space		Hard living space: villages, settlements, traditional streets, towns.	

(continued)

Table 4.2 (continued)

Scale	Fineness	Basis	Result	Type	Analysis Points	Objects	Purposes
Composite landscape scale	Moderate, medium resolution	Category of component	Group	Natural space group	1. Characteristics of space group: nature, type, function, area, edge form. 2. Characteristics of relationship between space groups and external environment: trend, distribution, spatial proportion, and spatial layout.	Vegetation community, waterbody group, terrain topography.	1. Grasp the original power of ecological process formation. 2. Form a basic understanding of landscape spatial pattern.
				Human space group		Building group, road network, open space system, farmland group.	
Basic landscape scale	Intricate and high resolution	Individual component	Monomer	Monomers of material space	1. Features of monomer space: type, extent, form, color, material, and details. 2. The role and status of monomer space: function, location, proportion, and distribution.	Topographical features, plants and animals, water bodies, production facilities, building settlements, infrastructure, open space.	1. Form a list of typical elements of landscape space. 2. Form an understanding of the basic landscape space.
				Monomers of non-material space		Climate, industry, production technology, social behavior, traditional culture.	

of landscape spatial structure with the overall features, function, extent, edge form, morphology, and other characteristics of homogeneous elements (Rodenburg and Nijkamp 2004), as well as the spatial proportion, location, distribution, and other characteristics of the homogeneous elements in the environment.

It includes two groups of natural element and human element In recognition of components at a composite scale with moderate fineness and resolution. The group of natural elements is the collection of natural elements in a region, such as plants, water networks, landform patterns, and geomorphic groups. The group of cultural elements is the cluster formed by individual and social elements in a region, such as buildings, road networks, open spaces, and farmland patterns. The purpose of cognition and analysis of grouped component is to find out the dominant elements in proportion, function, or morphologic form, also to explore its function and role in space and trace back the source and motivation of various ecological processes, and understand the formative mechanisms and real meanings of landscape spatial patterns.

The fineness and resolution of components are recognized in the highest elaborate way at the scale of basic landscape space, on which the individual components should be identified and landscape space should be decomposed. The space with mono-element could be classified into two categories of space with monomaterial elements and space with mono non-material elements (Table 4.1). The individual characteristics of components should be analyzed from the nature and characteristics of each element including type, extent, shape, color, material, and details, and from the function and position of mono-element in space including function, location, proportion, and distribution. The main purpose of cognition and analysis is to distinguish all factors which influence the environment and to analyze the functions of each element in landscape space.

The cognition of components also includes climate and their influencing factors at regional and local scale (Shaw et al. 2013), which is the understanding of climate characteristics and the way how it affects other elements in a region. Climatic factors would influence local terrain, water, soil, animals, plants, and other factors and shape physical landscape of region through factors of wind speed, precipitation, sunshine, temperature, moisture, and other processes. Additionally, climate factors also directly affect living habits and production modes of people living in the climate region, such as clothing, diet, belief, entertainment, and farming, and form a unique cultural landscape of the region (Fig. 4.7).

The cognition and analysis of climate factors of landscape space are helpful to understand local characteristics in this area of natural and cultural landscape. A full understanding of climate factors could help to make the best site and ecological design according to specific climate conditions and choose appropriate approaches to adapt influences of climate factors, so as to improve the quality of eco-environment and avoid potential disasters.

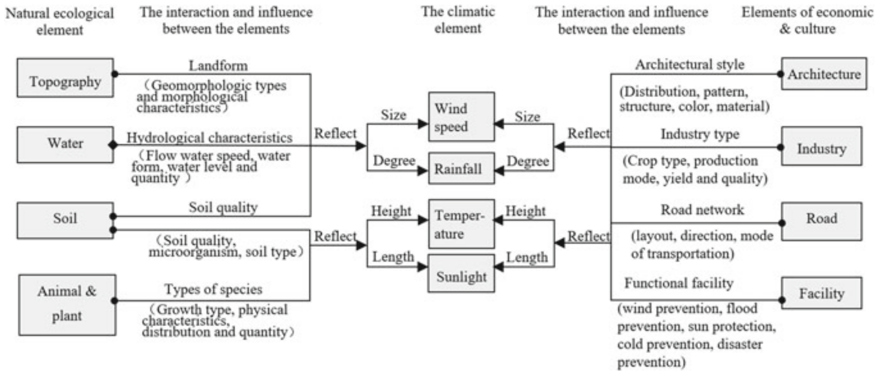

Fig. 4.7 Effects of climate elements on other components

4.3 Landscape Spatial Pattern: Mosaic and Nesting

Spatial pattern is an important carrier for adaptation to the context and coordination of total human ecosystem and landscape in spatial dimension, as well as the combination mode and layout characteristics of landscape components in space extending along horizontal direction, which is also the description and expression of spatial process and combination of local cultural landscape, and reflects the current characteristics and development trends of residential pattern in landscape. According to the overall research framework of landscape space C-3P system, the analysis includes classification and its characteristics, the cognition and analysis of spatial patterns at multiple scales (Fig. 4.8).

4.3.1 Classification and Characteristics of Landscape Pattern

Spatial pattern of landscape could be classified into three systems which includes a variety of typical spaces and spatial units. Generally speaking, spatial patterns mainly include three categories of natural spaces, productive space, and constructed space, which can be tested at all scales.

Natural spaces are the context mainly providing ecological services and composed of natural components, including woodlands, mountain area, water body, green space, and other types. Landscape space with different environmental backgrounds is dominated by various types of natural space. For example, landscape space in water network is dominated by diversified forms of water space, such as river, stream, lake, pond, and river network. Natural space is characterized by natural environment as a main body, low impact of artificial interference and influence, low population density and basically presents the natural and original landscape appearance (Lautenbach et al. 2011). Natural space is the spatial carrier of various ecological

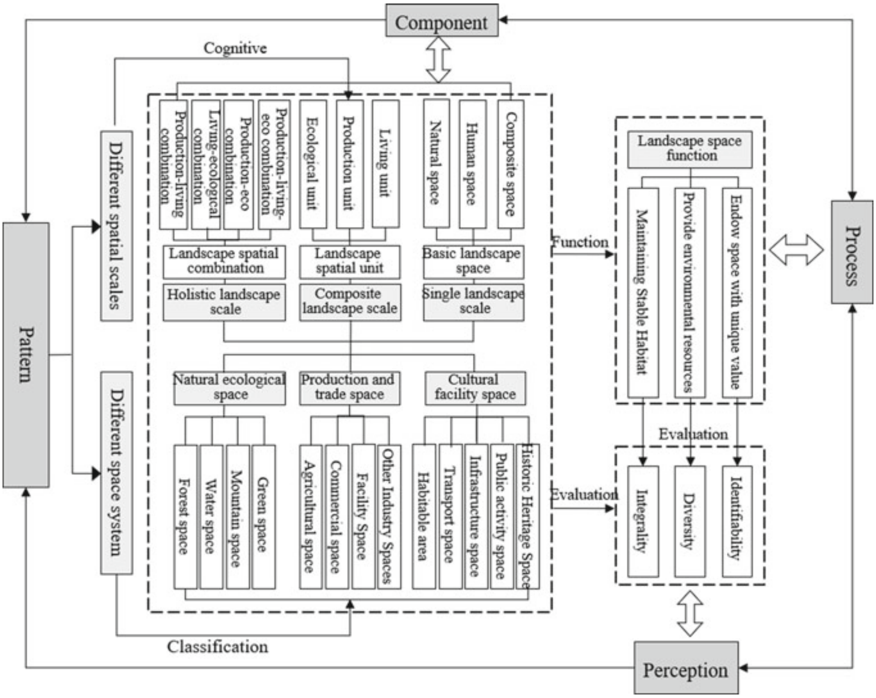

Fig. 4.8 Framework of landscape pattern analysis

processes, which maintains the stability of structure and function of natural system and provides a relatively safe habitat for the healthy, and sustainable development of human society.

The integrity of landscape spatial pattern is the key to maintain stability of habitat, which means the completeness of specific space and the continuity of landscape in space. Highly integrated landscape spatial pattern could avoid the phenomena of isolated and fragmented landscape and ecological problems such as degradation or even loss of natural habitat under the impact and influence of urbanization.

Production space refers to the space of contact and interaction closely between man and nature, as well as man and man. It is also the space where production, trade, and other economic activities occur actively, including agricultural production, commercial trade, supporting facilities, and other types. In the process of long-term historical development, small-scale family economy has always been the main economic type of landscape. Therefore, agricultural production space occupies a large proportion in production and trade space. A variety of agricultural production modes have been developed under various environmental backgrounds, and thus, diversified land use texture and space patterns of agricultural production have been derived (Priemus et al. 2004).

With the development of modernization, more and more industrial and economic elements are introduced into landscape and led to diversified development of industrial types and corresponding spaces, such as planting parks, industrial factories, and sightseeing agricultural parks. The diversity of production space could provide abundant materials and space resources for landscape, change the monoproduction mode, and thus promote the development of local economy and industrial innovation. However, in this process, the balance should be paid attentions to between tradition and modernity and ensure the preservation and continuation of traditional characteristics while injecting new vitality and resources into landscape spaces.

Cultural space is the space formed by accumulation of regional traditional culture over a long period of time, which includes space for living, transportation, infrastructure, public activity, historical relics, and other types. Compared with the other two types of space, cultural space is a part of traditional cultural landscape space with high recognizability and specific landscape personality and is also the key object for conservation of traditional cultural landscape space (Schaich et al. 2010). Spatial pattern with high identifiability is the essential features of landscape carrying the locality, tradition, and culture of place.

4.3.2 Scale Analysis of Landscape Spatial Pattern

The cognition of spatial pattern occurs in symbolic elements of space, in which people obtain the symbolic vocabulary of a spatial entity with the orientation of knowledge or experience of the part-whole relationship to express based on simplification, combination, and comprehensiveness of element attributes. The process of recognizing spatial pattern is to seek for the organizational rules dominated by landscape elements in the seemingly chaotic and disordered environment and to describe the symbolic characteristics based on certain objective and reliable observations. The purpose of spatial pattern cognition is to find out the regularity and typical mode of element in landscape space and use it as a guide or example of graphic form to apply to the restoration, planning, and design of ecological space. Therefore, the cognition and analysis of spatial pattern should start from the relationship between components of landscape and be carried out at three scales which are basic space at monolandscape scale, multi-space units at composite landscape scale, and space mosaics at holistic landscape scale (Toth 1988a, b). (Table 4.3).

The cognition of landscape spatial pattern at holistic landscape scale is to summarize the structural relations and combinations of three types of space formed by different elements based on the integration of components. At the same time, landscape spatial combinations with different types and functions are identified and analyzed and pattern vocabulary is extracted. According to the overall combination mode of components, landscape space could be classified into the combination of production and ecological space, combination of production and living space, combination of ecological and living space, and the combination of ecological, production, and living space with high level of coupling. The analysis focus on the features

Table 4.3 Cognition and analysis of spatial pattern at three research scales

Scale	Pointcut	Cognition	Analysis points	Content analysis	Purposes
Holistic landscape scale	The whole of elements with different properties and the three types of spaces formed by them	Different types of space combination: Production-ecological space combination, Production-living space combination, Ecological-living space combination, Ecological-production-living space combination.	The structural features presented by spatial combinations.	Composition characteristics, arrangement mode, combination form, and interaction relation.	The pattern of spatial structure with stability, balance, and locality formed by each spatial unit is extracted as the level of simple sentence of landscape pattern language.
Composite landscape scale	Cognitive results of landscape spatial combination and different types of group element.	Three types of spatial units constituting spatial combinations: Ecological space unit, Production space unit, Living space unit.	The overall distribution law and combination form of landscape spatial unit.	The scale, area, shape, function, boundary relation, and other attributes of a spatial unit.	The landscape space combination is further disassembled. To extract the level of phrase of landscape pattern language. Divide different functional areas in landscape space.
			The combination relation of basic landscape space in landscape space unit.	The basic space layout, trend, combination form, and other composition characteristics, the interaction between the space, the law of repetition, and other ecological relations.	

(continued)

Table 4.3 (continued)

Scale	Pointcut	Cognition	Analysis points	Content analysis	Purposes
Monolandscape scale	Cognitive result of landscape spatial unit and combination form of different elements	The basic space composed of monomer elements of different types: Natural space, Human space, Composite space.	Monomer features of components.	Basic features of elements such as type, quantity, and location.	To identify the relationship between components with certain functionality and typicality. Orientate the nature and function of the basic landscape space; the level of word of landscape pattern language is extracted.
			Relations between components in space.	The layout, combination mode, and interaction of the components, as well as the space function that the components jointly exercise, etc.	

of combination structure including composition, arrangement mode, combination form, interaction relationship, and so on. Thus, the structural pattern of space with stability, balance, and locality (Wang and Han 2014) , which is shown in each type of landscape space, is extracted as *'Simple sentence'* of landscape pattern language.

It is to further disassemble into three types of space with various spatial combinations to recognize landscape spatial pattern at a composite scale, so as to obtain multiple units of landscape space with similar forms and functions. Landscape space units could also be classified into units of ecological space, production space, and living space. As the result of spatial pattern observation at mesoscale, landscape spatial unit is the level which is most frequently contacted and dealt with in the process of ecological planning and design. One of the analyses of landscape space unit is combining relations of typical landscape space within the space units, such as space layout, combination form. The other is regarded as a whole, and its properties are analyzed, such as scale, area, shape, function, configuration, and boundary relationship. The pattern of landscape spatial unit could be extracted as *'Phrase'* of landscape pattern language (Han 2017; Fu 2014; Wang and Cui 2015). The recognition of landscape space formed by spatial units helps to identify the different functional areas dominated respectively by ecological, production, and living functions within space.

It is to start with the elements and study the way how a basic space is formed by elements in a way of association and arrangement through recognizing landscape spatial pattern at a monoscale. The pattern formed by basic landscape space is considered as expressing unit of *'Word'* in landscape pattern language (Han 2017; Fu 2014; Wang and Cui 2015), which is the most simple and basic form of combination. Therefore, basic landscape space could be understood as the minimum landscape space with independence and completeness, which has fewer elements or types, and spatial relationship between elements is simple and intuitive. According to the types of components, basic spaces could be classified into natural space such as trees, hillside, woodland, valley, farmland, fishery pond, and cultural space such as courtyards, orchards, markets, industrial parks, settlements, villages, streets, as well as mixture space such as a nodal space formed around the dominant elements such as buildings. At this scale, the resolution of spatial observation is relatively high and spatial scope involved is relatively minimal.

The cognition and analysis of basic landscape space are the key to organize the independent and dispersed cognition of elements into a whole and are also the way to understand spatial pattern at a larger scale and spatial scope. Therefore, one of the cognition and analysis of basic landscape space mainly is the components which consist of the space and the other of it is the relationship between components in space. It is to separate the relations among typical components from the chaotic and disorderly environment through analyzing basic landscape space and express them through the discernable graphics or schemata, namely the *'Words'* of landscape pattern language.

4.4 Spatial Process: Logic and Grammar

The study of spatial process is a summary of the temporal and spatial evolution law of landscape spatial pattern and its evolution of driving mechanism. It could reflect the change and development characteristics of landscape space in dynamic process, which are mainly manifested as the evolution of landscape spatial pattern and the transformation between different spatial patterns. The interaction and dynamic change between these subsystems and external systems are the result of the joint action of natural forces and non-natural forces (Chen and Wang, 2022). Spatial process is the main reason and form of these driving forces. According to the research framework of landscape space C-3P system, the analysis of spatial process includes classification and its characteristics of spatial process in different spatial systems, and the cognition and identification of dominant processes which play a major role in formation and evolution of landscape spatial patterns at multiple scales (Fig. 4.9).

4.4.1 Classification of Landscape Spatial Process

Spatial process of landscape refers to natural and cultural processes which shape, influence, and change spatial pattern of landscape. Among them, natural process mainly refers to ecological process in nature, while human process includes the social and economic process, and the human and cultural process. None of landscape environment could be completely separated from the intervention of human society and the role of human activities. All landscape spaces would be profoundly affected by human activities on the basis of natural process. An a large spatial scale, the geomorphological erosion, weathering, and other natural processes often play a leading role in shaping and evolving landscape spatial pattern. At a small or medium-sized scale, the transformation and influence of social and economic processes, human and cultural processes on the landscape spatial pattern are more obviously (Table 4.4).

Natural process refers to all kinds of biotic and abiotic processes in natural context, which is the basis for forming a stable natural environment and the first step to understand landscape spatial pattern from a perspective of spatial process (Ndubis 2013). Abiotic processes mainly include water cycling, soil erosion, atmospheric circulation, land coverage change, climate change, etc. Biotic processes are dominated by the succession of animal and plant populations and others including population dynamics, propagation of seeds or organisms, and interactions between predators and herbivore. Ecological functions are different with various ecological processes which exist in specific ecological space, so the diversity is generated for spatial processes in species and spatial distribution. A stable natural process is the basic condition for maintaining the normal functions of ecosystem and forming a livable environment because natural process is the basic process of landscape formation, which also supports and promotes the occurrence of other cultural processes. The

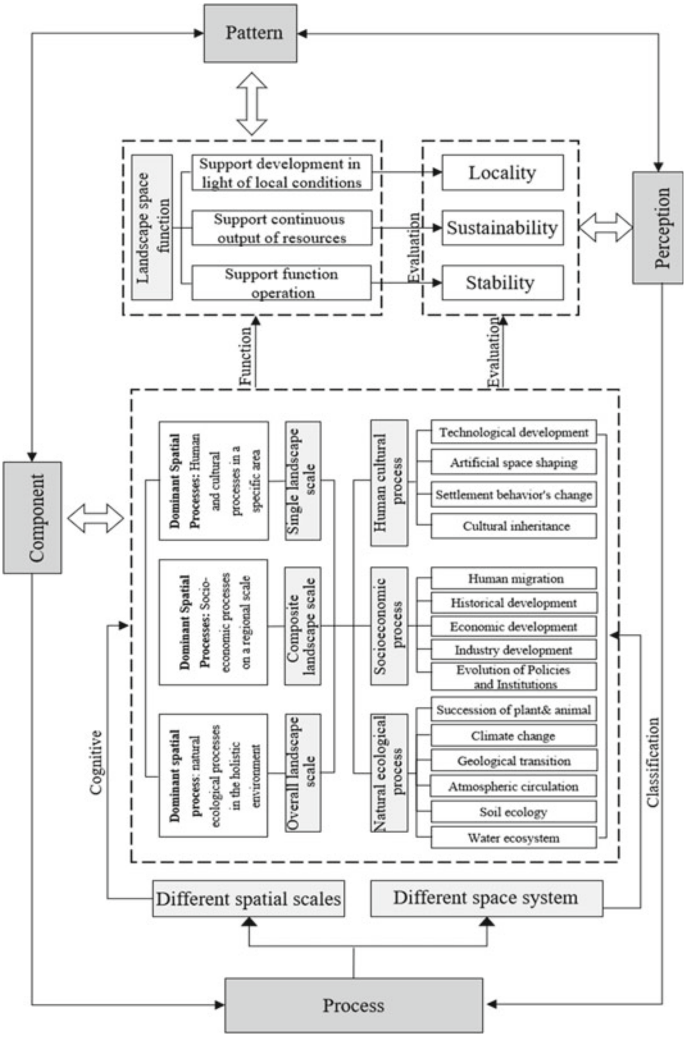

Fig. 4.9 Framework of landscape spatial process analysis

stability of natural processes could measure the resistance of landscape to external disturbance and its ability to recover from the influence of disturbance.

Social and economic process refers to social activities, economic, or industrial development which has a heavy impact on landscape environment and space where human beings live and develop in a certain period of time. It includes the evolution of political system, population migration, industrial developing, economic development, and historical process (Gao et al. 2011; Fan and Zhuang 2014). For landscape space, the industrial developing represented by human farming activities is one of

Table 4.4 Classification of landscape spatial process

Spatial process		Scale and scope	Affecting factors	Effect
Natural process	Abiotic processes include: water flowing process, soil erosion process, atmospheric circulation process, geological change process, climate change process, etc.	Holistic landscape scale. Holistic natural environment.	The media in ecological flows of landscape: wind, water, animals, etc.	1. To form a stable and livable natural environment. 2. To maintain the normal functioning of ecosystem. 3. To support and promote the occurrence of other human processes.
	Biological processes are dominated by the succession of animal and plant populations, and others include population dynamics, propagation of seeds or organisms, and interactions between predators and prey.			
Socio-economic process	Social and economic processes include political system evolution process, population migration process, industrial development process, economic development process, land use transition process, and historical development process.	Composite landscape scale. Regional or watershed area.	Mode of production, economic structure, policy, war, means of production and technology, political factors, etc.	1. To provide conditions for the development of regional economy and industry. 2. To ensure the stability of social system and population structure in region.

(continued)

Table 4.4 (continued)

Spatial process		Scale and scope	Affecting factors	Effect
Human-cultural process	Evolution process during a long time: the process of change of settlement behavior and cultural inheritance.	Single landscape scale. Area or site scope.	Settlement mode, settlement habits, social structure, ideology, science and technology, customs and culture, etc.	To provide local and targeted support and promotion for the development of region according to local conditions.
	The transformation process in a short period of time: artificial space shaping process, technology development process.			

the earliest human processes in the shaping of natural landscape by human intervention. Through the exploration of development, evolution, and locality of human farming history in a region, a profound knowledge could be discovered to the origin and shaping mode of the diversified cultural landscape space. In addition, landscape space is inevitably impacted and interfered by external driving forces under the influence of urbanization and modernization, which to a large extent affects nature, tradition, and authenticity of landscape space, and further changes the patterns of landscape space. The sustainable development of China's society and economy has stepped into a critical period today with the influence of economic globalization, but the traditional mode of agriculture cannot adapt to the contemporary requirement, of which the small-scale family economy needs to meet the growing material and cultural needs of local residents and cater to the trend and development of overall economic situation. The changes in economic structure and production mode would bring about evolution and innovation of spatial structure. The sustainability of socio-economic processes is an important indicator for evaluating the health and sustainable development of landscape.

Human process is an artificial and directional process of landscape spatial pattern on the basis of natural, social, and economic process, which refers to the dynamic mechanism of processing and changing landscape space in a certain direction in accordance with human wishes, driven by cultural, social, ideological, and other human factors during a long evolution, including the changing process of settlement behavior and cultural inheritance. For landscape space, the change of human settlement is one of the earliest processes of human intervention into natural landscape (Hu and Wang 2015). From the aspect of settlement, the mode, habit of settlement, and social structure of human beings change constantly over time, which is reflected in the change of settlement mode, scale, location, and other characteristics in landscape space, and landscape spatial pattern was formed for the original landscape of settlement, grassland, farming, colonial and planning, rural and urban landscape, and other landscape dominated by the influence of human activities. Therefore, it could get a glimpse of the formative mechanism of existing landscape spatial patterns and internal mechanism to maintain the stable status quo through the exploration of human settlement evolution (Ozdil 2016). The processes of cultural inheritance refer to the evolution of people's ideological consciousness, such as *Fengshui* and religious consciousness in landscape space (Gao 2016). The change of ideology is reflected in landscape spatial patterns, which is manifested as the formation and development of overall forms of villages and settlements, internal spaces, neighborhood groups, and individual residential spaces.

4.4.2 Scale Analysis of Landscape Process

The purpose of cognition and analysis of landscape spatial process is to predict the changing direction of landscape pattern in the future by revealing the spatial reasoning, basic process, and inner mechanism of spatial pattern and to formulate corresponding management countermeasures to protect and inherit. Spatial process is the driving force of pattern formation and evolution which is helpful to identify and analyze the characteristics of spatial process (Arganaraz and Entraigas 2014).

Landscape process always has certain spatial and temporal laws, which is formed at a large spatial and temporal scale, such as the process at watershed scale, geological and geomorphic transition, climate change, and other natural factors, and plays a leading role in shaping and updating the holistic landscape pattern. At mesoscale of space and time, the social and economic processes formed by human driving factors, such as population migration, political and economic reform, and regional social and economic environment evolution, are the leading processes which lead to the change and development of landscape pattern. At a microscale, the cultural process formed by cultural factors, such as technological innovation, cultural inheritance, and change of values, which plays a leading role in the transformation and shaping of landscape pattern (Toth 1988b). The cognition and analysis of spatial processes should have different emphasis and objects at different scales.

Three types of spatial processes are generally the driving forces to form the system with internal order, which was made up by combination and connection of spatial processes under certain rules and levels (Fig. 4.10). On the one hand, the characteristics of landscape spatial pattern were shaped at different scales by three spatial processes acting on the functions corresponding to the spatial and temporal scales; on the other hand, the effects of these three spatial processes are superimposed on each other, forming a feedback which promotes or restricts each other, but there must be a distinction between dominant spatial process, non-dominant spatial process, direct spatial process, and indirect spatial process. Therefore, during the cognition and analysis of spatial processes, the cognition and analysis should be carried out for spatial processes with significant and dominant roles at various spatial scales, so as to help understand the mechanism and rules of the formation and evolution of typical landscape spatial patterns.

There is an interaction between spatial process and spatial pattern (Fig. 4.10). The process of landscape space does not exist in the form of tangible patterns, but rather tends to interpret and describe existing graphics or patterns, which is an internal mechanism beyond visible phenomena and needs to be inferred and revealed through the characteristics of landscape spatial pattern which is the instantaneous expression of various landscape ecological process. Landscape spatial process is the dynamic characteristics beyond the static landscape spatial pattern. Because of the complexity and abstractness of various spatial processes, it is difficult to study the evolution of spatial processes quantitatively and directly. Therefore, the cognition and analysis of landscape spatial process require the cognition of nature through the phenomenon of landscape spatial pattern and further understanding of the pattern created through description of landscape spatial process.

In combination with the above features of landscape spatial process, the dominant spatial process at three spatial scales is perceived and analyzed so as to reveal the formative reasoning and evolution rules of landscape mosaics.

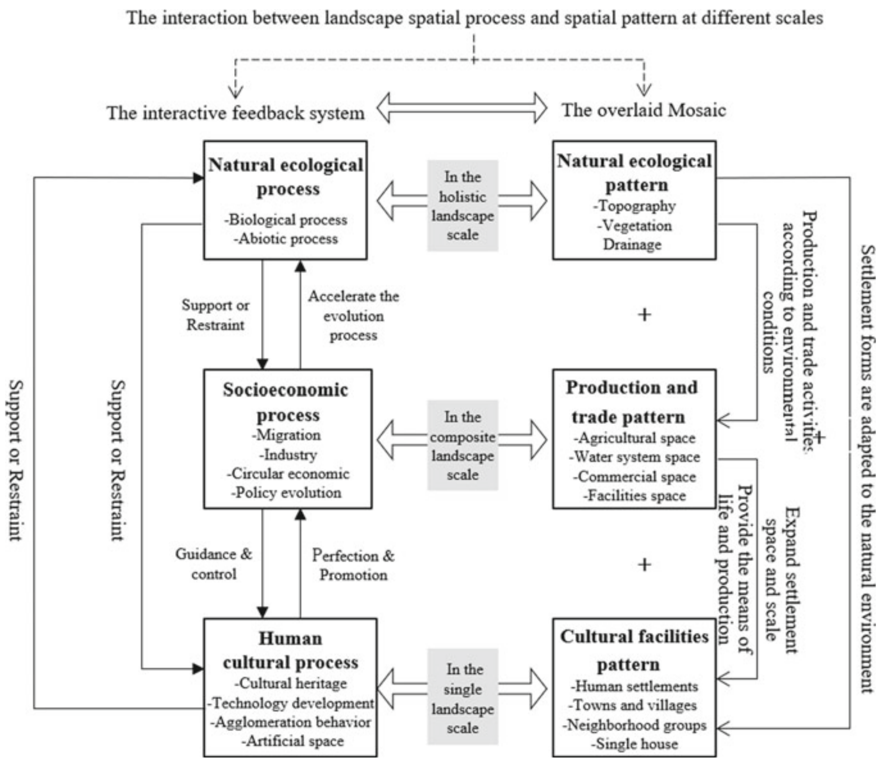

Fig. 4.10 Interaction between spatial process and spatial pattern

Landscape space is gradually formed after a long historical evolution which was driven by the interactions between man and nature, especially in the early stage, the overall form and layout of landscape space mostly show natural laws and natural dominance with less human consciousness. In other words, the patterns of landscape spaces at overall scale are mainly influenced by natural processes which are both driving forces and resistances to the initial development and formation of landscape spaces.

The formation of landscape spatial pattern might be the result of comprehensive actions of multiple ecological processes because of their diversity, but there would still be a dominant natural process in evolution process, which could be regarded as the internal driving force of the main ecological characteristics of the region, which is the key point of landscape cognition and analysis to control the evolution process of regional pattern on the whole. The evolution of landscape space depends on the comprehensive effect of political, social, economic, and cultural factors. As a top-down regulation and management, the implementation of local policies and transformation of economy, to some extent, the changing scale and structure of population and other social and economic processes guide and promote the evolution of landscape spatial pattern.

The changes and implementation of national policies, laws and regulations on protection, and laws of urban and rural planning are important policy factors affecting the development of landscape space artificially, which promote or restrain the evolution of landscape spatial pattern in different degrees. Since the effects of policy, economy, social environment, and other factors tend to be regionalized, it should be paid attentions to the integration, development, rising, falling, and changing of landscape spatial pattern dominated by cultural landscape under the impetus of human factors. At this scale, it is necessary to combine the historical background and local context of landscape space to explore the internal relationship between formation and growth stages of spatial pattern and corresponding social and economic processes, so as to clarify the shaping and influence of spatial process on spatial pattern.

Human processes are the power sources to shape the spatial spirit of a region with specific landscapes, which endow landscapes with strong regionalism and vitality, and make landscape spatial pattern to carry and inherit the feature of regional culture so as to express the local spatial pattern. The cultural process should be focused on its shaping and transformation of the space at a scale of monolandscape in a specific region. On the one hand, the non-material cultural customs, traditional thoughts, and concepts should be investigated in landscape space so as to understand the reasons for emergence of various artificial spatial patterns, additionally it can begin from landscape pattern, analyze the characteristics of settlement space at different levels, and examine the constant changing of living intention, living state, esthetic tendency, and space demand of local residents from perspective of users.

The characteristics of existing landscape spatial pattern could be explained, and the basis could be found for its formation through cognition of the first two kinds of processes. It needs to master more methods and logics of shaping landscape space through cognition of the last process and seek ways to local ecological planning and design. The analysis of spatial process in landscape space could be reflected by dynamics method diagram in order to express clearly the different states presented by the whole system at different stages.

4.5 Perception of Landscape Space: Ideology

Landscape perception comes from concrete objectives which the observers stay in and obtain the images and response to, which is a subjective expression under the physical and psychological effects based on the objective observation of current situation of landscape space. The result is not only reports of objectives, but also the addition and reference of connections and expectations in mind of observers. For landscape designers and managers, landscape perception is the ability of space processing which transforms objective scenery into subjective images, captures the main features, key values and potential advantages of landscape space, and makes use of them through tools of planning and design (Booth 2012; Dube 1997). For landscape users, landscape perception is a way to use and enjoy landscape, from whom landscape perception is an important way to know the status of space and the preference, evaluation of space.

Landscape perception is a process of objective cognition of landscape space components, pattern, and process, as well as subjective expression by human based on the overall framework of C-3P. The perception description of characteristics of local residents in landscape space was investigated from physical and psychological feeling so as to reflect the comprehensive cognition results of landscape space in production, life, leisure, and recreation based on the above three dimensions. The analysis of landscape perception includes the classification and landscape perceptions in different spatial systems and cognition and landscape perception stages at different spatial scales of landscape space according to the C-3P framework of landscape space (Fig. 4.11).

4.5.1 Classification of Landscape Perception

Perceptions of landscape space is the mental image of external material features of space, namely the visual, auditory, smells, and other physical feelings stimulated by the morphology and color, and perceptions of spiritual connotation of space, namely the psychological feeling and subjective association stimulated by historical context, social culture, and other connotations of landscape space. The perceptual result of the former is more disturbed by objective environment and objects. The latter is more dependent on the educational and cultural background, personal experience, and other subjective factors of observers. The perception of landscape space established on these two levels could connect the trends of landscape space with social and cultural values and make decisions on future protection, optimization, development, and management of landscape from a perspective of humanity. According to the

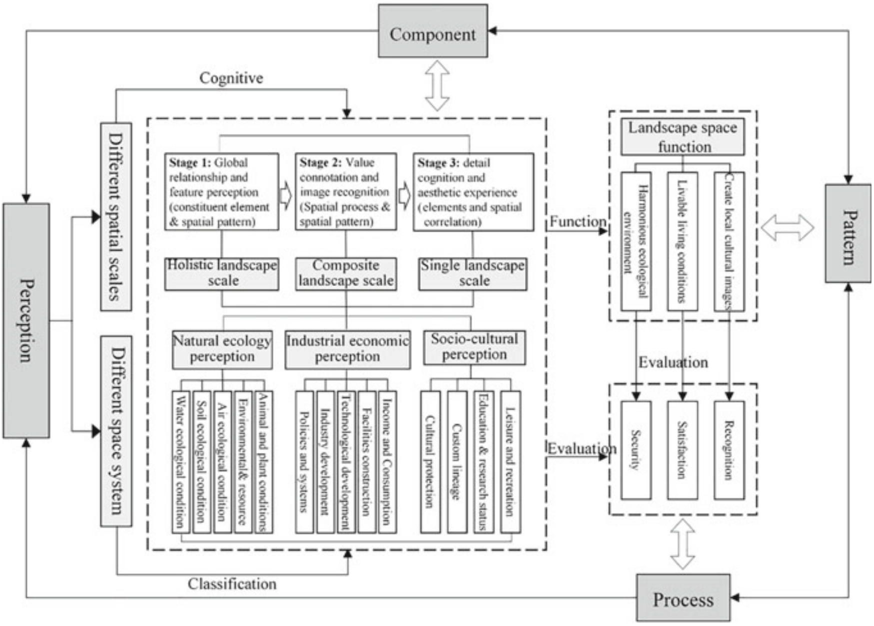

Fig. 4.11 Framework of landscape space perception analysis

three subsystems of landscape space, landscape perceptions could be carried out from the status quo of natural spaces, industrial economic level, and social and cultural situation.

The perception of natural environment is mainly to express the physical and psychological security supplied by current situation of natural spaces to people, which mainly includes the conditions of water, air, animals, and plants based on current situation of natural spaces. The perceptions on natural spaces could reflect whether an ecosystem in landscape space is healthy and stable enough, so as to reveal potential disasters and risks which may exist within it.

Production space and social-economic processes are mainly to express satisfaction of people with various material and spiritual conditions under current industrial and economic level through perceiving the political and economic environment formed by the comprehensive influence of economic factors. The perception includes the level of policymaking, industry development, science and technology innovation, facility construction, and income and consumption. The perception of industrial economic level could reflect whether the production system of landscape provides sufficient conditions for people to meet their material and spiritual needs so as to reveal the drawbacks and deficiencies existing in economic system.

Human facility and social process are mainly to express the identification of people with cultural representation and spiritual connotation formed by current conditions to perceive the social and cultural landscape formed under the construction of culture and daily life. The perception includes the status of cultural protection, custom inheritance, education, and recreation.

4.5.2 Scale Analysis of Landscape Perception

Landscape space is always more than what people can feel simply by being visible and audible, which is perceived in a gradual process from unintentional to intentional, from whole to detail and from appearance to connotation. For a same space, landscape images perceived are always different due to different observers and involvements in details of landscape elements. It could be said that perceptions on large-scale space come from the superposition of feelings on small-scale space, and the experiences brought by small-scale space are based on the macrobackground shaped by large-scale space. The perception of landscape goes through the perception process of overall relationship and feature, value connotation and image, detail cognition, and esthetic experience with the change of scale (Table 4.5).

The first stage of landscape perception is the overall relationship and prominent features of spatial pattern consisting of spatial components with landscape quality at holistic scale. The relationship was found out between landscape quality of components and the surroundings, as well as other elements with different strengths and weaknesses, and then describe its subjective feelings from geometric compositions and heterogeneity.

The overall impression on environment and psychological feelings of perception would be created by the atmosphere and artistic conception through the esthetic and inspiration of form, color, structure, and others. The reason why landscape perception highlights the integrity and weakens the detailed features at the first stage is to ensure that the interrelations between various parts in space. The description and evaluation of landscape at holistic scale require the marks of various environmental characters.

Human being is the cognition subject of scenery, and the cognition is a process of gradual sublimation of esthetics and appreciation of scenery. According to the law of human perception and the advancement of perception scale, spatial pattern should be deeply perceived through the characteristics presented by physical appearance of landscape space at second stage which is usually performed at a composite landscape scale in order to observe spatial patterns and processes clearly. It requires to jump out of what has been viewed by the eyes and to examine the source and ongoing process of landscape spatial pattern presented in a static way to describe and evaluate landscape space at composite scale from a continuous and dynamic perspective.

The third stage is the perception of features and functions of specific elements in landscape space at monolandscape scale, which focuses on the daily perspectives of perception. The description of landscape at monoscale enables each component of landscape space to be perceived separately in a relevant environment highlighting the diversity of landscape. Cultural connotation and spiritual significance are the characteristics and essences of landscape space, and the perception of visual function

Table 4.5 Three stages of landscape spatial perception

Perception stages		Stage 1: global relationship and feature perception	Stage 2: value and image recognition	Stage 3: detail esthetic experience
Key points of perception		The overall relevance of components. Prominent features of spatial patterns.	The value of spatial processes. The image of spatial patterns.	The personality traits of the elements. The esthetic value of the elements.
Angle of perception	Physical perspective	Significant feature, attraction points, singularity points, and impression points in the overall structure.	The operation effect (dynamic mechanism) or shaping result (static pattern) of various active spatial processes and the salient characteristics of spatial patterns.	Constitutive elements and identifiable features of basic landscape space (visual, auditory, tactile, olfactory, etc.).
	Psychological perspective	Landscape spatial patterns or components through the formal beauty and inspiration to create the atmosphere of artistic conception.	The intrinsic value and functional effect of spatial process and the connotation of life, esthetics, and ecology reflected by spatial patterns.	The beauty degree of landscape resources such as the scenery of sky, land, water, and human landscape.
Approach of perception description	Physical senses	Geometric composition characteristics, heterogeneity, spatial filling, uniformity, clarity, etc.	The contrast of the spatial patterns, the harmony, and security of spatial pattern.	Visual specificity, continuity, dominance, directionality, etc.
	Psychological senses	Feel the overall environment of nature, diversity, authenticity, and so on.	The artistic and cultural features of human landscape, the epochal feature, commemorative feature of historical landscape, etc.	The beauty of image, color, line, dynamics, sensory, and so on of spatial details.

and individual characteristics of components at monoscale is the premise of cognitive composite, cultural image, and spiritual connotation of space at holistic scale.

4.6 Dimensions of Landscape C-3P Analysis

The construction of C-3P system of landscape space at three scales studies the key points and approaches of spatial cognition at holistic scale, composite scale, and monoscale, which is the construction of technics and methods in the analysis system (Table 4.6).

Table 4.6 Framework of C-3P analysis of landscape space at three scales

Scale	Holistic landscape scale	Aggregated landscape scale	Basic landscape scale
Object	The total human ecosystem formed by landscape space.	Each composite subsystem in landscape space. Each mosaic unit in landscape mosaic.	The basic landscape space composed of space collections at multi-level.
Feature	Macro, abstract, low resolution.	From concrete to abstract, moderate resolution.	Micro, concrete, high resolution.
Purpose	Grasp the overall structure of space. Obtain basic information of spatial origin, environmental background, and key factors affecting the overall space. Extracting the simple sentence of pattern language.	To explore the laws of spatial evolution derived from nature and artificial. Collect local ecological wisdom to form the basis of spatial optimization and development strategy. Extracting the phrase of pattern language.	Extract the smallest space unit (basic landscape space) that exists independently and has integrity to form the material of space promotion and protection strategy. Extracting the word of pattern language.
Key point of research	The overall morphological characteristics and internal driving factors.	Static geometry of space and its dynamic mechanism.	The form and function of basic landscape spaces.
Key point of perception	Spatial patterns and spatial processes.	Spatial pattern.	Components and spatial perception
Key points of analysis	The interaction and feedback mechanism among the four dimensions.	The interaction between spatial patterns and the other three dimensions.	Bottom-up spatial construction and coupling.
Path of analysis	Pattern, process—component—perception	Pattern—component, process, perception	Component, perception—pattern—process

4.6.1 Holistic Landscape Scale

At holistic landscape scale, the extent of research includes a region, a space with large area and the completeness, or an area with specific ecological functions. Landscape space is regarded as a total human ecosystem at this scale, and the cognition of landscape space is achieved by studying the overall characteristics, changing trends, and development potentials of a system (Wang et al. 2012). In general, the research is abstract and the resolution is the lowest due to landscape concerned at macroscale. This makes the overall morphological characteristics of landscape space and driving factors become the cognitive focus at this scale. The former refers to overall structure of landscape space, the latter refers to dynamic mechanism which influences the development and change of landscape space. At the same time, it could predict the spatial development and evolution results which may be brought about by the dynamic mechanism (Wang et al. 2006).

The cognition and analysis of four dimensions are carried out at holistic scale. Firstly, the cognition lies in spatial pattern and process, which would assist to grasp the overall structure of space. Secondly, the analysis focuses on interactions between four dimensions, including the relationship between components of spatial pattern, vocabulary extraction of landscape pattern language, the shaping and continuous influence of spatial process at holistic pattern, and the influence of spatial pattern and its components on overall image and atmosphere of spatial perception.

The analysis of landscape space at holistic scale is basic understanding of space and also the first step of in-depth and detailed analysis. The cognition and analysis at this scale are relatively comprehensive, and the cognitive results have features of universality and regularity. The formative principles and results could be obtained through knowledge of related disciplines and reasonable derivation (Thinh et al. 2007). Therefore, this step could be completed with the help of geography, ecology, environmental science, and other disciplines based on remote sensing and spatial information processing technology such as ArcGIS.

4.6.2 Aggregated Landscape Scale

On composite landscape scale, landscape space could be seen as a composite ecosystem formed by coupling of three subsystems of nature, production, and human living, which is a mosaic of landscape space composed of different and interrelated spatial units. The structural and mosaic features of landscape space are obviously, and the combination of space and heterogeneity of landscape pattern could be clearly observed and described easily at this scale, which contains the rich and active processes of nature and human and reflects evolution of spatial patterns on temporal scale (Wang 2011). The static geometric features and dynamic mechanism of landscape space become the focus of landscape cognition because it is easy to monitor and predict the spatial heterogeneity of landscape pattern.

Firstly, the study on spatial pattern presented in form of landscape spatial units is to describe the geometric and structural features of a spatial pattern from the dimensions of components and spatial combinations and extract the *'words'* and *'phrases'* for landscape pattern language, which is helpful to grasp landscape characteristics at this scale and is also the basis of landscape spatial pattern evolution research. Secondly, the analysis focuses on processes investigating the natural and human dimensions related to formation of spatial pattern, explaining and summarizing the driving mechanism and evolution law of spatial pattern from temporal and spatial perspectives, as well as ecological practice wisdom reflected in the locality. Therefore, the change of spatial pattern could be predicted qualitatively or quantitatively, which is of great significance to landscape space planning and management, resource utilization, protection, and optimization, which is also necessary to perceive the symbolic and artistic conception and extend meaning endowed by human beings from dimension of spatial perception.

Composite landscape scale is the most intuitive and common scale in landscape planning and design, on which the cognition and analysis of landscape space requires the combination of remote sensing and GIS technology (Wang et al. 2016). With the interdisciplinary development of geography, ecology, sociology, environmental science, and other disciplines, not only could it recognize and describe the static characteristics of landscape pattern subtly, but also it is necessary to find out local spatial process by means of field investigation and resident interview, further to analyze the local dynamic change and internal mechanism of landscape spatial pattern.

4.6.3 Basic Landscape Scale

Landscape space could be seen as a harmonious, unified, and diverse spatial mosaics with multiple layers formed by different forms of transformation and combination of basic spaces considering from the basic or monolandscape scale (Wang, 2014, 2015a, b). When the research is carried out at a small spatial scale, the objects concerned are more specific and the precision of analysis is higher than that of other scales.

Spatial pattern shaped by local residents through activities of spontaneously spatial organization from bottom to up is often full of human connotation and local characteristics, which creates forms and functions of basic space (Freeman and Ray 2001). Basic landscape space is the smallest space which exists independently and remains completely and the simplest form of elements combination under the premise of completeness for spatial function. Through the processes of horizontal splicing and vertical nesting between basic spaces, the unit combinations and even the whole landscape spaces could be shaped at a larger scale.

The perception of basic landscape space firstly focuses on the types, functions, layouts, techniques, and cultural connotations of components in basic landscape space which presents the subjective description of the status and characteristics, and from which the *'words'* of landscape pattern language could be extracted and become the materials of landscape space promotion and protection strategy (Wang and Cui

2015). Secondly, the analysis focuses on the process of construction and coupling of basic landscape space which is formed by the combination of components and is formed by the mosaic and nesting of landscape space units.

The analysis on basic landscape space is a step to perfect the details of basic structure and pattern and which is also the link between the best exploring of landscape connotation and essence of landscape. The basic landscape space is the local expression of spatial form because of obvious correlation between landscape space and daily life at this scale. It is more necessary to go deep into an actual space through field investigation to experience the real production and living scene in process of investigation and analysis using mappings, photographs, remote sensing images, literature, and other methods. In addition, interviews and inquiries with local residents are the important ways to further understand the evolution of local history, culture, and current situation of landscape space. The evaluation of landscape space dependent on people's wishes is very important for the formulation of landscape space protection and development strategies.

The C-3P system provides a method to deconstruct and analyze landscape space from multiple levels and new perspectives. The existing problems are diagnosed, and the reference strategies are proposed through the cognition of prominent characteristics in component, pattern, process, and perception. The index system composed of spatial dimensions would be connected with the actual situation through empirical cases, and the techniques and methods at various spatial scales would be implemented in combination with the actual situation so as to conduct an empirical study on the system of established spatial analysis to test its feasibility and effectiveness.

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Chapter 5
System of Landscape Pattern Language

5.1 Theory and Method with Spatial Reasoning

5.1.1 New Framework of Landscape Cognition and Shaping

Vocabulary and spatial relationship of landscape could be learned and accumulated. In the historical process of natural landscapes and excellent cultural landscapes, all landscape reflected highly the common features of space variability, context dependence, and human centricity. Good samples of landscape space had been verified by history and proven to be useful, easy to use, and effective in coordinating human–earth relationships. Therefore, the exploring and learning of inner mechanism and characteristics of these samples become an important path for learning, inheritance, and development of these knowledge and technologies, and which has become important to learn and accumulate through mining, inheritance, and innovation of design vocabulary, spatial logic, organizational relations, and vocabulary evolution of excellent samples by using landscape pattern language.

Landscape pattern language encourages designers to generate local landscape with place and context, which is not only a theory, but also a design method. Pattern language emphasizes the cognition, learning, and excavation of landscape features of the site. On the one hand, through mining the space variability of existing landscape, the context dependence of environment and excellent sample spaces of human centricity form a local design vocabulary and spatial logic relationship; on the other hand, due to the changes of time and context of landscape, the relationship could also be discovered and shaped between design vocabulary and spatial logic which keeps pace with the times, and traditional vocabulary would be combined with the evolution of vocabulary organically to shape local landscape adapting to changes and complete the inheritance and innovation of landscape. This kind of landscape design fully shows the characteristics of traditional and local landscape and could combine with the development to show new technology, environment, and materials in order to design local landscape of new era and provide an effective path for the inheritance and innovation of landscape.

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Pattern language helps to reveal inner logics of total landscape through exploring spatial mechanism of landscape. The core issues such as scale, space, and process are always the knowledge gaps which puzzle professional learning and spatial cognition in landscape planning and design. Pattern language uses landscape spatial units instead of landscape components individually as the basic structure of space, relying on the splicing and coupling process extended on horizontal direction and vertical nested process of spatial units to realize the effect of landscape space and scale changes, also effectively unify the space, scale, and process in formative mechanism of landscape space in order to reveal the mechanism of landscape space, excavate internal logic of holistic landscape, and provide a path for design of total landscape.

5.1.2 Pattern Language Being Learned and Accumulated

As a theory and method of landscape space cognition, understanding, inheritance, and shaping, research on landscape spatial characteristics, extraction of spatial vocabulary and spatial logic have become important frameworks of pattern language which is a dynamic, constantly changing, and developing system. The relations between new vocabulary and space constantly enrich the system of pattern language, meanwhile, some vocabulary gradually phase out from pattern language due to lack of realistic functions and meanings; therefore, the pattern language which continues developing with changes of context becomes the power source of continuous innovative design. At the same time, with the context changes, the approach of the traditional design vocabulary and spatial relation adapting to modern context has become the key to cultural adaptive theory of pattern language. Therefore, the continuous inheritance, adaptation, and adjustment of pattern language have become big topics which need further research and discussion.

With logic of spatial units as basic parts to form hierarchically the structure and reorganization of landscape space, some space units show higher landscape functions and ideographic functions and used as transitional spaces to support the link and buffer of landscape; however, functions and meanings of some spatial units are not clear. Therefore, how to determine the effect and performance of landscape spatial units becomes the basis of space and sample selection for landscape pattern language. At present, there are many researches on performance of architectural space and urban space; however, there is a lack of corresponding system and method for evaluating the performance of landscape space, which also restricts the study of vocabulary and spatial mechanism of landscape pattern language. The spatial performance evaluation of potential ecosystem service has become an important research path to support pattern language, which needs to be further deepened and discussed.

The theory and method of landscape pattern language provide a new angle and path for landscape spatial analysis, description, representation, characterization, and shaping, which are not exclusive to other landscape spatial theories, but also have diversity and selectivity in spatial analysis and design. As an attempt of a new path, pattern language theory and method still have many theories and key technologies to be further explored and studied. At the same time, more practice is needed to validate it, and more interests are welcome to join the research in this field.

5.1.3 Pattern Language Being Integrated and Innovated

Landscape is often one of the important features of the era with distinctive feature which reflects the changing of social ecosystem and corresponding changes of landscape. However, landscape changes in a large cycle could truly reflect the dominant characteristics of a period because of partial and transitional changes. The pattern language depending on local mechanism of landscape space has the characteristics of the era, which reflects the different characteristics of the time and meaning of expression.

The diversity of space and variability of practice create rich vocabularies and spatial logics of landscape. On the one hand, landscape vocabulary and spatial logic formed in history could be learned and accumulated and become the vocabulary source of modern designers for creating landscapes. On the other hand, the future is full of unknowable factors and imagination, it has become an important source of motivation for the pursuit of innovation to meet future needs and pursue future development trends in landscape planning and design. Therefore, pattern language should not only be accumulated from history, and the innovation and development of landscape planning and design vocabulary should also be achieved through the integration and demand innovation of pattern language in diverse contexts.

5.2 Framework of Landscape Pattern Language

Pattern language is a comprehensive system composing of landscape space and its relations with language structure, characteristics, organizational process, functions, techniques application, individual meanings, pragmatics, and rhetoric. Spatial pattern is the vocabulary of landscape language, which composes a complete and organic system with both form and meaning under the influence of landscape spatial process, logic relation, and formative mechanism (Fig. 5.1).

5.2.1 Vocabulary of Pattern Language

The theoretical system of landscape pattern language is mainly composed of spatial pattern vocabulary, space morphology, syntax and grammar, among which space morphology and syntax are grammar of landscape pattern language. Pattern vocabulary, as the foundation of landscape space components, mainly consists of *'word'*, *'phrase',* and *'simple sentence'* of space. *'Word'* is composed of different forms of

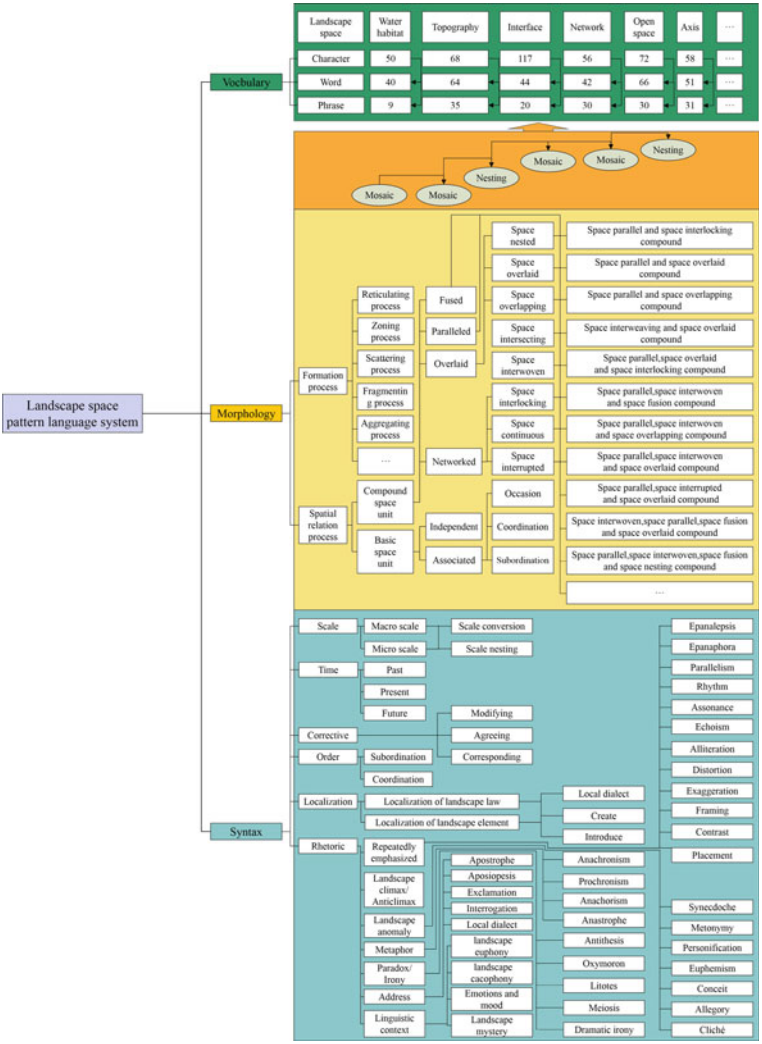


Fig. 5.1 System of landscape pattern language

single component or type in landscape space, and a type of word could be expressed by a variety of different forms and act as the basic unit of landscape pattern language. The *'phrase'* of spatial vocabulary is combination of individual landscape components or types of words, it can be a repetition of same form of landscape words, or a combination of different forms of landscape words. The *'simple sentence'* of space vocabulary is an independent landscape space type composed of multiple landscape phrases and is also the constituent unit or combined space of landscape.

5.2.2 The Morphology of Pattern Language

Morphology of landscape space means a relatively complete and inner relationship of landscape spaces which combined of a number of landscape words or phrases in a particular landscape context, which could be controlled to form a classic space unit. The morphology of landscape usually includes formative process and spatial relations. The morphology of formative process could be classified into the networking, fragmented, banding, scattering, and coring process. The morphology of spatial relations could be classified into single and composite morphology. The single morphology could be an independent basic landscape space composed of independent landscape phrases, or it could be a combination of interrelated landscape spaces determined by the accidental, coordinated, and subordinate relationships. It could also be an interrelated space combination of mutual influence determined by contingency, coordination and subordinating relations. The composite morphology shapes the laws of landscape spatial sequence through space fused, parallel, overlaid, nested, overlapping, intersecting, interwoven, interlocking and space continuous, interrupted, and other internal relations.

5.2.3 The Syntax of Pattern Language

The relationship between sentences in landscape space is the syntax of landscape language, which is the basic criterion and relationship for transformation from basic spatial unit, compound spatial unit of landscape to the overall landscape. The main syntactic relations of landscape space include the scales of macro, meso, and microscope, time and tense of landscape in the past, present, and future, the modification of landscape agreeing and corresponding, the order of landscape coordinating and subordinating, and the locality of landscape and landscape rhetoric.

The emphasis with repetition includes placement, framing, contrast, exaggeration, distortion, alliteration, echoism, assonance, rhythm, parallelism, epanaphora, epanalepsis, landscape climax, and anticlimax after the climax. Landscape anomaly mainly includes anachronism, prochronism, anachorism, and anastrophe. Landscape metaphor mainly includes synecdoche, metonymy, personification, euphemism, conceit, allegory, and cliché. The paradox and irony mainly include antithesis, oxymoron, litotes, meiosis, and dramatic irony. The address mainly includes apostrophe, aposiopesis, exclamation, and interrogation. The language context of landscape architecture mainly includes euphony, cacophony, mood, and mystery.

It could be seen that space vocabulary, morphology, and syntax together constitute the complex landscape pattern language, of which the theoretical framework is an open system and the vocabulary and spatial relationship of designers can be supplemented and enriched through the expansion and deepening of research and the continuous accumulation of practice (Fig. 5.1). In order to continuously build a more complete and adaptive system of pattern language, we could also fully excavate the existing pattern languages in design process and carry out innovative development to form a burgeoning system of pattern language with the characteristics of the times.

5.3 Inner Logic of Landscape Pattern Language

Landscape pattern language has specific internal logics from perspective of the components and their interrelations of pattern language theory (Fig. 5.2). It reveals the essential relationship between frameworks of pattern language in temporal dimension and spatial dimension.

5.3.1 Relations of Spatial Logic

Spatial logic is the spatial relationship between the basic vocabularies corresponding to spatial scale. It could be classified into horizontal and vertical spatial relations in composite space unit, of which the spatial juxtaposition, intersection, interweaving, interruption, and spatial continuity are horizontal spatial relationships, while the

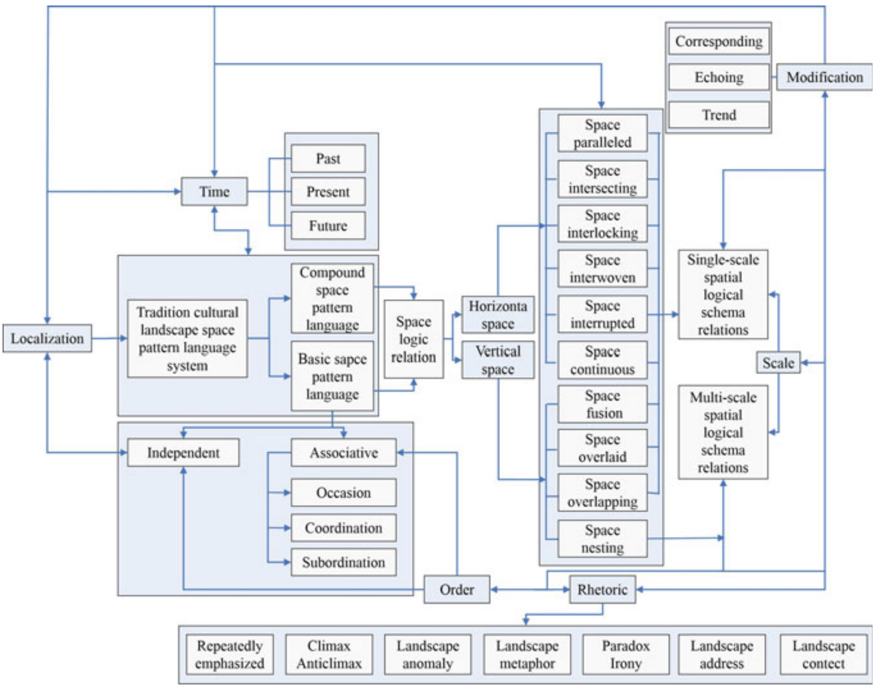


Fig. 5.2 Inner logics of landscape pattern language

spatial fusion, superimposition, overlapping, and nesting are vertical spatial relationships. There is another issue of spatial scale involved in horizontal and vertical spatial relations, in which the spatial juxtaposition, intersection, interweaving, interruption, continuity, fusion, superposition, and spatial overlap are the relations of spatial pattern at monoscale, and spatial nesting is relations of spatial pattern at multiple scales.

5.3.2 Locality of Pattern Language

Corresponding to temporal dimension, it is the premise to determine landscape type for construction and landscape locality plays a certain role in the whole process of language system construction with the development from past to present and the prediction and expectation of the future. It could be classified into the independent and related unit in the system of basic space units and the initial classification of space types determines its scope of application, to which the extracted vocabularies of landscape are typical and basic vocabularies with a certain scope of application for this kind of space. In the early stage of planning and design, people made detailed investigations and analyses on the environment of study area and the status quo of the site under the guidance of syntax in local pattern, made detailed analysis and summary of local landscape elements and rules, and also chose spatial vocabulary correspondingly as basis of planning and design.

The uniformity is a main feature of regional landscape. From perspective of landscape integrity of Jiangnan water towns, landscape mosaic with farming paddy fields as matrix, roads, rivers and irrigation channels as corridors, and residential areas, and ponds as patches, it can be seen that the differentiation of matrix, patches, and corridors is obviously, and the mosaic characteristics of paddy fields, ponds, and residential areas are generally forming landscape with high uniformity. At the same time, the patches are highly fragmented with the patch-corridor-matrix differentiation in regional landscape.

Waterscape is not only the soul of regional landscape, but also the landmark of regional landscape in Jiangnan water towns. Channels and water networks are intertwined, and ponds are dotted around to become the landmark of the regional landscape system, in which unique farming activities, settlement culture, and transportation tools have been formed in natural environment with plenty of waterbodies. The factors related to water are the key driving forces to total human ecosystem and also the characters different from other features of local landscape.

In the research area of Jiangnan water towns, traditional water towns work as the soul and center of regional landscape, especially for the environment of human settlement. Landscape changes are dramatic, which are gradually disappearing in historical period. The continuation of landscape is mainly concentrated in relatively well-preserved ancient towns in the south of the Yangtze River, of which the layout, architectural style, and artistic decoration could show the history of local landscape and had become the landmark of regional landscape (Fig. 5.3).

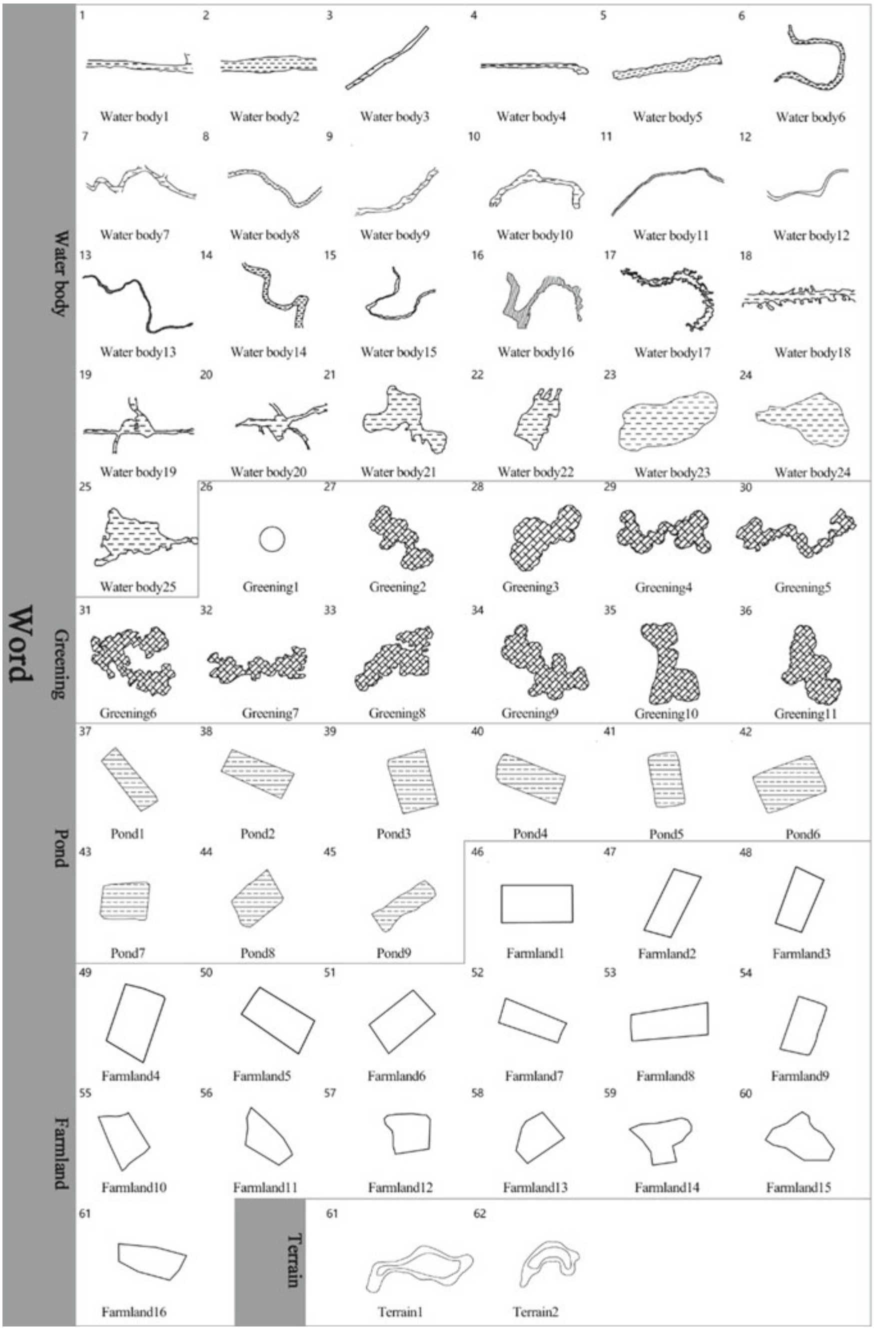
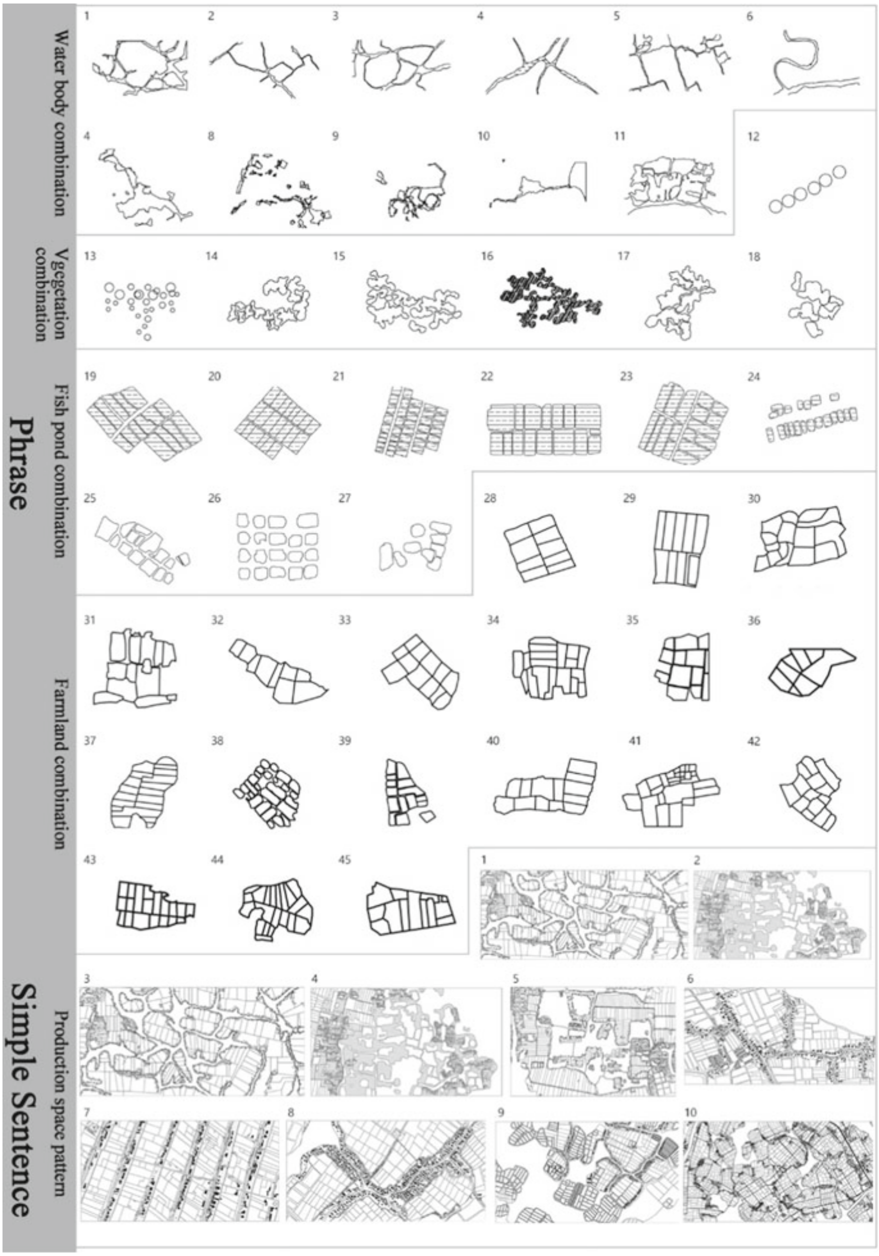


Fig. 5.3 Basic spatial vocabulary in the Jiangnan water town area



1-11water body combination1-11 12-18plant combination12-18 19-27fish pond combination19-27
28-45farmland combination29-45 1-10production space pattern

Fig. 5.3 (continued)

5.3.3 *Scalability of Pattern Language*

5.3.3.1 Scale and Scale Effect

Scale is a basic parameter of landscape space and also basic feature of landscape pattern language, which is known that scale could be classified as spatial and temporal scale, but what is the scale exactly in landscape space? What factors determine the scale? Issues such as these have always been the questions which puzzle the cognition and shaping of landscape space, and they are the problems which could not be defined in existing system. From an international perspective of scale research, the scale effect, scale transformation, and scale nesting are three key topics of research in the world, which are precisely the main characteristics of inner logic of pattern language.

The scale of landscape space not only has the objectivity determined by space, but also has subjective perception of landscape space, which has a direct but not the only relationship with size, height, area, quantity of space and length, and frequency of time, and is not completely determined by these factors. A big question in the relationship between scale and scale effect of landscape scape: Does the scale determine its effect or does the scale effect determine the scale? There are objectively scale differentiations in landscape space, but space of what extent is a large-scale space? What extent of a space is small-scale space? What extent of space is medium-scale space? Is the scale effect a continuous change or a jump change? Landscape pattern language believes that the objectivity of scale determines that different scales have different scale effects, but the change of scale effect is the specific causes of difference in scale size. It could also be said that when scale effect changes greatly, landscape spatial scale has undergone substantial changes.

5.3.3.2 Scaling and Scale Nested: Multi-scale Spatial Processes

In the past ten years of international conferences on landscape architecture and landscape ecology, multi-scale issues of multiple scales have become one of the important topics of '*Ecology at Multiple Scales*'. From perspective of landscape scale research, scale analysis mostly focuses on research at different scales from site to region. Landscape scale effect (Jelinski and Kulkow 1996; Wu 1996) is a phenomenon that the effect of landscape space would change when landscape space changes its size of basic unit due to space aggregation and also is a phenomenon that landscape space varies with the scale, which is manifested in the interaction of scale-structure-process.

Scaling refers to the transformation of information between different scales or organizational levels. Upscaling is the process of deducing information on a small scale to a large scale, and vice versa is downscaling. By comparing the research of various disciplines, it is found that the properties observed on one scale and the principles and laws summarized by people are still valid on the other scale; however, they may be approximate or need to be modified according to the specific scale. The establishment of small-scale information needs to be integrated with large-scale environment, and large-scale information or pattern needs to be applied to small-scale environment. The disciplines of architecture, urban and rural planning, landscape architecture, geography, ecology, atmospheric science, earth science, biological oceanography, physics, and fractal geometry all involve researches on scale transformation, but compared with other disciplines, landscape architecture and urban and rural planning are in the initial stage of scale transformation research because of the lack of systematic theories.

The rapid development of scale transformation issues has greatly enriched the scale conversion theories in various disciplines. The theory of hierarchy and self-similarity is used in scale transformation to analyze the characteristics, functions, and relationships of different scales, as well as the similarity between local and local, local and global characteristics in form, time and space in order to provide theoretical basis for cross-scale conversion and construction of scale deduction (Withers et al. 1999; Johnson et al. 1999).

Nested structure is a spatial phenomenon and process which couples landscape space from small scale, medium scale to large scale through natural and socio-ecological processes to form a holistic landscape. It was first proposed by Darlington (1957), and then explored by Simberloff (1980) and Levin (1985) and others. Patterson and Atmar (1986) first systematically applied the analysis method of constructing a matrix at community scale. After that, the theory of nested structure was widely used in field of community ecology (Worthen and Rohde 1996; Feeley 2003; Donnelly and Marzluff 2004; Bloch et al. 2007). According to the similarity of landscape composition, the pattern is divided into three categories of the complete nested structure, significant nested structure, and non-nested structure. In recent years, due to the important role of analysis on nested structure in studying the composition of habitat species and distribution patterns (Mac Nally and Brown 2001; Nally 2002; Bell and Donnelly 2006; Feeley et al. 2007; Jonson and Jonsell 1999), it has gradually become one of the effective tools for the research of community structure and landscape habitat (Lomolino and Perault 2000; Bloch et al. 2007). Nested structure is also widely used in social sciences, landscape ecology, species diversity (Bakermans et al. 2012; Dickson et al. 2014; Bergin et al. 2000; Saunders 2002; Fabian et al. 2014), regional landscape, and research on the nested characteristics of communities, and it also uses the nested features of landscape to establish urban planning and management methods (Brunckhorst et al. 2006).

5.3.3.3 Pattern Language Theory on Scale and Scaling

Scale is a basic feature of landscape space, and scale design is a basic principle of landscape architecture. In the system of pattern language, C. Alexander believed that the most important thing was to find out the universal characteristics of excellent spaces then schematize and apply them to actual architectural design. Alexander summarized the patterns from three aspects of town, buildings, and construction, which are three basic scales of space and the nested relations of space (Alexander et al. 1978).

In the book *The Language of landscape*, Anne Spirn also studied scale issues and proposed that landscape scale varies greatly from the microscopic to the macroscopic, which could be divided into many types from a square meter, more than 10 square meter, garden, park to the whole region. At the same time, Anne Spirn believed that landscape should not be simply divided into scales, this is exactly the flaw in C. Alexander's research, but should be the continuous, combined, and nested relationship, and she mentioned the right need for research of scaling in landscape architecture and the characteristics of landscape on time scale (Spirn 1998). It could be seen that Anne Spirn went further than C. Alexander on the issue of scale research, and she recognized the reality and needs on scaling and nested structure in socio-ecological practice research.

5.3.4 Temporality of Pattern Language

There is a certain degree of order in basic unit of the spatial association, such as coordination, subordination. The two major spatial grammatical relationships of modification and rhetoric play a leading role in overall landscape pattern language. Under the combined activities of two dimension of time and space and under the action of two major syntactic relations of modification and rhetoric, the spatial units and combinations can better meet the needs of actual planning and design and improve the applicability of landscape pattern language. It should be done that reasonable analysis of the past and present conditions and reasonable expectations of future direction of the base with guidance of temporal syntax. The process and pattern of landscape are all completed in the specific context, which is a historical process and part of which is still preserved and exists for a long time and plays a very important role in daily life of local residents. It is the right reason that the process and pattern are also that of the present and the future whether it is applicable in the future depends on the change of context. Therefore, the temporality of pattern language is manifested in the process behind landscape.

Traditional buildings and settlements are widely recognized as typical of local cultural landscapes with fitness to environment, which are safe strongholds built by people for their long-term survival in nature and also an integrated system with relations of obedience and defense to nature, which was constructed by people with unique understandings of nature and created harmonious spaces for living. Therefore, it could fully reflect people's unique knowledge of nature and society and become a typical representative of socio-ecological landscape. The forms of architecture and settlement have become direct patterns which reflect traditional culture landscapes in region; however, it is precisely because the directness and representativeness of architecture and settlement landscape attract people's much attention, and other essential elements and characteristics of socio-ecological landscape are ignored in the process of local interpretation.

Land texture is mainly the productive landscape under the relationship of man–land interaction, which is a direct reflection of agricultural production and farming and also a specific form of understanding and using nature in the process of agricultural production. From perspective of total human ecosystem, the forms of land use express the comprehensive characteristics of natural and cultural landscapes of semi-natural and semi-technical ecosystem, which are specifically affected by topography, water bodies, farming ways, agricultural types, population size, and other factors. The types of land use in different natural environments are different, and the forms corresponding to land use are also different. From comparison of land use textures in typical areas of Jiangnan water towns, it has formed a morphological characteristic of extremely irregular borders similar to the structure of cell in land use, but it has formed a very regular dike-pond structure of pattern of land use in the Pearl River delta plain. Due to the conditions of low mountains and hills, a land-using pattern combining dam field and terraces has been formed in long-term history in Huizhou cultural area locating at the south of Anhui Province, while obviously in the northern central plains, most of land use features are rectangular and regularly distributed as the pattern of chess due to the flat and dry farming. These differences directly reveal the characteristics of socio-ecological landscape, and the form and texture of land use have become an important pattern of socio-ecological landscape.

Water resource is an indispensable component for human life and production, which is also thought as the soul of landscape compositions in which water becomes an important, dominating, and guiding component of landscape evolution. Therefore, the relationship between water body and the process of human life and production and the characteristics of water utilization had become the important manifestations of local and traditional cultural landscapes. In the region of Jiangnan water towns, water body becomes the center and axis of both production and living landscape and could be seen that all buildings are linearly distributed along the river and become the axis of settlement and site of daily activities from the relationship between settlement and water. Most of settlements in Huizhou in Southern Anhui are located on one side of waterway to form a pattern adjacent to water in form of clusters with their own unique axis instead of pattern centered a river as landscape axis. In Pearl River delta, the settlements are often surrounded with water bodies in the dike-pond system which consisted of total landscape. In the central plains of China, the utilization of groundwater and rainwater instead of river is the dominant factor in controlling settlement development due to characteristics of dryland farming, settlements have always developed in clusters with a uniformly distributed and regular pattern. The mechanisms of water factor is different to guide the formation and development of landscapes in different regions, which rooted in traditional culture context of a region and reflected the important local features and landscape pattern.

Residential pattern is the characteristics of holistic landscape and pattern formed by comprehensively considering the surroundings and natural environment, land resources and utilization, building and settlement forms, and water resources utilization in the long-term historical process under the support of local knowledge. The residential model is a comprehensive reflection of socio-ecological landscape and also the inner manifestation of local landscape. In the area of Jiangnan water towns, it can be clearly seen that the typical residential mode are composed of linear settlements with houses distributed along waterways, farmland on both sides of settlement, and intertwined fishery ponds. In the Pearl River delta plain, landscape patterns and residential modes are obviously in clusters surrounded by dike-pond patterns. In the hilly and mountainous areas of Southern Anhui, a mountain dwelling pattern formed by a combination of dam field and terraces extending along a valley and facing a valley with a stream flowing through the village. In the central plains of China, all villages looking like small islands float in dry land farming with grid structure. With the development of social economy and continuous deep understanding of nature, residential mode is a dynamic process formed in the course of historical development and is continuously improved and adapted to the natural and social changes, and finally, it is a comprehensive system full of local knowledge. At the same time, the unique residential culture dominated by local knowledge is important part of landscape personality with the expansion of local knowledge, which is influenced by locality and residential landscape.

When the Chinese version of *Illustrated History of Landscape Design* written by Elizabeth Boults was published, Elizabeth and her collaborator Chip Sullivan wrote in the preface of the Chinese version, this book aims to provide readers with an overall framework for understanding how humans artfully shape nature and meet their own needs through the perspective of landscape architecture. Landscape design works in different historical periods are the cultural and artistic products of the specific historical period. Chinese traditional gardens are like this, in which painting, poetry, and gardens are closely related together and made us immersed in and inspired by. The book *Illustrated History of Landscape Design* itself is a work of art, which includes a poetic organization of research into factors which influence the artificial environment, and through which people are encouraged to recognize the great landscapes of the past to create more beautiful gardens, parks, and green spaces in the future. This statement preliminarily outlines the author's research on classic works from different periods through the research methods of graphic and pattern and summarizes the basic principles of landscape design in different historical periods and the basic vocabularies of design corresponding to the era.

A historical research system was built using landscape pattern language to recognize, analyze, and summarize the development and changes of landscape architecture in different historical stages. Elizabeth Burton divided human history into nine historical stages of landscape design, which include the period from prehistoric times to sixth century, sixthth to fifteenth century, fifteenth century, sixteenth century, seventeenth century, eighteenth century, nineteenth century, twentieth century, and twenty-first century, studied the famous landscapes of various places in these historical periods, and finally, summarized and formed the concepts, principles and vocabularies of landscape design in different historical periods. In the research process, a large number of illustrations and comic strips are used as materials, and the academic conclusions are made through diagrams and patterns revealing the whole process of the development of landscape design language based on historical methodology and also becoming an important approach to reveal the research on landscape pattern language.

5.3.5 *The Order of Pattern Language*

The mutual coordination and subordination of extracted typical patterns are determined in practical applications with the order of space grammar. If the typical patterns are applied to implement planning and design in the area of Jiangnan water towns, several major types of landscape spaces could be identified as residential model, rural landscape spaces, corridors with gravel and lawn, fishery space, and wetland.

Comparing with patterns of living space in Southern Anhui, Guangdong Plain, and Henan in Central Plains, it could be clearly seen that linear settlements composed of houses distributed along waterways, the farmland on both sides of settlement, intertwined fishery ponds, all these forms are typical landscape patterns of Jiangnan water towns.

Rural landscape spaces in south of the Yangtze River mainly reflect the regional landscape characteristics of Jiangnan water towns, which are reflected in shaping landscape feature at three types of arable land, grassland, and woodland. Of course, these three types of landscape do not exist in isolation but blend together with close relationships each other and would form two different interlaced zones, one of which is that between arable land and grassland, and the other is that between grassland and woodland. Biological species in the interlaced zone are often more abundant than those in ordinary space, which would greatly improve the biodiversity of landscape spaces.

The main feature of leisure resort is to transform and utilize fishery ponds in the area to form unique landscape activities and scenery. In addition to fishery ponds renovation, buildings in landscape space also follow residential patterns of the south of Yangtze River and are linearly distributed along waterways with specific scale.

Landscape spaces of corridor with gravel and lawn are the regeneration of waterway landscape in the region of Jiangnan water towns. Through the transformation of topography, abundant water system in the area is used to create a landscape corridor with high visual quality, in which lots of sites with rich landscapes are formed for people to travel and play through construction with materials of gravel and lawn.

Landscape space of Jiangnan fishery pond is regeneration of traditional life scene which is an important part of human landscape of the south of Yangtze River. It mainly builds a landscape pattern centered on the lake, surrounded by fishery ponds on three sides, and lawns with sparsely woodland on one side, which not only has a wide view but also has unique regional landscape characteristics.

Wetland is the most widely distributed type of landscape in this region, which includes rice fields, fishery ponds, crop ponds, lakes, and waterways. There are two main types of wetlands, one of which is the imitative natural wetland mainly referring to the shrub-tidal wetland, and the other is the artificial wetland landscape mainly referring to ponds for cropping. Among them, the shrub-tidal wetland is mainly reflected by construction the shape of water body and the construction of various community of aquatic plants. The crop ponds mentioned here refer to keeping the form of fishery ponds in the area and transforming to plant various crops with higher ornamental properties and can create various required habitats according to the needs of crops. According to the space syntax of order, the above six landscape spaces can be reasonably distributed in planning and design of site in actual application. Of course, due to the difference of existing conditions of site and specific goals of planning and design, the spatial order of arrangement would be various, but the final goal of the order of space syntax is to find the optimal combination in sequence of space.

5.3.6 Modification of Pattern Language

The corrective rhetoric mainly includes three ways of consistency, conformity, and integration. The landscape spatial sequence under the process has a high degree of consistency, and the structure of water network in a basin has a high degree of consistency with hydrological process. The relationship between different types of landscape space shows compatibility of the relationship under effect of unified ecological law. In the process of human utilization of nature, the transformation of nature and construction of artificial landscapes have many spatial relations which need to be organized in landscape space. In the study of corrective relationship between landscape spaces, it is necessary to determine what relationships are consistent and what relationships are compliance based on existing problems in a practical process, to adjust the spatial relationship through landscape arrangement. Under the guidance of corrective space syntax, basic patterns of the selected spatial vocabulary could be adjusted and debugged according to actual situation of site in the actual case design, so that it is more suitable for application of actual cases. For example, the consistency and integration of water system, the compliance and integration of relationship between building layout and water network which is the final form of planning and design after combining water network and the cellular water system (Fig. 5.4).

5.3.7 Rhetoric of Pattern Language

The structure of landscape spaces includes not only splicing on horizontal direction and nested relationship on vertical direction, but also various comparative relationships between spaces, which usually includes landscape emphasis, abnormity, and landscape meanings and metaphors.

The emphasized relationship formed by the repetition of landscape space unit, which is manifested not only in basic spatial unit, but could also in the repetition of different scales of space. The difference here is just the basic unit which is landscape element using as one way of emphasis in repetition. Parallel repetition, initial repetition, and interval repetition are all concrete forms of repetitive emphasis. The emphasis can be distinguished as the beginning and the ending to forming a strong contrast, frame selection, exaggeration, and distortion.

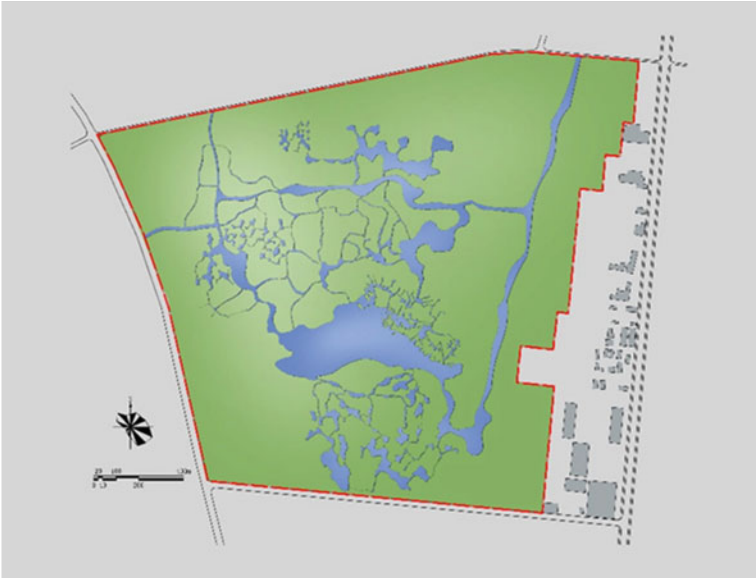


Fig. 5.4 Application of modification in water network design

Landscape abnormity breaks the rhetoric of original landscape sequence, which includes landscape spatial relationships such as untimely, inversion, and spatial dislocation. Landscape special meanings and metaphors are special ways and rhetoric with specific meaning formed with form and composition. The intuition about pattern language from a perspective of graphics is that it has a specific form which could be analyzed through two big questions: What driving forces promoted the form? And what relationships of spatial combination created the form? Based on these, it could be seen that the specific driving forces and spatial relationships are both the inner mechanisms to landscape form, but it is not absolute that whether the driving forces are also related to spatial relationships as well.

Just like the relationship between pattern and process mentioned in landscape ecology, it is not a process that inevitably leads to a specific pattern, or there is a process behind a specific pattern. The two are not necessarily corresponding just one relationship, but might be related with various processes. Therefore, the rhetoric of pattern language also tries to establish a connection and logical expression by analyzing driving forces and spatial relationship (Figs. 5.5 and 5.6). All could be analyzed that theory of landscape pattern language is based on basic spatial vocabulary of time and space, which form a series of basic spatial units and combinations under the influence of locality, scale, time, order, revision, and rhetoric.

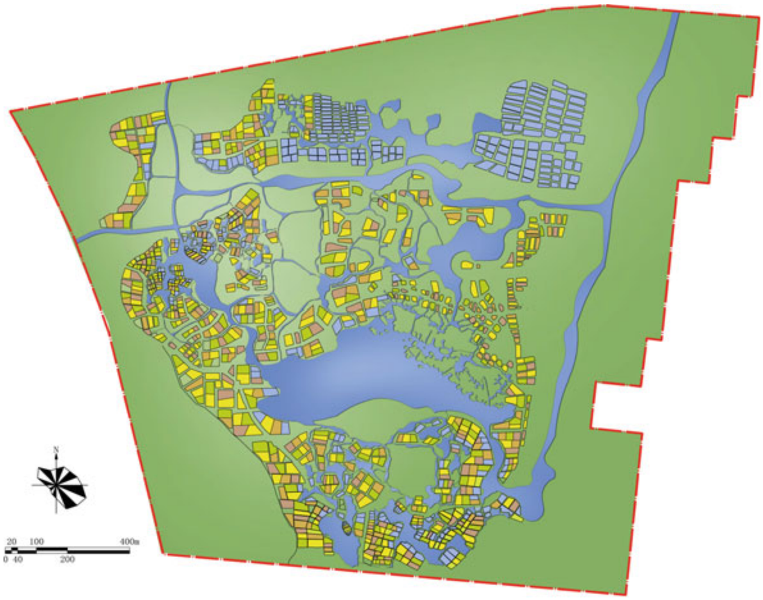


Fig. 5.5 Emphasizing through repetition of land texture

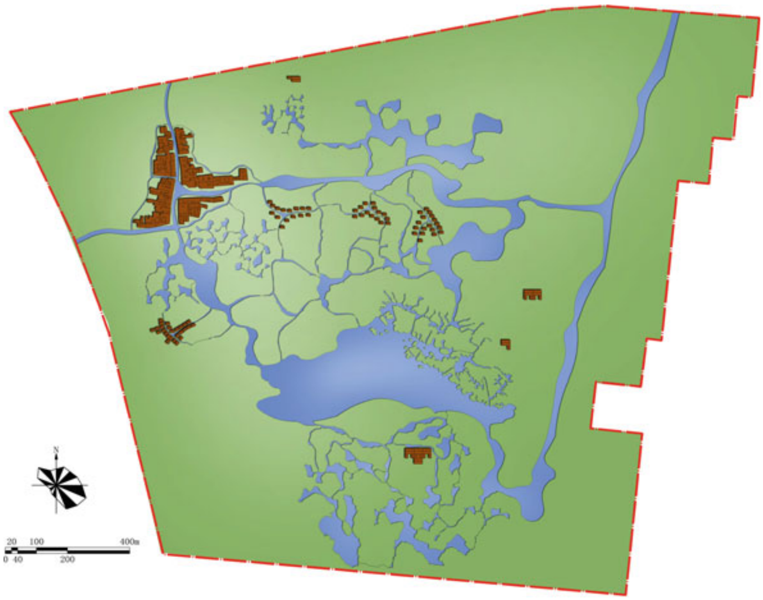


Fig. 5.6 Emphasizing through repetition in settlement space

5.4 Locality and Universality of Pattern Language

5.4.1 Locality of Pattern Language

Cultural landscape is a type of that existing within a specific geographical area, which is formed and survived under a specific geographical environment and cultural context and also is a record of historical human activity and a carrier of cultural inheritance with the important value of history and culture. In addition, regional cultural landscapes appeared and evolved in accordance with specific geographical environments, and a large number of materialized historical landscapes and non-material traditional customs have been preserved to build a regional cultural landscape system which was mainly embodied in living space with architecture and settlement landscape, productive space with land use form and ecological space with environmental ethics.

Antrop (2005) pointed out that local landscape existing in a region would help to maintain the diversity and sustainability of landscape and make cultural landscape more recognizable. Kelly and Moles (2000) pointed out that it would have far-reaching significance for people who live in a specific area and be closely related to local residents, farms, woodlands, rivers, and buildings. The diversity and detail of these local characteristics as well as traditions and memories associated with them are the root of the richness and uniqueness of European landscape. The essential characteristics of cultural landscape and regional cultural landscape would distinguish a place from others and prominently reflected in local natural environment, local knowledge system, and local material spaces. They are deeply reflected in the material space of living and productive landscape and formed a unique pattern language, which are mainly reflected in architecture and settlement, land use, water resource utilization, and local residential pattern.

Among them, the residential pattern is a comprehensive manifestation of architecture and settlement, land utilization, and water resource utilization in traditional and regional cultural landscape. Therefore, locality is the concrete manifestation and carrier of cultural landscape in total human ecosystem.

Buildings and settlements are widely recognized typical cases of local landscape, which are safe strongholds built by humans for long-term survival in nature and are the system of unity of opposites based on fully reflection of the unique knowledge system of nature and society established by people. However, with interpretation of locality, the directness and representativeness of architecture and settlement landscapes often make people overlook other essential elements and characteristics of traditional cultural landscapes.

Land use is a kind of productive landscape under the process of human–land interaction, a direct reflection of agricultural production and farming civilization, and the specific form of understanding and using nature in the process of agricultural production. It expresses comprehensively the characteristics of natural and cultural landscape because land use is specifically affected by topography, water bodies, farming methods, agricultural types, population size, and other factors, land use types and forms vary correspondingly in different natural environments. For example, the boundary of land in area of Jiangnan water towns is extremely irregular and resembles the morphological characteristic of cell structure, the extremely regular dike-pond structure formed in the Pearl River delta plain, land use pattern of dam field-terrace in Southern Anhui, as well as grid structure which show the land use characteristics of rectangular shape and regular distribution with relatively regular and larger unit area in the central plains of North China. These differences reveal that the characteristics and texture have become an important traditional pattern of regional cultural landscape.

Water is not only an important landscape element of traditional cultural landscapes, but also the relationship with water bodies and water utilization in the process of human life and production dominate and guide the evolution of landscapes. For example, water bodies in the area of Jiangnan water towns have become the center and axis of all production and life landscape, and all buildings are linearly distributed along the river which works as an axis of settlements and the main public open space for human activities. The settlements in Southern Anhui Province are mostly located on one side of water body with the pattern of water-adjacent cluster, but settlements always form their own unique development axis instead of the river. Waterscape has various dynamic mechanisms to guide the development of landscape in different regions, which roots in traditional culture of regional landscape and has become an important local feature and source of landscape pattern language.

The living pattern reflects the characteristics of holistic landscape and its spatial pattern formed comprehensively by the process of surroundings and natural environment, land resources and utilization, building and settlement forms, and water resources utilization in the long-term historical process under the support of the local knowledge system. With the development of society and economy and the deepening understanding of nature, the continuous improvement of living pattern and adaptation to changes of nature and society are the comprehensive manifestations of local knowledge system and residential culture. It can be seen that the typical living patterns of Jiangnan water towns with linear settlements distributed along waterways and farmland-fishery ponds intertwined with each other through landscape comparison. The patterns of mountain dwelling formed by landform pattern are combined with settlements in group, living pattern of regular farmlands dike with fishery ponds, and the combination of dam field-terraces extending along the valley formed in Southern Anhui Province, which leans against the mountains as background, faces the valley, and a stream flows in front of the village.

5.4.2 Universality of Pattern Language

The locality and universality of pattern language are realized through pattern vocabularies and spatial relations. The exemplary and common characteristics of excellent ecological spaces around the world determine the universality and local characteristics of pattern language. The universality can be learned, inherited, and promoted, while the locality can be explored, discovered, and shaped; therefore, pattern language is an important method and path for shaping local landscape.

The local and exotic vocabularies are both explored to reflect spatial patterns and logics in the system of pattern language, so the vocabularies that designers master and quote also have these two characteristics. The exotic vocabulary is accumulated by designer through learning and practical experience. Some of foreign vocabulary can be combined with environment and scale to implement the transformation of environment and scale, and some vocabulary has non-transferability of environment and scale. Therefore, designers would choose corresponding vocabularies by themselves.

Local vocabulary is a unique landscape vocabulary formed by designers relying on professional knowledge and skills to recognize, understand, and excavate site landscape. Generally speaking, it has a strong landscape personality, which is the embodiment of site culture and spirit. Whether it is a local vocabulary or an exotic vocabulary, both of them have the characteristics of locality and universality. Universal vocabulary often focuses on basic special features of landscape, while local vocabulary focuses more on individual characteristics of landscape. Therefore, the locality and universality of pattern vocabulary and spatial logic are relatively, but the system of pattern language has both locality and universality corresponding to any kind of landscape space.

5.5 Research Path of Pattern Language

5.5.1 Selection and Processing of Typical Sample

5.5.1.1 Selection of Typical Sample

Typical patterns are the basic materials for research of pattern language which requires firstly the selection of typical spaces as the source of refinery. Although there are many types of landscape spaces catering for the selection of typical patterns, the study believed that the following criteria could be used to preliminarily judge whether the selected spaces have values of being included in the construction of landscape pattern language.

The selected space as typical pattern needs to have the basic form, structure or composition characteristics of consistence with landscape space type, needs to have a complete and unified landscape context and texture and have a relatively deep historical and cultural context, and on which the inheritance formed a unique and stable settlement pattern, lifestyle, life philosophy, and social customs. The arable land form, farming and irrigation ways, and crop selection of space where the typical pattern existed are all formed based on natural and geographical environment and climatic conditions, its production ways is self-contained, respectful, and sustainable. The space as a typical pattern with good ecological condition is reflected in the coverage with rich vegetation, complete water system, and the coordination and integration between activities and natural environment. The ecological ethics and traditional ecological wisdom derived from coordinated man–land relationship could also be regarded as the basis for judging whether the space is typical and valuable to incorporate into construction of landscape pattern language.

The first two criteria are to make the research relevant closely to pattern language, avoid the overlapping of different landscape types and low research efficiency, and ensure the completeness of pattern selection. The remaining four criteria would be used as supplementary. The reason of which is difficult to meet four standards at the same time in actual operation, but the research requires that at least one of them must be met in the process of specific, typical pattern selection. In summary, when the space satisfies the basic items and at least one supplementary criterion, it could be selected as a sample space of typical pattern.

The research comprehensively considered the particularity of scale requirements of networked space and the operability of typical pattern selection and finally determined the scale which typical patterns are mainly concentrated in mesoscale and microscale with range of 1:200–1:500. The particularity of scale requirements for network is a special morphological structure. For the research of spatial pattern on network, the transformation of scale may lead to changes in the morphological structure and its characteristics; therefore, the scale should be defined as a continuous interval in the research of network. The form and composition of landscape space network under different scales are different, which are determined by scale effect of landscape. The research expects to reduce the effects of scale and its stability of remote sensing images as much as possible within the defined scale because basic composition and identification of landscape elements are relatively stable within the defined scale.

5.5.1.2 Processing of Typical Sample

The research on typical pattern processing includes basic processes which are the classification and identification, as well as digitization of landscape mosaic. Under normal circumstances, the preliminary processing of selected typical patterns first needs to classify and identify landscape elements which mainly include mountains, water bodies, farmland, woodland, roads, and buildings. The types of landscape elements can be supplemented or continue to be subdivided on the basis of above-mentioned categories corresponding to landscape space. Landscape elements are preliminarily interpreted with remote sensing image on the basis of determining the composition in typical pattern space.

After the preliminary analysis and interpretation of landscape elements, the follow-up work is to digitalize landscape elements according to the definite categories, which mainly include: using AutoCAD to separate layers for full-frame depiction of maps from remote sensing image based on category of landscape element, strengthening the key elements of spatial pattern, weakening other secondary

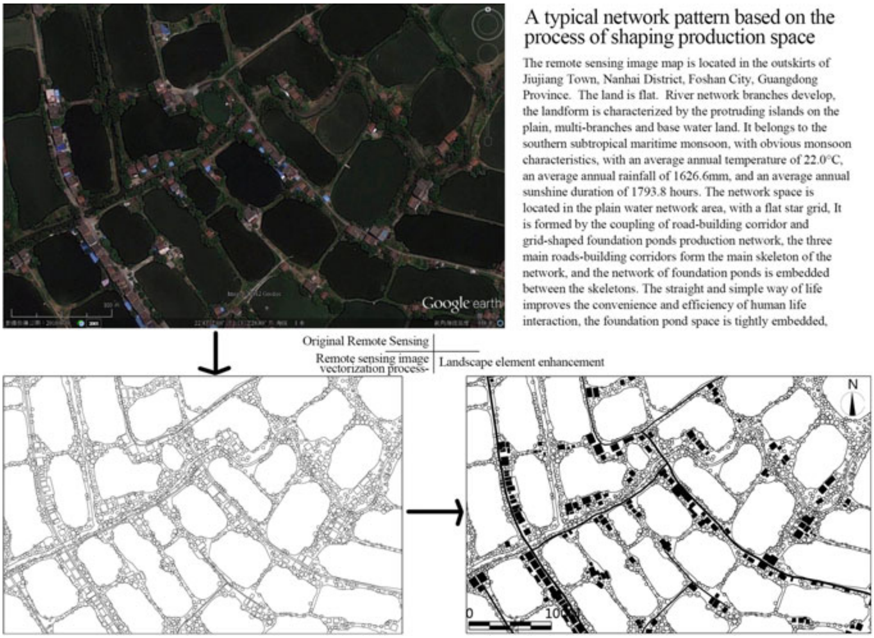


Fig. 5.7 Vectorization and extraction process of a typical pattern

elements, and clarifying the main structure and layout of element based on the characteristics of landscape space combined with the preliminary recognition of formative mechanisms and characteristics of different types of patterns (Fig. 5.7).

5.5.2 *Extraction of Pattern Vocabulary*

5.5.2.1 Pattern Vocabulary and Space Unit

The extraction of pattern vocabulary in form of words, phrases, and simple sentences is realized respectively according to the needs of specific landscape space research. It is necessary to clearly define the pattern in form of word, phrase, and simple sentence of landscape space. In the specific extraction process, the word is meaning expression of the smallest space unit, but the number of it is the largest. It is necessary to clarify the extraction criteria from perspective of improving extraction efficiency and supporting subsequent research, which needs to meet the requirements of spatial form and the diversity of composition. The limitation of this standard depends on influences of the word extraction results on subsequent research, for example, the choice of word of network with too many morphological types has little effect on subsequent analysis of the internal structure of network. The extraction process of word could be controlled from perspective of landscape element categories.

While for the research on composite landscape, the form of word is very important for researches on subsequent phrases and simple sentences, so the selection of word needs to serve the diversity of forms. At the level of word, it is mainly the space formed by the preliminary combination of patterns extracted from landscape elements. It could be classified according to the combination form, type, and the function or method of space combination as well. At the level of phrases, it is mainly the combination of different landscape spaces extracted from the level of words which form simple or complex spatial patterns, and at the level of phrases, it already has a more complex spatial organization relationship.

5.5.2.2 Pattern Expression

In order to clearly express landscape ecological pattern and element relationship of network, all spatial patterns are mapped in black and white, in which vegetation is mainly expressed in circles to reflect the size, density, and texture of plants, and in specific situations with cloud lines, such as large areas of woodland, wetland, and other spaces of vegetation community, settlement spaces are expressed with polylines for overall configuration, water bodies playing an important role in the construction of overall network pattern are expressed with polylines to depict the shoreline, and the secondary water systems are expressed with single lines. It is necessary to ensure that the plane shape of water body and the connection relationship between the primary and secondary water systems are reflected on the whole. Roads are mainly aimed at the direct connections between settlements, which are mapped by the way of combining double lines and single lines and reflected the integrity of roads and their connected settlements on the whole. Farmlands mainly are expressed with single line to represent the boundary reflecting the texture, especially some of which need special expression, such as terraces or ponds, are represented by double line to describe the boundary or pond base.

After the preliminary interpretation of landscape components, the composite spatial nodes are mapped by using polylines to represent its outline, of which the number of each element type is labeled in form of letter and number combination, where A represents a settlement node, W represents a water system node, V represents a vegetation node, and C represents a composite node. In addition, network patterns in mountainous and hilly environments will appropriately supplement contour lines to reflect topographical changes based on needs of spatial expression.

5.5.3 Lexical Analysis and Extraction

According to the afore-mentioned theoretical framework of landscape pattern language, lexical analysis is mainly composed of two parts, in which one is the formative process and the other is spatial relationship. The two parts are interrelated and corresponded to a certain spatial organization and formative mechanism, but the correspondence here is not absolute. The formative process could be analyzed by the ways of induction and deduction. When the research of landscape types has relatively rich procedural analysis results, on this basis, pattern vocabulary can be used to deductively discuss, and the newly acquired mechanism in the process of discussion can be added to the final results. For example, the lexicon of natural landscape in the context of cultural landscape is mostly embodied in the process of network, fragmentation, linear, scattered, and the nucleation. The lexicon of cyberspace in cultural landscape is common in the formative process of star network, cluster network, grid network, ribbon network, and interweaving network, and these processes are common types based on the research results of cultural landscape. The research path of induction is the result of formative mechanism reconstructed by specific analysis of spatial relationship which mainly lies in basic spatial units and aggregated spatial units. Each category could be divided into multiple types according to the analyzed spaces with different patterns.

It needs to be pointed out that the research could adopt different methods of independent analysis or integrated analysis of the two according to actual needs due to the correlation between formative process and spatial relationship. At the same time, when analyzing the formative process, the order of space organization of the two mechanisms analysis could be interchanged due to the different analysis path of induction or deduction.

5.5.4 Syntactic Analysis and Extraction

In the process of constructing the theoretical framework of pattern language, the study puts forward six main syntactic structures of locality, timeliness, scale, order, rhetoric, and amendment. As a syntax, it exerts the overall planning function of words, phrases, and simple sentences. This is universal in different types of landscape spaces, but there are certain differences between the manifestation and overall planning of its influence. For cultural landscape, local and temporal syntax are the basic existence, and scale is also used as the basic syntax. Whether it is the key components of syntactic analysis needs to be determined by the specific conditions of research object. The research needs to analyze and explain the formative mechanism of landscape space from perspectives of multiple scales and single scale when the research object has a complex scaling mechanism. The elaboration of order, rhetoric, and corrective syntax is mainly reflected in the analysis of formative mechanism of landscape space at single scale.

5.5.5 Pattern Language System Construction

According to the spatial characteristics of selected typical pattern, it could be constructed that a system of landscape pattern language fitted the sample spaces correspondingly and completely, which is jointly constructed by the spatial vocabulary, lexicon, and syntax obtained through the above-mentioned pattern vocabulary extraction, morphological analysis, and syntactic analysis steps (Fig. 5.8).

5.6 Research Methodology of Pattern Language

5.6.1 Methodological Framework

According to the research method of landscape pattern language, the methodology of it mainly depends on the essential characteristics of landscape space and overall characteristics of total human ecosystem carried by landscape space (Fig. 5.9). On the whole, the research methodology of landscape pattern language is mainly characterized by integration of scientific theory research, applied research, and practical research and is the ecological practice research under the guidance of scientific theory and ecological wisdom.

The first is research methodology of structuralism and deconstructionism. Landscape space is the carrier of ecosystem, and the systematicness and structure of ecosystem also are consistent with that of landscape space, so did the scale of ecosystem and the scale characteristics of landscape space, as well as the internal transformation of landscape space information between scales. This is the characteristic of total human ecosystem and landscape. On the other hand, the research and cognition of landscape space requires deconstructive thinking and analysis. The internal processes and mechanisms between the parts and components are explored through decomposition of the whole landscape and which could be reorganized and shaped through mastery of these mechanisms and vocabulary. Therefore, structuralism and deconstructionism are the important methodological basis of landscape pattern language.

The second is self-organizing collaboration and logical design methodology. The formation of landscape space is the overall process and result of human–land interaction, and part of which is driven by the self-organized and coordinated process of natural and human ecosystem with horizontal differentiation, stitching, and vertical compounding and nested structure, another part of which is formed under the purpose of human beings based on needs and values of individuals or groups. Therefore, self-organized and collaborative development and logical design are both important methodological foundations for the study of landscape pattern language.

The third is methodology of spatial reasoning. The structure of landscape space and process on horizontal stitching, vertical nesting, and scale transformation are

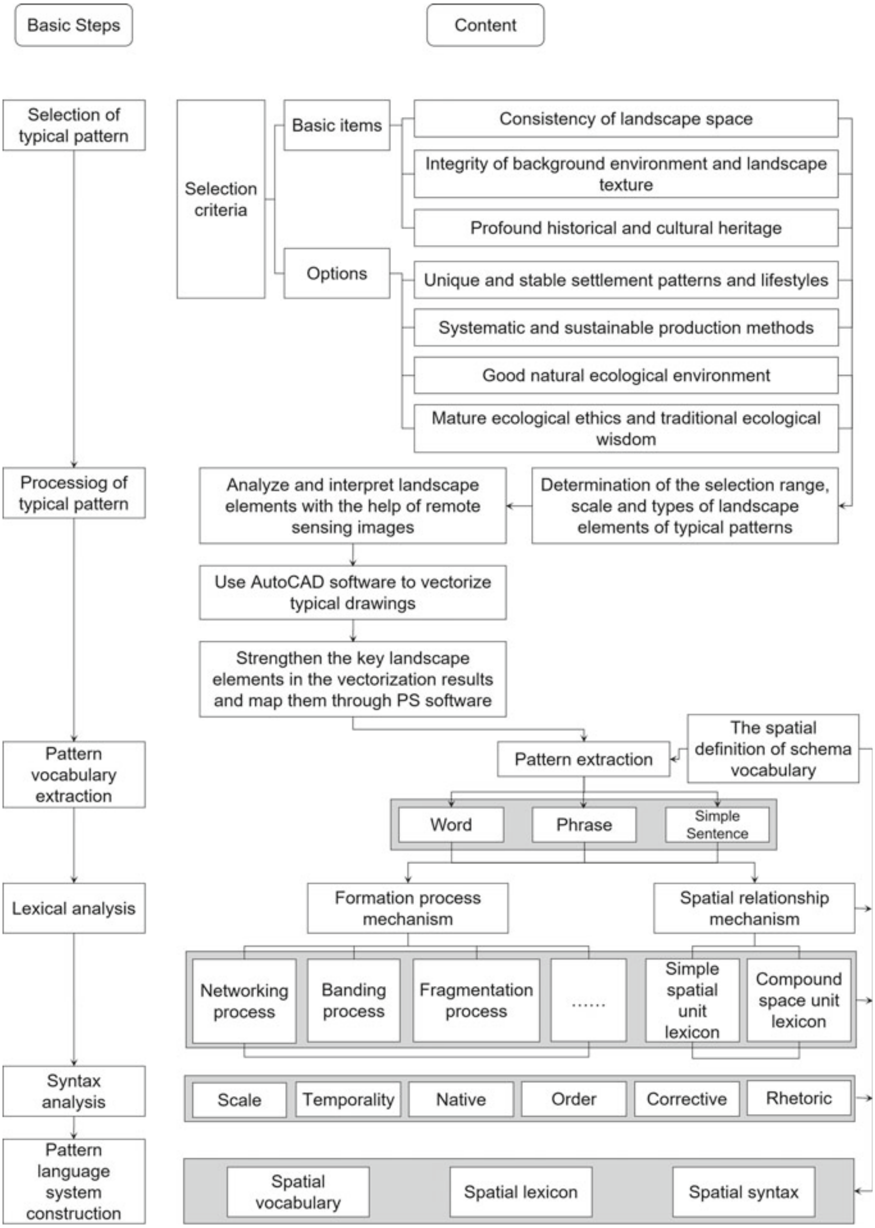


Fig. 5.8 Steps for constructing a pattern language system

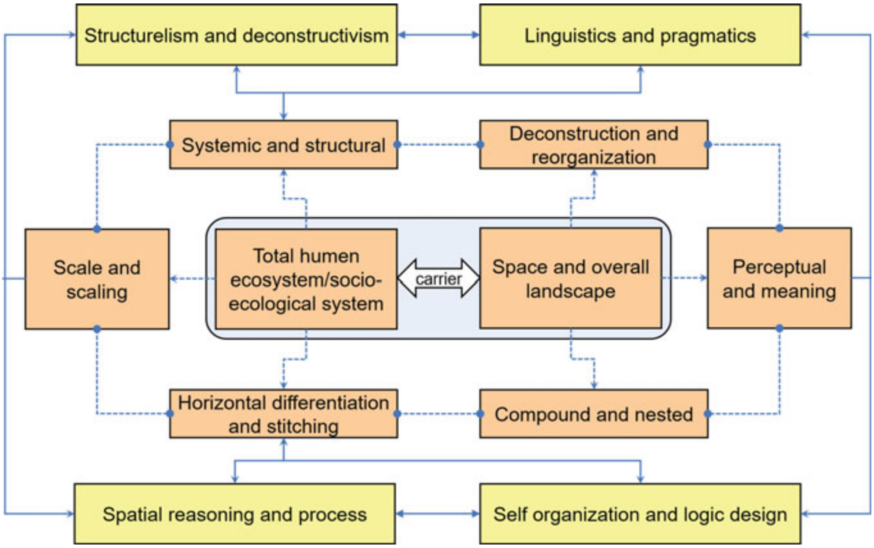


Fig. 5.9 Methodological framework for the study of landscape pattern language

all internal processes of landscape space which have strong regularity and objectivity. The interrelationships and logics of landscape space determined by ecological process often show mutual relations and regularity, which provides an important methodological basis for the research of spatial logics and reasoning of landscape space.

The fourth is methodology of linguistics and pragmatics research. The internality, spatiality, designability, and nested structure of ecosystem determine the characteristics of landscape space and also determine the structure of landscape pattern language. The ideography of landscape also determines the ideography and function of pattern language. Therefore, the structure, nesting and semantics of linguistics have become the important basis for the study of landscape pattern language. In addition to the diversity of ecosystem and the contextualization of landscape, pragmatics provides a methodology basis for the study of landscape pattern language.

5.6.2 Structuralism and Deconstructionism

In 1922, an Austrian philosopher Ludwig Wittgenstein proposed in *Tractatus Logico-Philosophicus* that the world is an integrity composed of many *'states'*, and each *'state'* is a chain composed of many things and exists with the certain relationship which is the right structure of the *'state'*, the object of our research and also the first theory of structuralism currently known. In 1945, a French anthropologist Claude Levi Strauss regarded social and cultural phenomena as an expression of deep structural system and through which people could organize the world. It was found that many important disciplines had established a close relationship with the theory of structuralism which had made a big step in advance and developed deeply by the 1960s. Structuralism is also an important theoretical basis for the systematic approach, of which the connotation determines that the whole is of priority and importance to the part in spatial logic. And its synchronicity shows that the relationships among various elements within system are not only interrelated but also coexisted at the same time.

The philosophical origin of deconstructionism could be traced back to 1967, the philosopher Jacque Derrida (1930–2004) put forward the theory of deconstructionism based on criticism of structuralism in linguistics. He believed that the symbols of linguistics could reflect the reality, and the study of individual is more important than the study of overall structure. The concept of deconstruction means the decomposition process, which emphasizes to break, superimpose, reorganize, and create a new incomplete whole through individual and partial research. Landscape space is a system with highly systematic and structural integrity, in which landscape space is a polymer under the theory of spatial structuralism from the process of landscape components, basic units, composite units, and complex units to total landscape.

The logic of landscape pattern language is the process of applying landscape vocabulary and spatial logic to shape the whole landscape space based on the theory of structuralism. But on the other hand, the built landscapes around us are always considered as the holistic landscape, behind which how to understand and analyze the systematic process has become an important support for studying and dissecting the holistic landscape effectively and accurately. It is necessary for the study of landscape to dissect and decompose the holistic landscape, which requires deconstructionism theories and thinking methods to implement the unitization process and landscape analysis, and the right path to obtain the accumulation of pattern vocabulary and spatial logic. Therefore, the structuralism and deconstructionism have become an important methodological basis for the theoretical system and method of landscape pattern language.

5.6.3 Self-organized Synergetic Theory and Logical Design

How does a system automatically change from disorder to order and from low level of order to high level of order under certain conditions? The question can be answered with the theory of self-organized synergy through revealing the synergetic mechanism among various elements in system, which is the basis of self-organization process, and is the direct source of new structure through competition and coordination between parameters in system. Fluctuations are the result of independent movement of systematic elements or various coordinated movements locally, as well as random interference of environmental factors, which are measured by deviation extent reflecting the actual value of system deviating from the average value. When a system transfers from one stable state to another state and the independent movement and coordinated movement among system elements reach the stage of equilibrium, any small fluctuations would be quickly amplified into a huge fluctuation which affects the entire system and drives the system into the state in order.

The formative and evolutionary processes of landscape space have certain characteristics of self-organization, which exist and evolve naturally, and especially in the built landscape, which is artificially built but isolated and spontaneous. The diversified landscape units are influenced and conditioned each other during the formation of holistic landscape and finally are created to be famous landscapes, such as living landscape. The type of landscape is formed under the expected design logic, but some landscape spaces are formed in the context of overall planning and design. Whether it is a landscape formed completely in the process of self-organization or a landscape formed in a logical design, it would be affected by environmental factors, landscape elements, and users' intentions in the formative process of landscape and the evolutionary process of self-adaptability, which shows a co-evolutionary process of self-organization. The goal is to extract and summarize the high-quality and efficient spaces with highly self-organization and co-evolution through the processes of cognition, analysis, evaluation, and pattern abstraction of landscape space, which are the results of self-adaptation, optimization, and coordination of landscape spaces and are the important methodological basis for evolution and adjustment of vocabulary and logic of landscape pattern language.

5.6.4 Spatial Formative Process and Reasoning

The formation and evolution of landscape space are the process of space generation, among which in the natural world some are the inevitable results of interactions among all natural factors, such as topography, hydrology, light, wind, temperature, soil, plants, animals, but some are the accidental results based on a stable relationship due to accidental reasons in natural environment. Whether it is an inevitable result under a stable relationship or an accidental result under a disturbance factor, the characteristic of inevitability is existed definitely in the process of landscape space formation and evolution from the perspective of occurrence. The appearance of man-made landscape is artificial space designed and created by designers with manifestations of their subjective wills; on the contrary, landscape design is to shape the products catering to social needs because of the attribute of sociality of designer's values in a specific social environment, so the inevitability of landscape space generation in a period could correspond to the period, which is the result of natural and social laws in landscape environment and reflects the basic characteristics of cognition, evaluation, and utilization of landscape space.

At the same time, the inevitability or relevance is existed in spatial units with structure, function, expression in the process of mutual connection. Basic supports are provided for the study of spatial logic by the relevance between spaces in landscape pattern language, in which spatial reasoning is a method of spatial logic research based on spatial relevance, such as structure or function. A series of spatial reasoning and relationship models could be established by summarizing and refining association process and logic of existing landscape space. Spatial reasoning is an effective method to carry out the research on spatial mechanism and relationship of landscape pattern language and provide the basic methods and ideas for the establishment of spatial lexical, syntactic, and grammatical system and to be an important methodological basis of landscape pattern language.

5.6.5 Multiple Meanings and Pragmatics of Landscape

Landscape not only has the structure and organization of language, but also has the special meaning and cultural value which human endowed to landscape. The values of natural landscape and meaning expressed to the natural world are reflected systematically through the habitat richness, burgeoning species, equivalent competition and survival of the fittest, and biodiversity, dynamic changes, beautiful scenery as well as the food chain. Cultural landscape is more dependent on values and meanings of landscape, in which artificial landscape is a type of landscape driven by cultural values, and its basic functions and roles are showing the values and meanings. Landscape meaning is also multiplied and would be different and deviate from the original values of landscape itself according to the changes of context, tone, time, and space.

Pragmatics studies landscape words in a specific context, and the way to understand and use language through the context. The speaker often does not simply express the static meaning of words in the use of language; the listener usually needs to understand the actual intention of the speaker through a series of psychological inferences. It is far from enough to understand the pronunciation, vocabulary, and grammar which make up the language in order to truly understand and use it properly. Landscape pattern language is a system with words, phrases, and simple sentences corresponding directly to different types of high-quality spaces which include the basic units, aggregated units, and holistic units. On the basis of attributes, structure, form, and function of space unit, a pattern generally expresses a certain meaning and plays a basic function of language acting as a vocabulary; therefore, landscape pattern language has an accurate function under the conditions of landscape construction environment, scale, and custom. Thus, the research method of pragmatics is the basic theory and methodological foundation for studying the structure, function, and meaning of landscape pattern language.

The process of landscape planning and design is to help people who live in natural system or use limited resources in a system to find the most suitable way of life and production (McHarg 1969). Landscape pattern language is also one of them to explore this approach just like other theories and methods. Landscape pattern language is a practical tool for the study and application of local expression of landscape and spatial reasoning judging from the existing engineering practice and teaching of ecological planning and design, which incorporates the professional advantages of geography for cognizing the environment and those of landscape architecture for expression the environment and assimilates inspirations from the theories and methods of language, architecture, art, environmental science, anthropology, ecology, and other disciplines. Therefore, the research method of pattern language must also be a synthesis of multi-disciplinary research methods.

It is necessary to explore the research of methodology and the research of scientificity, practicalness, and effectiveness of landscape pattern language on the theoretical and ideological basis. The methodology research of pattern language mainly provides basic ideas for the study of pattern language to deal with the phenomena, problems, and processes of landscape based on system science, linguistics and logistics, pattern, and modularization.

The research methods of landscape pattern language, such as the method of space prototype, typical samples, induction, analysis, and evaluation, still rely on the qualitative research of landscape space, focusing on logical thinking and practical verification and design application. Although it has been carried out to evaluate quantitatively on performance of landscape pattern language to some extent, it is necessary to be reformed and expanded for further research methods compared with the effectiveness verification research of pattern vocabulary. In particular, it would be a major revolution in the research of landscape pattern language through conducting research on efficiency and constructing landscape space system with efficient service according to ecosystem services or landscape services.

5.7 Practice Application and Verification

5.7.1 Representation of Ecological Space of Landscape

It requires a real language to guide and constitute the basic paradigm and framework of ecological design in landscape ecological practice, which include basically landscape elements, space units, basic combinations, spatial patterns, and ecological processes. Spatial patterns, such as patterns of natural landscape, patterns of cultural landscape, and patterns of ecological network, are connected into a holistic, complete, and dynamic landscape through ecological flows and processes working as the internal connections. Among them, it has formed five landscape aspects to interpret and reveal landscape pattern language of traditional and regional cultural landscape, which include the pattern of architecture and settlement, texture of land use, method of water utilization, culture of local community, and traditional dwelling. Professor Wang, the author of the book, discussed local ways of landscape garden design and total human ecosystem design through the planning and design of *Jiangnan Ecological Park* (Wang et al. 2009). The study of landscape pattern language has formed a systematic framework from theory to practice through nearly 10 years of continuous research.

Firstly, the methods and technical specifications of research had been initially established, which mainly include the classification of landscape space, division of spatial scales, selection criteria of typical spaces, mapping standards of typical patterns, description parameters of patterns, and ecological effects evaluation of pattern and formed a standardized method and technology for the study of landscape pattern language.

Secondly, a system of traditional pattern vocabulary of cultural landscape has been established openly, which mainly includes the pattern vocabularies of water habitats, ecological interface at small and mesoscale, landscape ecological network, land form, public open space in village and town, landscape axis of traditional village, and semi-natural landscape spaces and accumulates pattern vocabularies with 862 words, 743 phrases, and 409 simple sentences in totality related to these 7 typical spaces.

Thirdly, spatial logic and syntax of landscape pattern language and grammatical system have been initially established, which include the logical relationship of landscape space at single scale and multiple scales, and established 10 types of syntax and 6 types of grammar with the horizontal and vertical spatial dimensions at single scale and multiple scales, respectively.

Fourthly, a platform of practical application and verification of pattern language has been initially established, which mainly includes water environment landscape, ecological interface, ecological network, land form and productive landscape, open space in village, landscape axis, and other applications of landscape pattern language in planning and design. The multi-scale research on landscape pattern language of Northern Shaanxi highlights the local landscape vocabulary and application. The locality and particularity of landscape pattern language are particularly critical for the development of landscape architecture, and it had become an important cornerstone for the application and verification of pattern language theory. For example, as a representative landscape of neo-Chinese style in the south of Yangtze River, and the success of Suzhou Museum design lies in the organic combination of design vocabulary and language of Suzhou classical gardens with modern design technology, materials, and design language.

Fifthly, landscape pattern language is not only applied in ecological practice, but also applied in teaching landscape planning and design in college to establish a teaching system with clear knowledge points which direct the students to form their own design language.

5.7.2 Representation of Landscape Space Types

Lots of verifications had been carried out to apply the theory of landscape pattern language by the research team corresponding to different landscape spaces, such as pattern language of water habitat, interface at mesoscale and microscale, landscape network, land form, semi-natural landscape, public open space in traditional village, and landscape axis of traditional village. The theory of landscape pattern language also provided a correction approach to improve the systematic completeness through practical verification and is further extended to all types of landscape spaces. For example, the theory was used in the design practice research of Suzhou classical gardens and its pattern language researches (Hu and Wang 2015; Wang and Wang 2015) were carried out, which were essentially of great exploratory significance for landscape gardens planning and design with high degree of conformity to the characteristics of Suzhou local culture.

The exquisiteness of Suzhou classical gardens is embodied in the cognition of infinite extension and expansion endowed with limited space. The garden builders combined various elements of landscape, sometimes with waterbodies and sometimes with imitative mountains, of which spatial forms are ever-changing. The common types of space in Suzhou classical gardens include the courtyard enclosed with architectures, space of rockery, combination space with courtyard and corridor, space enclosed greening, space of waterbody and imitative mountain, and so on. The research classified landscape spaces based on spatial components in order to comb clearly the system of landscape pattern language.

The architectural spaces are mainly composed of buildings in Suzhou classical gardens in which architecture is the most critical elements of space, and the basic outline of space could be formed through the relations of connection, separation, and combination of garden buildings. The aggregated space with rockery and water is composed mainly of rocks and waterbodies, of which the pattern is the basic framework of classical gardens and difficult to form a garden without waterbody, as well as the supporting and controlling elements of classical gardens. The imitative mountain is the essence of stacking stones and combing waterbody in classical garden, which is the imitation of natural mountains. The space enclosed with greening is composed mainly of plants which act on the role of separation and connection among spaces of classical garden and could be used as green barriers and green bridges. There are other spaces including the space composed mainly of paving and other elements, which are the non-dominant space and auxiliary spaces combined to others.

The space of classical garden is a highly fusion landscape with the combination of human spirit and natural landscape which imitate the section of natural spaces aggregated with imitative mountain and waterbodies and also is a highly condensed and abstract space of cultural landscape created artificially with the comprehensive characteristics of strong value orientation of literati and intention of interests. Therefore, landscape pattern language of Suzhou classical gardens has been formed their own unique vocabulary, syntax, and grammatical relationships of garden design.

There are various spaces of architecture, greening, and combinations with imitative mountain and waterbody in Suzhou classical gardens with big changes of scale and obvious differences, rich elements, and forms of spatial combination and various design vocabulary of words, phrases, and simple sentences composing the system of landscape pattern language which is also richer and changeable. It could create different landscape spaces and their effects with subtle changes of classical gardens, and design vocabulary of landscape pattern language would be more and more abundant in actual situations.

It is the various combinations, diverse combination methods of landscape elements, and complicated spatial relationship in the construction of Suzhou classical gardens that form a diversified syntax and grammar system of landscape pattern language and various aggregated landscape spaces with the relations of spatial combination, modes, and spatial sequences and create lots of scenic spots and gardens with unique features due to differentiated applications.

It is the diverse spatial edges between landscape spaces, transitional spaces and combinations due to limited space, various types, and big changes of landscape spaces that make landscape pattern language of classical gardens more abundant in Suzhou classical gardens which were built in a specific historical period and experienced a long time of refinement and development and formed a relatively stable style and characteristics. It had formed the stable system of design vocabulary, syntax, and grammar and formed a stable and representative mode of space combination and construction method. Therefore, landscape pattern language of Suzhou classical gardens is a stable and integrated system which provides the complete vocabulary and logic for the design of classical gardens.

5.8 Teaching Application and Verification

5.8.1 Thoughts of Teaching

It had played a critical role in landscape pattern teaching thoughts of Simon Bell through long-term researches, practices, and teaching experiences of ecological planning and design, which were fully reflected in his series of works. He raised four big questions of landscape architecture in the book *Landscape: Pattern, Perception and Process*.

Firstly, it is an important way through landscape planning and design to achieve the international, national, regional, and local levels of contracts, plans, regulations, and guidelines in global sustainable development and environmental protection based on understanding of landscape patterns and processes.

Secondly, it should be noticed that encouraging local experts who understand local landscape pattern and process well participate actively in the process of decision-making in community.

Thirdly, design vocabularies such as landscape pattern, cognition, and process are the common media of landscape architecture and environmental disciplines in landscape architecture research, planning, design, and management.

Fourthly, the methods of landscape pattern, cognition, and process are widely used in different environments and cater to the needs of landscape environment, scale, resources, and policies of the nation and local government through adjustment and adaptation.

Simon Bell proposed three important visions in 1999 for the development of landscape architecture education by the year of 2020 and reflected his teaching thoughts of landscape architecture. Landscape pattern and process would become the common vocabulary of industrial and technical experts in the field of land research, and the language of pattern and process would become an important part of professional teaching in all landscape architecture colleges. It could supplement and improve the reading, writing, and arithmetic skills in language learning and application through pattern language teaching on landscape pattern, perception, and process.

Annie W. Spirn carried out the researches, practices, and teaching experiences of landscape language integrating nature and human ecology based on her major of art history and accumulation of experiences in ecoplanning and design in Wallace, McHarg, Roberts and Todd's Studio, whose teaching thoughts of landscape language is fully reflected in her rich and influential works. She proposed the thematic idea of urban nature and the design of cities based on natural processes in the book *The Granite Garden: Urban Nature and Human Design*, as a development of this idea, it had further been expanded and put forward from landscape language to *'Landscape is a language'* with its own grammatical laws and rhetoric system. It was believed that if the language could not be learned and applied correctly, it would cause huge damage to human living environment. Landscape is a language of dialog between man and nature with functions of reading, understanding, expression, and meaning of language.

The composition of landscape language is complete, which includes the unit, sequence, and environment of landscape. The meaning of *'Land'* refers to the place where people live in, so the language of landscape is the dynamic system connecting the place and people living in together. Landscape unit is composed of landscape elements, independent spatial units, and the combinations formed by these basic spatial units, which is the basic composition and source of landscape vocabulary. Landscape elements mainly include natural elements such as topography, landform, soil, water, rocks, plants, animals, and celestial phenomena, as well as human elements such as buildings, labor, people, structures, activities, local language, and cultural landscapes. Various elements are combined into basic spatial units according to specific processes and relationships and compounded into a basic landscape pattern.

Landscape sequence is the spatial orders of landscape unit organization and the important means of expression in landscape grammar. It is the lack of spatial orders or the conflict of multiple orders that cause chaos and unharmonious in spatial organization of landscape. Landscape sequence was formed with landscape units through complex combination, of which the complexity but disorder is always confusing and the order but singularity is sometimes boring.

Landscape environment shapes the contextual relationship of landscape language and affects the organization of landscape space, which is also the important components of landscape grammar. The relationship between landscape and environment is prominently reflected in basic landscape compositions, such as trees, rivers, clouds, birds, mountains, buildings, and people. The dialog between people and environment with landscape as a link is reflected in the locality of landscape elements and the maintenance of local spatial structure. There are many contextual relationships in landscape environment, either interacting or independent, closely or loosely connected, or even not connected. These complex relationships could be integrated, paralleled to each other, or superimposed on each other.

Landscape pattern language is a symbol system using pattern as a material form and is composed of vocabulary and grammar to satisfy specific functions and express landscape semantics. Landscape grammar is a rule arranging all landscape elements to express various meanings, mainly including scale and tense, transformation and inheritance, and continuation and innovation of laws. People sometimes abide by certain rules, and sometimes they break the rules and create new grammars which make man-made landscapes interesting and complex. Landscape grammar itself could not be identified as right or wrong, it is just sometimes misunderstood and misused. Landscape pattern language has the most unique rhetoric and design skills and has worked as an important theory and method for landscape shaping.

5.8.2 Features and Inspirations of Teaching

The teaching of landscape practice based on pattern language is a process of integration of prototype, model, and pattern, in which it reflects the organic and systematic characteristics among design vocabulary, context, and landscape. Nested structure in space is inherently consistent with the ecological process.

Deep experience and perception are important ways to learn and understand landscape pattern and landscape language. There are two addresses that Simon Bell emphasized the perception of landscape space, and Anne Spirn emphasized the deep reading and understanding of landscape, which are essentially the same and both emphasize the context, logic, and language of landscape, as well as highlight the harmonious environment, suitable users, and fitting landscapes in the process of landscape experience and perception. Anne Spirn encouraged designer to stand at the standpoint of users who participate extensively, combine with the narrative characteristics of landscape, and form an integrated design.

The changes in landscape environment must be adapted through landscape planning and design because of environmental adaptability of landscape pattern or landscape language and apply creatively the mastered design vocabulary and landscape language. It mainly includes the teaching of basic pattern principles, linguistic principles, vocabulary recognition, perception and writing, and the teaching of process, grammar, rules, and pragmatics, as well as landscape language weaving and environmental shaping in the modules of landscape pattern language teaching designed by Simon Bell and Anne Spirn.

5.8.3 Application and Practice of Teaching

5.8.3.1 Pattern Language as a Medium to Teach

Landscape pattern language is a system which expresses relatively and clearly the characteristics and patterns of space and use a graphical system of language to describe the process of ecological planning and design, as well as engineering practice. It uses images including prototype and model diagrams to help students grasp more intuitively and clearly the basic compositions, characteristics, forms, and functions of ecological landscape, as well as compositions and combinations of these characteristics in graphics through teaching pattern language as a medium in landscape ecology, which is one of the foundation and core ability training of landscape ecological practice. After studying landscape pattern of Simon Bell and landscape language teaching system of Anne Spirn, it has been experimented in department of landscape architecture of Tongji University with the teaching of landscape pattern language in the course of landscape ecology as a pilot of ecological courses construction since 2010, which taught ecological space as the key point with the orientation of ecological practice. The teaching combined landscape pattern and landscape language into one to form a practice-oriented teaching system of landscape ecological pattern language.

5.8.3.2 Basic Principles and Structure of Teaching

Landscape pattern language is composed of universal basic patterns, unique patterns under special circumstances, basic combination patterns, and complex combination pattern, which forms a spatial combination to meet a specific function or functional group under the control of spatial law and process and expresses the unique human spirit or landscape meaning. Landscape pattern language has formed a basic vocabulary system based on the composition and combination of ecological space patterns and a grammar system based on the rules of natural ecological process and human ecological process. It satisfies the needs of landscape function through duplication, transformation, and adaptation of landscape pattern, reflects the internal process of landscape design, express design ideas, and fully display humanistic spirit of landscape. It could form the basic knowledge and skills of reading, comprehension, practice, and creation with the teaching of basic principles and compositions of landscape pattern language.

5.8.3.3 Recognition, Perception, Illustration, and Expression

The identification of typical ecological spaces is a compulsory link which must be carried out in teaching of ecological spaces, a transition link of teaching from theory to practice, and a bridge of teaching from concept to mapping in landscape ecological design. Four procedures here are the standard formulation and selection of typical ecological spaces, the changes of typical space scale from whole to part and its ecological cognition, the analysis of ecological space pattern and cognition of combination features, and the extraction of spatial elements and their combination modes. Students can be guided to correctly understand the basic laws and techniques of ecological space and skills of planning and design through these processes and skills training. Graphical methods are used to illustrate the spatial composition, scale nested and combination relations of ecological spaces, and grasp the best way to express landscape with illustration on the basis of ecological approach to cognition.

5.8.3.4 Vocabulary Collection, Process, and Coupling

The module of ecological design includes four basic links of landscape context, basic compositions, pattern language, and ecological process, which are the background, main points, paradigm, and basis of ecological design. The teaching of basic pattern is classified as that of natural and cultural units and as source of space aggregation with basic units in ecological design. The teaching of aggregated pattern studies the process of combination and their pattern effects of ecospaces at multiple scales in landscape ecological design. Three types of space must be coordinated and unified in spatial organization to balance the relations among residential, yielding, and ecological space in planning and design of people-centered landscape. Three basic units of space are combined in different structures and ways to form a spatial pattern which is both diverse and complete corresponding to spatial scales and on which it would be the best way of teaching with space classifications and their combinations.

5.8.3.5 Application and Optimization

The teaching of pattern language application is firstly to find the prototype of pattern vocabulary to match the context of site, of which the environmental characteristics, evolution process, human spirit, shaping goals, functional requirements, landscape scenarios are all the prerequisites for determining the application of vocabulary. The second is to teach the mechanisms and approaches of coupling and matching between ecological process in site and design process of site. The third is to teach the integrating process and matching pattern vocabulary with aggregated space of landscape. These matches are the key procedures of the application of landscape pattern vocabulary.

Pattern vocabulary can be accumulated in various context, the rationality of pattern and pattern structure are also changing as time goes by, and the application of pattern vocabulary involves environmental adaptation and design optimization, which include the changeability of landscape environment and their processes, the adaptation of pattern applications to technical changes, pattern suitability and optimization, pattern vocabulary at single scale, and adaptation and optimization at multiple scales.

The patternized and verbalized system and teaching practice of Simon Bell and Anne Spirn provide the alternative practice-oriented and diversified approaches to teaching optimization for theoretical system and teaching research of landscape architecture, which need to be improved in China and mainly reflected as followings:

The teaching of landscape ecological practice lacks design principles of *'Ecology Roots'*, as well as theoretical research and teaching research on vocabulary of design, which are actually empirical knowledge or borrowing theories from other disciplines from a perspective of domestic situation. Rather than a system of independent principles and methods established as a discipline goal of landscape architecture, it is landscape pattern language that build the theoretical and methodological system of knowledge, understanding, adaptation, and application of landscape ecological planning and design.

The teaching achievements of landscape architecture are normally expressed with graphics, which integrate theoretical systems, technical training, approach analysis, and multiple goals together. Graphics are the comprehensive expressions and would become an important way of learning. It would be useful for designers to integrate the real graphic of landscape with the designed graphic starting with landscape graphics to interpret, analyze and understand landscape pattern, and master the laws and mechanisms of sustainable landscape beyond landscape graphic from a perspective of design teaching.

Landscape pattern has been developed from a traditional tool to a system of design language, which helps students to master relevant theories and strengthen the connection and application of practice. It was noticed that some key issues need to be further explored from the teaching experience in Tongji University. For example, it has become the biggest obstacle to read, resolve the graphics, and also the biggest bottleneck in application of pattern language because of the lack of knowledge about natural and human processes behind landscape graphic for students majored in landscape architecture. It is easy to grasp the application of pattern vocabulary at single scale, while it is more difficult because of the nested and coupling process of landscape at multiple scales.

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Chapter 6
Vocabulary of Landscape Pattern Language

6.1 Ecological Interface at Micro–mesoscale

6.1.1 Basic Patterns

6.1.1.1 Basic Types

Ecological interfaces at small and medium scale could be classified into four categories of interfaces between waterbody and terrestrial flatland, terrestrial flatland and flatland, waterbody and sloping land, and terrestrial sloping land and sloping land.

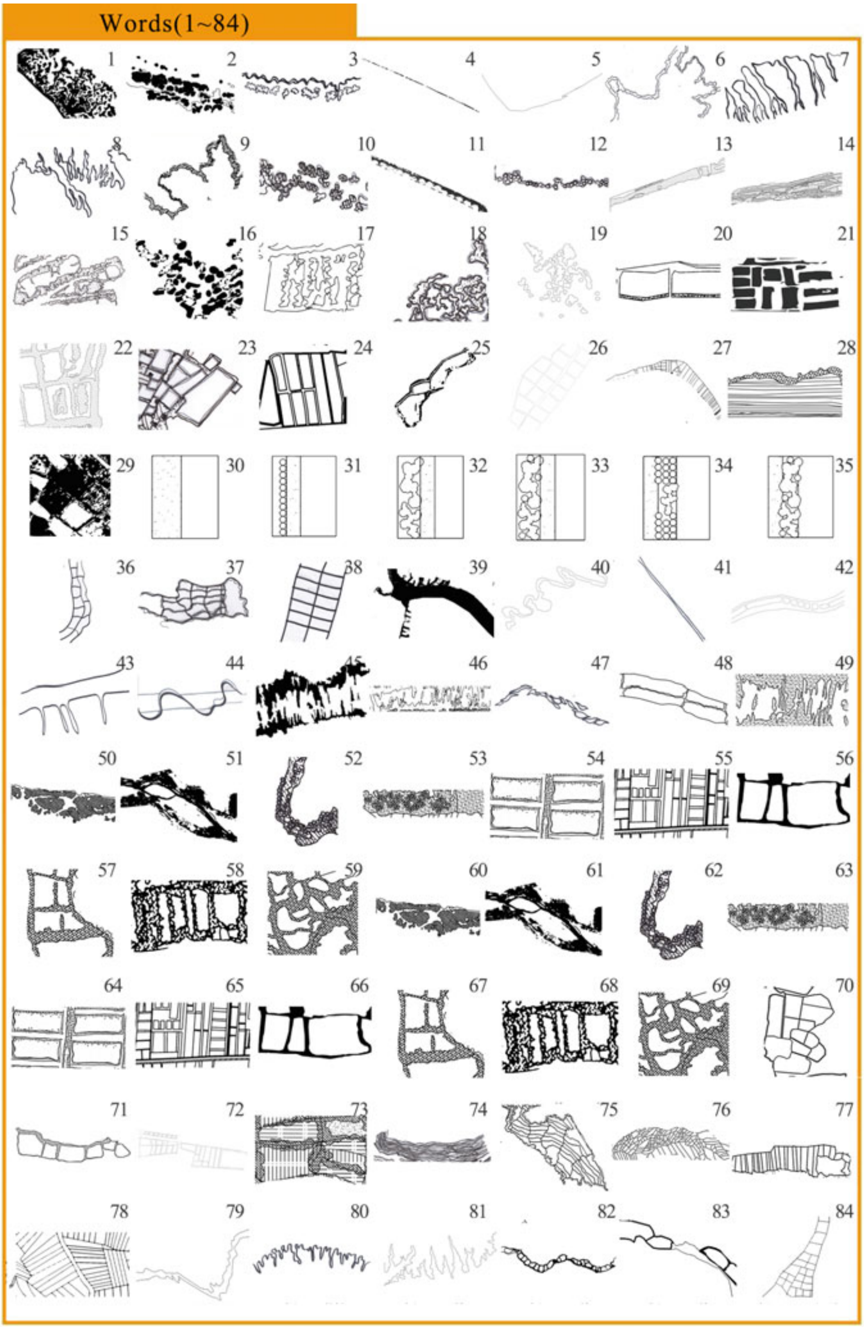
For the interface between waterbody and terrestrial flatland, there are 36 patterns numbered from 1 to 36 as *'words'* considering three basic elements of plain shape, internal texture and standardized form, and 18 patterns numbered from 118 to 135 as *'phrases'* in four types with the features of fragmentation, linear extension, finger-like, and grid transformation (Fig. 6.1).

For the interface between terrestrial flatland and flatland, there are 33 patterns numbered from 36 to 69 as *'words'* with two basic elements of plain shape and internal texture, and 15 patterns numbered from 136 to 150 as *'phrases'* in three types with elements of linear extension, fragmentation, and grid transformation. (Fig. 6.1).

For the interface between sloping land and waterbody, there are 18 patterns numbered from 70 to 87 as '*words'* with two basic elements of graphic form and internal texture, and 9 patterns numbered from 151 to 159 as *'phrases'*, in three types with elements of linear extension, grid transformation, and finger-like (Fig. 6.1).

For the interface between terrestrial flatland and sloping land, there are 30 patterns numbered from 88 to 117 as *'words'* with two basic elements of graphic form and internal texture, and 12 patterns numbered from 160 to 171 as *'phrases'* in three types with elements of linear extension, grid transformation, and finger-like (Fig. 6.1).

Y. Wang, *Landscape Pattern Language*, EcoWISE,
https://doi.org/10.1007/978-981-19-6430-5_6


Words(1~84)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84

◀**Fig. 6.1** Pattern vocabulary of mesoscale ecological interface. 1~3 Fragmented, 4~6 Linear, 7~9 Finger-like, 10~21 Inner texture: revetment, 22~27 Inner texture: pond, 28~30 Internal texture: natural vegetation, 31~36 Standardized form, 37~39 Grid type, 40~45 Linear planar form, 46~48 Broken type, 49~54 Inner texture: vegetation, 55~63 Inner texture: fishery pond, 64~69 Inner texture: field, 70~72 Linear type, 73~75 Grid type, 76~78 Inner texture: pond, 79~81 Inner texture: vegetation, 82~84 Inner texture: field, 85~87 Inner texture: waterfront, 88~93 Finger-like, 94~99 Gentle finger-like, 100~102 Grid finger-like, 103~108 Inner texture: natural vegetation, 109~117 Inner Texture: field, 118~123 Fragmentation type, 124~129 Linear type, 130~132 Finger-like, 133~135 Grid type, 136~138 Linear type, 139~144 Fragmentation type, 145~150 Grid type, 151~156 Linear type, 157~159 Finger-like, 160~162 Linear type, 163~165 Grid type, 166~171 Finger-like, 172~177 Living and ecological space combination, 178~183 Living and production space combination, 184~192 Ecological and production space combination, 193~198 Ecological, living, and production space combination

6.1.1.2 Characteristics and Laws of Basic Pattern

The standardized forms of the interface between waterbody and terrestrial flatland have the feature of gentle slope and integration of terrestrial land and waterbody with the saturated soils, good conditions of eco-environment, and rich vegetation species which often consist of grasslands, shrubs, trees, wetland plants, and own diverse landscape types. The internal texture of interface is generally composed of four types of elements which are natural vegetation, ponds, fields, and revetment. The form of fragmented interface with irregular land texture is greatly affected by the impact of external forces, which could be subdivided into the interfaces of punctate fragmentation and banding fragmentation. The representation of punctate fragmentation is generally the dense forest land composed of hard waterfront or trees, most of which are offshore and occupy a small area. The representation of banding fragmentation is mostly wetlands along the entire banks of rivers and lakes generally with large area and irregular edges. The linear interface has a relatively stable shape with single land texture and is less affected by external forces. The shape of the finger-like interface is formed by natural factors such as wind, landform, and topography. The finger-like interfaces with wide openings are mostly residential living spaces, farmlands, and woodlands. The finger-like interfaces with narrow openings are mostly composed of shrub, wetlands, and grass wetlands. The wetlands gradually evolve into closed and stable wetlands with the process of the narrow openings shrinking. Grid transformation interfaces are mostly production spaces with regular shapes, such as artificial ponds, fishery ponds, or fields of solar salt.

The internal texture of interface between terrestrial flatland and flatland is generally composed of three types of elements which are natural vegetation, ponds, and cultivated lands. The broken interface is generally composed of river and homogeneous adjacent systems beside fields or forests with fragmented land texture. The small patches gradually appeared and scattered unevenly in the central waterbody with the washing and erosion to homogeneous systems on both sides. The linear interface is divided into productive and ecological types, of which the productive type is generally composed of farmland and economic shelter forest belt, while the

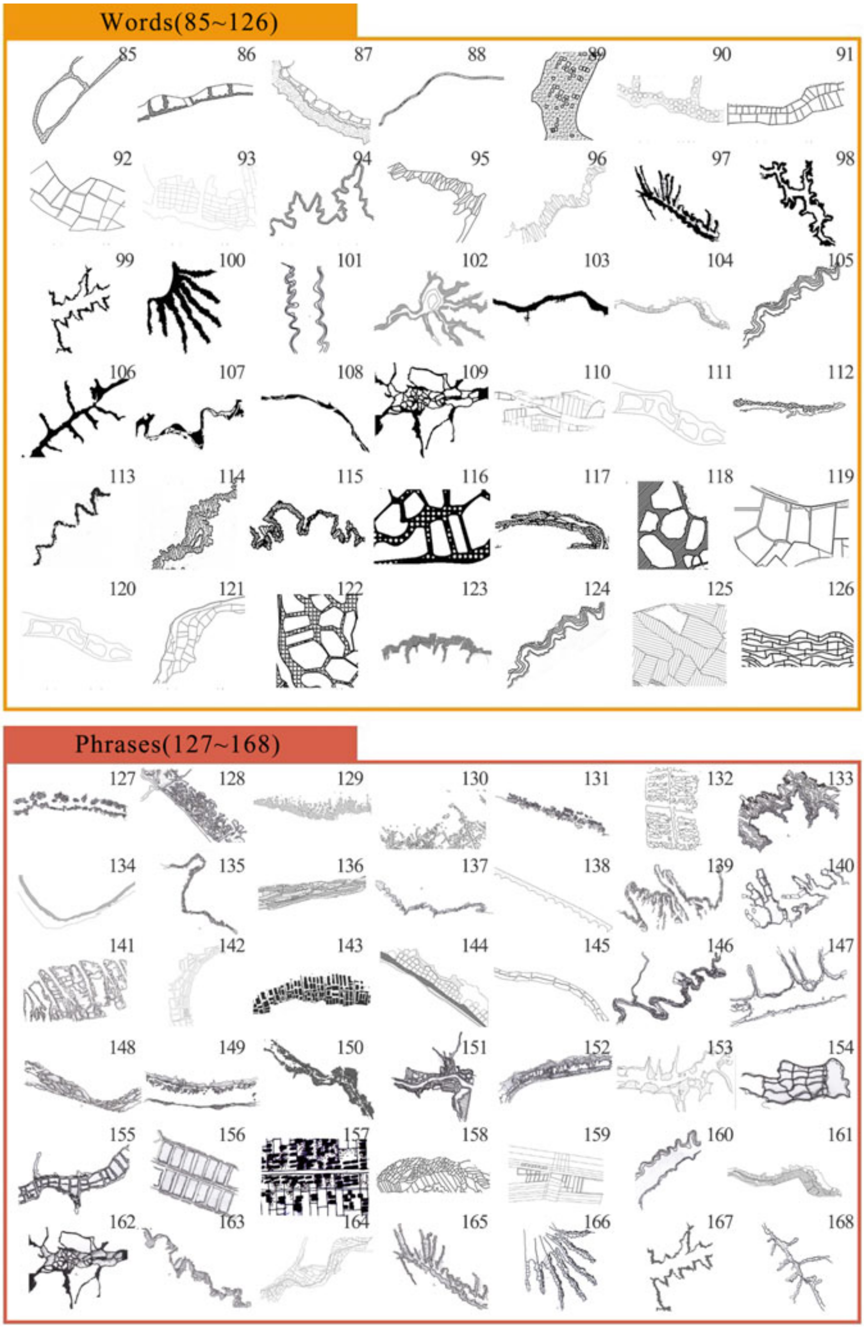


Fig. 6.1 (continued)

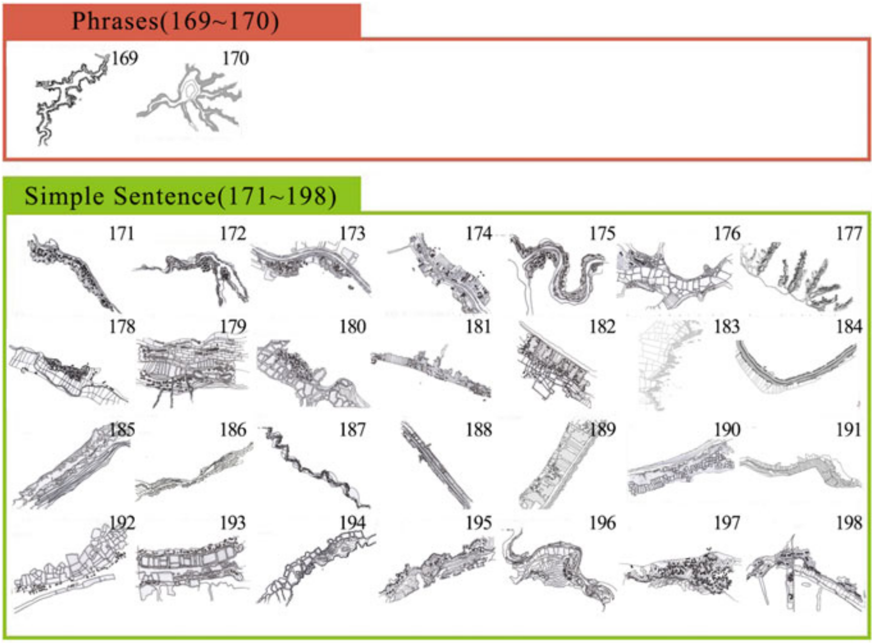


Fig. 6.1 (continued)

ecological type is composed of trees and shrubs along the river. The grid interface is mostly composed of farmland or artificial fishery ponds, while few residential buildings are regularly distributed in the grid. Farmland and fishery ponds are divided into regular and organic types, of which the regular type is tightly arranged in a square shape with the dike-pond covered by low shrubs, and the organic type has a small area with different sizes or shapes, which has a layout of organic honeycomb.

The internal texture of interface between waterbody and sloping land is generally composed of four types of elements which are natural vegetation, ponds, farmlands, and revetment. The plants of the interface are mostly trees, wetland, and aquatic plants with well-developed roots, which form the protective revetment along the shoreline. The finger-like interface is mostly formed by hard sedimentary rock or metamorphic rock with uneven texture. The shoreline is irregular, and the revetment is narrow while the slope is steep with few vegetation, or it could be a curved river channel composed of woodlands with large curvature. The linear interface is generally the flexible revetment, mostly located in embedded shallows or ponds, low-slope meandering river beds, or curved river channels with inclined bed, or they are stone-based bank revetment with uneven interface texture, which is narrow and steep with few vegetation, or they could be the production space composed of ponds and farmlands with a wide interface, a gentle slope, and rich vegetation. The grid interfaces are mostly composed of production spaces with a large area and approximately oblong shape. The dike-pond system is directly connected with farmland and buildings, and there is few vegetation on the dike, or they could be a square with small area and few vegetation on the dike. They are mostly arranged in an orderly manner facing the waterbody in the serpentine shape along waterfront, and connected to the main roads, or they could be productive units with different sizes in square.

The interface between terrestrial sloping land and sloping land is formed by intermeshing of the slopes. The pattern of sloping land is closely related to the homogeneous landscape on both sides, of which internal texture is generally composed of three types of elements which are natural vegetation, ponds, and farmlands. The linear interface is generally a belt-shaped pattern with a sense of rhythm or direction, which is generally formed at the bottom of valley, or it could be a slope with the same texture on both sides, which is formed by the belt-shape terraces between mountains and rivers, or waved hills, winding rivers, and buildings in the settlement, or it could be a linear zone with abundant vegetation and steep slope in the transition zone between the slope and the flat. The finger-type interface is generally valley between sloping land with waterbody and farmland. The size of waterbody is variable, and a small area of water has an obvious erosion shape of shoreline, which is elongated, narrow, and deep. While a slightly large area of waterbody has a shoreline eroded into polyline, or it could be a forest corridor between the slope and the flat with curved forest linear space and the smooth bend. The grid interface is mostly formed by production spaces with irregular polygons of basic units which generally distributed linearly or in clusters, and the shape is like cells packed tightly. The main body is farmlands with trees and shrubs or ponds interspersed partly, or it could be small fields which are cultivated due to the steep slopes. The lynchets are in shape of a ladder, the field units are narrow trapezoids, and the layout is generally elongated along the contour line and rises up with steep slope.

6.1.2 Aggregated Pattern

6.1.2.1 Types of Aggregated Patterns

Aggregated patterns of basic units and their spatial patterns are summarized from ecological interfaces at micro and mesoscale from the basic context of phrases, which include 28 patterns for 4 types of living and ecological space combination, living and production space combination, ecological and production space combination as well as ecological, living, and production combination numbered from 172 to 199 (Fig. 6.1).

6.1.2.2 Characteristics and Laws of Aggregated Patterns

For the combination pattern of living and ecological spaces, most of ecological spaces are rivers, streams, wetlands, or vegetation communities. Dwelling space is located on one side of ecological space in cluster or an organic layout, or ecological space locates in the middle, and dwelling space locates on both sides of it in a dotted or centralized layout, or dwelling and ecological spaces are integrated as a unity, in which vegetation communities are the matrix, living spaces are adjacent to waterbody, and there are few vegetation buffers.

For the combination pattern of living and production spaces, production space is mostly farmland or artificial pond, while dwelling space is located on one side of production space at larger scale, and ecological space is interspersed inside dwelling space, or the living and production spaces are integrated into three ways which include the alternative distribution of living and production spaces, production space with a large area surrounding a clustered living spaces, and the living spaces scattered in a large area of production space.

For the combination pattern of ecological and production spaces, production spaces are generally farmlands or artificial ponds, and ecological spaces are generally woodlands, streams, rivers, and floodplain wetlands. Production spaces are generally attached to ecological spaces, of which ecological conditions could be used better for production activities at the edge area. Sometimes, ecological space is the center surrounded with a large area of production space, and the main part of the center is mostly ecological stream with shrubs and aquatic plants, etc. The diverse form of landscape mosaics can enlarge and prolong the interfaces, which effectively increases the edge effect along stream or river. Sometimes, ecological space and production space are integrated in distribution of alternatives.

For the combination pattern of ecological, living, and production spaces, production spaces are general located on one side of living space, in which ecological spaces are interspersed, or living spaces are attached to ecological spaces such as rivers and slope forests, or the production, living, and ecological spaces are integrated with large area of production spaces in which living and ecological spaces intersperse each other, or the ratio of ecological and production spaces is balanced with the configuration of living space distributed in ecological spaces in dots.

6.1.3 Vocabulary System

6.1.3.1 Vocabulary System Construction

Landscape pattern language of ecological interface at small and medium scale is constructed with basic units as words, space combinations as phrases, and holistic units as simple sentences reflecting patterns of ecological interface according to ecological processes (Fig. 6.1). The system summarizes a large number of pattern vocabularies of ecological interfaces to describe the characteristics, respectively. The common characteristics could be concluded through landscape patterns comparison in the same type of ecological interfaces, and designers could grasp the necessary characteristics to establish an ecological pattern determined by the key ecological process when they apply landscape pattern languages.

6.1.3.2 Characteristics of Vocabulary

Ecological interface at small and medium scale has abundant spatial types and varied forms, so the corresponding *'words'* and *'phrases'* of landscape pattern are rich too and can be used widely in practical applications.

It is easier for interface to form an ecological space than others with the characteristics of biodiversity and mobility of species, and in which it is easier to form three different types of ecological, production, and living spaces. So that it could easily form pattern language in ecological interface suitable for ecological design, which could be better applied to modern landscape ecological planning and design.

The edge effects are prevailing in ecological processes and landscape patterns in ecological interface, which mean richer biodiversity and more obvious ecological processes. The diversity formed by ecosystems on both sides of ecological interface and their internal texture is incomparable with other spaces, so landscape pattern vocabularies of ecological interface are more vividly for constructing pattern languages of various interfaces.

6.1.4 Pattern Language Application

6.1.4.1 Situation and Problem of Site

The Eco-park of Wolong Lake is located at 1 km west of Kangping County, Shenyang, Liaoning Province, which lies in the region of National Nature Reserve with area of 1952 km^2, where there are rich water resources, ecosystem and landscape resources, and unique natural and cultural landscapes which present as a total landscape pattern of rural farmlands.

The lake has long been used as a fishery base to develop aquaculture which is not beneficial to its long-term development because the eco-environment of Wolong Lake is too sensitive to disturb. The total landscape is homogenous at the beginning but fragmented gradually under the heavy impact of constructions and agriculture pollutions. The habitats lost so fast and aquatic ecosystems were damaged heavily to the undeveloped inner water networks as the results of land resources waste and water quality decrease (Wang et al. 2014).

6.1.4.2 Pattern Vocabulary Application

The application of pattern language in ecological interface of Wolong Lake is mainly analyzed and selected from three aspects of the master planning, revetment ecological design, and eco-design of artificial spaces (Fig. 6.2).

According to topography of the site, 12 revetment patterns being consistent with eco-environment are mainly selected from pattern language of waterbody-terrestrial flatland ecological interface, which were applied to different functional areas and

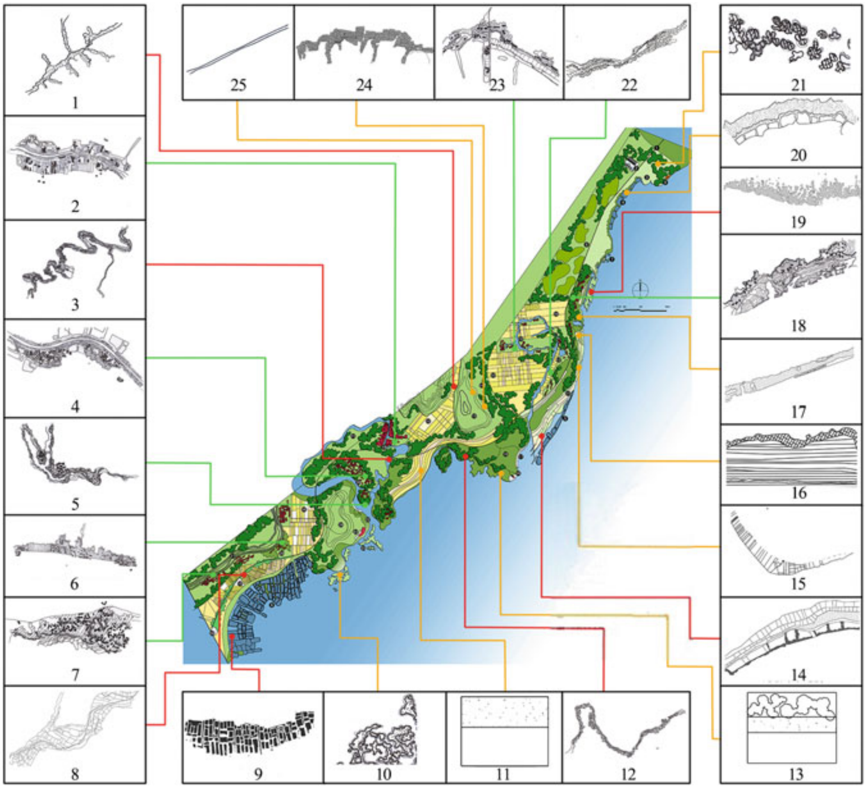


Fig. 6.2 Pattern language application in Wolong Lake conservation planning. 1 Field, 2 Living-ecological space combination, 3 Wandering linear type, 4 Living-ecological space combination, 5 Living-ecological space combination, 6 Living-production space combination, 7 Living-ecological-productive space combination, 8 Linear type combination, 9 Pond revetment, 10 Freshwater marsh wetland revetment, 11 Grass field revetment, 12 Woodland revetment, 13 Grassland shrub revetment, 14 Pond-field revetment, 15 Woodland-field revetment, 16 Grassland revetment, 17 Grassland revetment, 18 Living-ecological-production space combination, 19 Shrub wetland revetment, 20 Grassland-pond revetment, 21 Gravel beach lawn revetment, 22 Ecological-productive space combination, 23 Living-ecological-productive space combination, 24 Terrace, 25 Straight line

plots correspondingly. The 12 selected patterns could be classified into 3 categories of the natural gentle slope revetment patterns numbered 11, 14, 19, 33, and 120 (Fig. 6.1), production revetment patterns numbered 28, 31, 78, 134, and 153 (Fig. 6.1), and vegetative revetment patterns numbered 29 and 126 (Fig. 6.1). The natural gentle slope revetment patterns were chosen for the place where the slope waterfront is relatively gentle, and the space is large enough, which connected the soil as matrix of wetlands along the shore naturally with the original topsoil on the gentle slope, selected local native species of tree to recover natural ecosystem, then formed a natural transition zone from terrestrial landscape to aquatic landscape.

The production revetment pattern is suitable for the situation where land use is a production pond, or shoreline unsuitable for human activities, or the water quality suitable for fishery and shrimp breeding. The vegetative revetment pattern is suitable for waterfront where the slope is slightly steep, and the connection with waterbody is not strong, or the waterfront which could help the aquatic animals in Wolong Lake escaping from their predators and providing shelter. There are few intensive, artificial landscapes along waterfront due to the excellent environment and high ecological sensitivity of Wolong Lake. Therefore, only one pattern No.196 was chose to apply to implement ecological design in the combination patterns of waterbody-terrestrial flatland interface (Fig. 6.1).

According to the eco-environment of Wolong Lake and the functional planning, it mainly selected 4 basic patterns with similarity to land use in plain shapes of the site from pattern language of ecological interface between terrestrial flatland and flatland, in which the form is linear configuration as the whole but with different characteristics. The center of a straight linear pattern No.41 is ecological forests with single landscape and relatively simple habitats of communities (Fig. 6.1). The center of a meandering linear pattern No.137 is composed of narrow water channels with communities of arbors, shrubs, and grasses on both sides and relatively complex habitats of communities, extending interface between waterbody and terrestrial land, and various landscape elements (Fig. 6.1). The center of a combined linear pattern No.65 is a narrow ecological waterbody or woodlands with few vegetation and small area. The farmland is wide, and the units of fields are small and densely, which are gradually distorted with the change of terrain and forming tapered units where habitats are relatively simple (Fig. 6.1). The center of a linear combination pattern No.187 is a linear water space which is very narrow with few plants on both sides. The farmlands occupy a large area, and the units are perpendicular to the channels, while it is parallel to the channels for total structure (Fig. 6.1).

The combination patterns of ecological interface between terrestrial flatland-flatland in Wolong Lake ecological park mainly include the combination of living space and ecological space and combination of living, ecological, and production spaces. A combined pattern of living and ecological spaces No. 173 is located at the artificial bay, which is relatively closed, and habitat is relatively stable formed by the concave waterfront (Fig. 6.1). There are three types of combination patterns suitable for the dwelling, ecological, and production environment, in which dwelling space located on one side of waterbody with a pattern No. 174 (Fig. 6.1), or on both sides of waterbody with a pattern No.175 (Fig. 6.1) and even inside waterbody with a pattern No.199 (Fig. 6.1). According to the functions of site and environmental requirements, these three types of patterns are integrated to form an organic unity.

According to the two areas with slope land located at southwest and north of the site, three types of artificial patterns were selected in ecological interfaces between terrestrial sloping land and sloping land, which are patterns of farmlands, typical residents in the north, and terraces landscape for production. Production space of farmland with the pattern No.169 is distributed totally in strips, in which the field units are of different sizes and irregular shapes adapting to topography changing (Fig. 6.1). A terrace pattern No.114 (Fig. 6.1) is cultivated for productive crops, which changes with topography due to steep slope. The ridge of slope is constructed as terraces which are parallel to the contour and provide food for tourists and native residents although the field units are very small. The folk houses are remained in the original patterns of dwelling which located in group and dense layout with typical pattern and experiences of northern residents with a pattern No.198 (Fig. 6.1). The corresponding patterns of combination interface between slope land and slop land were selected according to the conditions and functions of unique landscape with steep slope in the site, where interfaces intermeshed between farmland and slope land with both productive and ecological functions, and the original dwellings are preserved in the south. Therefore, combination patterns of production and dwelling spaces were selected, that is to say, dwelling spaces are embedded in landscape matrix of productive spaces, which show an organic unity of terrace ecological space, farming production space, and dwelling space of residence in the Northern China with a pattern No.182 (Fig. 6.1).

6.1.5 Verification of Pattern Vocabulary Application

Landscape pattern language is one of the micro–mesoscopic ways to realize the shaping of macroecological landscape, of which the research aims to provide basic vocabularies necessarily for ecological planning and design. Ecological interface is an important type of ecological spaces, and which is also an important way of space identification and key point for ecological planning and design.

It is basic approach to analyze and interpret remote sensing images of typical ecological interfaces, through which a pattern prototype database of ecological interface can be established by using the platform of Google Earth and AutoCAD, a typical space or an optimal space can be selected among different combinations within the same type of ecological interface from the pattern prototype database; furthermore, these spaces can be abstracted and extracted to form landscape pattern vocabularies of ecological interfaces.

The systematic method for landscape pattern language research is constructed, and the system of pattern vocabularies was initially constructed consisting of 4 types of 171 basic patterns and 4 types of 28 aggregated patterns, in which not only has each kind of pattern their unique characteristics, but also all patterns have the common features.

It is found that landscape pattern language has a good significance to guide the design of spatial form and its combination through applying pattern language in planning and design of Wolong Lake Eco-Park, which was proved feasible and effective as a method. Lots of practical works are needed to further improve the prototype database of ecological interface, study the compatibility with ecological flows in the process of pattern selection, and practice on the basis of the framework proposed in this section because the study of landscape pattern language is currently in its infancy and would be supplemented with diverse types of ecological interfaces (Wang 2014).

6.2 Water Body and Habitat

6.2.1 Basic Pattern

6.2.1.1 Basic Types

Water habitats could be classified into five categories of rivers, ponds, lakes, wetlands, and streams. For river habitat, there are 20 patterns as words on six basic elements which are the configuration of standard part of river, river bend, river form, sandbar, shoal, and sandbank in river with patterns from No.1 to No.20 (Fig. 6.3). There are 9 patterns as phrases on five types of river habitat which are river form, the process of wetland, sandbar, shoal, and sandback in river with patterns from No.51 to No.59 (Fig. 6.3).

Stream habitats are relatively simple, and only one pattern No.50 was summarized (Fig. 6.6. 6.3). For water pond habitats, there are three types as words and phrases of natural ponds, ponds for human living, and ponds for agriculture production, which include 4 patterns as words from No.21 to No.24 (Fig. 6.3) and 5 patterns as phrases from No.60 to No.64 (Fig. 6.3).

For lake habitats, there are 22 patterns as words from No.25 to No.46 (Fig. 6.3).

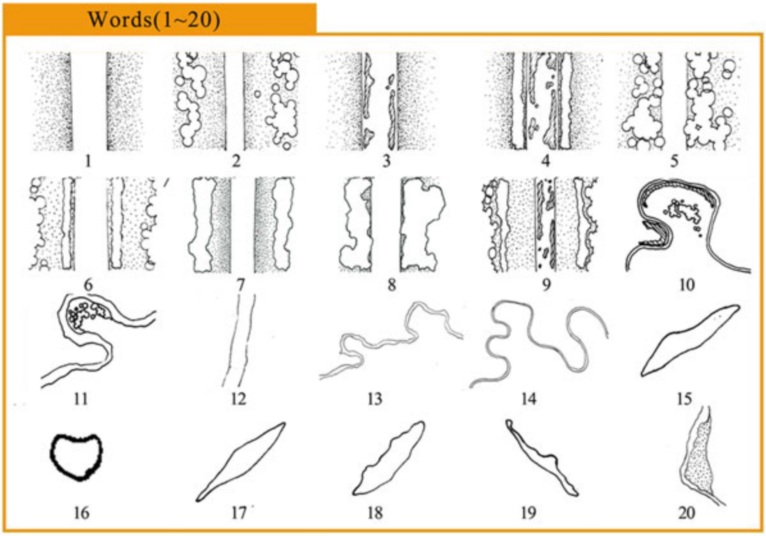
on five basic elements of lake shape, types of lake revetment, islands in lake and lake bays, as well as 21 patterns as phrases from No.65 to No.85 (Fig. 6.3) on four types of lake forms, type of lake revetment, islands in lake and lake bays.

For wetland habitats, there are three patterns as words of the point, band, and incomplete ring patterns from No.47 to No.49 (Fig. 6.3) and 5 patterns as phrases from No.86 to No.90 (Fig. 6.3) on two types of strip-shaped and scattered wetlands.

6.2.1.2 Characteristics and Laws

Rivers and streams are important representatives of landscape corridors. The bank of standard part of river is usually composed of grass slopes, shrubs, and trees. Plants grow generally in long strip along the inner edge of river bends, or the crescent-shape floodplain is formed on the inner side of river. Sandbanks are cuspate at both ends, wide in the middle, smooth on one side, and uneven on the other. Islands in river include irregular round islands, fusiform islands, and oblong islands. Floodplains are nearly crescent-shape and are mostly distributed on the inner side of river bends. To wetland patterns of river, plants usually grow along the banks or higher places in the middle of river bed, the wetland patches gradually expand until the coastal wetland patches, and the central patches are connected together. Patterns of stream habitat are in configuration of slender, and the shape is curvilinear naturally with tortuous line and sharp river bend.

Natural ponds and ponds for daily life are mostly irregular, of which the revetment has natural forms and is usually irregularly distributed, especially ponds for daily use are generally surrounded with some dwellings and dike with herbs and shrubs


Words(1~20)
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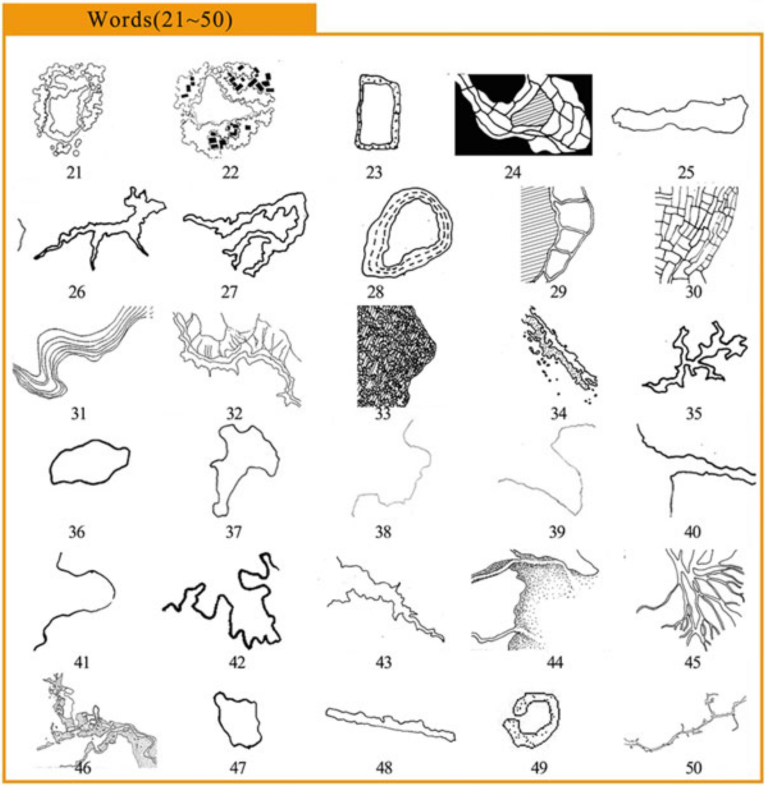
Words(21~50)
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◀**Fig. 6.3** Pattern vocabulary system of water habitat design. 1~9 Standard section of river, 10~11 River bend, 12~14 curve linear, 15 Sandbank, 16~19 Island, 20 River flat, 21 Natural ponds, 22 Ponds for living, 23~24 Ponds for production, 25~28 Lake, 29~34 Lake revetment, 35~37 Central island in lake, 38~43 Lake bay, 44~46 Confluence of rivers and lakes, 47~49 Wetland, 50 Streams, 51~53 River, 54 River wetland, 55~57 Island in the river, 58 Sandbank, 59 River flat, 60 Natural ponds combination, 61 Ponds combination for living, 62~64 Ponds combination for production, 65~68 Lake forms, 69~72 Lake shoreline, 73~82 Lake bay, 83~85 Central island in lake, 86~90 Wetland, 91~93 Living-ecological space combination, 94~95 Living-production space combination, 96~97 Productive-ecological space combination, 98~99 Living-production-ecological space combination

and natural ponds with abundant plants growing on the dike, which form a space of community with herbs, shrubs, and small trees. Production ponds are mostly regular polygons, mainly rectangular, with fewer plants on dike which are mainly herbs, in which some ponds for farming with irregular shapes according to land form and the dike directly connected to farmland and usually located in the center of it. Production ponds are usually distributed in a more regular manner which distribute in a grid-like shape when the number of them are big or in a linear shape when the number is small (Wang 2007).

Lakes in the region of plain have smooth shoreline, especially the place where river flows into lake is a little tortuous with semi-circular shape as whole. Lakes in the hilly area are in cross-shaped or branch-shaped, and lakes in arid areas are distributed randomly. Buildings are generally distributed along the edge of the artificial bay of lake, behind which are farmlands, woods, or ponds for lotus or fishery. Lotus ponds are formed when face the area with open, wide but shallow waterbody damped at the end of the bay. While fishery ponds are formed when face the narrow water-gate but extend long. The cluster of islands always consists of one large island and 2–3 smaller islands distributed in clusters in lake, in which the largest one is radially distributed and scattered with other smaller ones.

The area of strip-shape wetlands is generally large, of which the edges are in irregularly curves and appear along banks of rivers and lakes. The scattered type of wetlands is generally small in area, but some large patches of wetlands distribute in scattered spots, which usually locates in the middle of rivers and lakes.

6.2.2 Aggregated Pattern

6.2.2.1 Types of Aggregated Pattern

From basic context of phrases, basic combinations and spatial patterns in habitat of waterbody are summarized, which include 9 patterns from No.91 to No. 99 (Fig. 6.3) on 4 types aggregated spaces which are combinations of living and ecological spaces, combinations of living and production spaces, combinations of ecological and production spaces, and combinations of ecological, production, and living spaces.

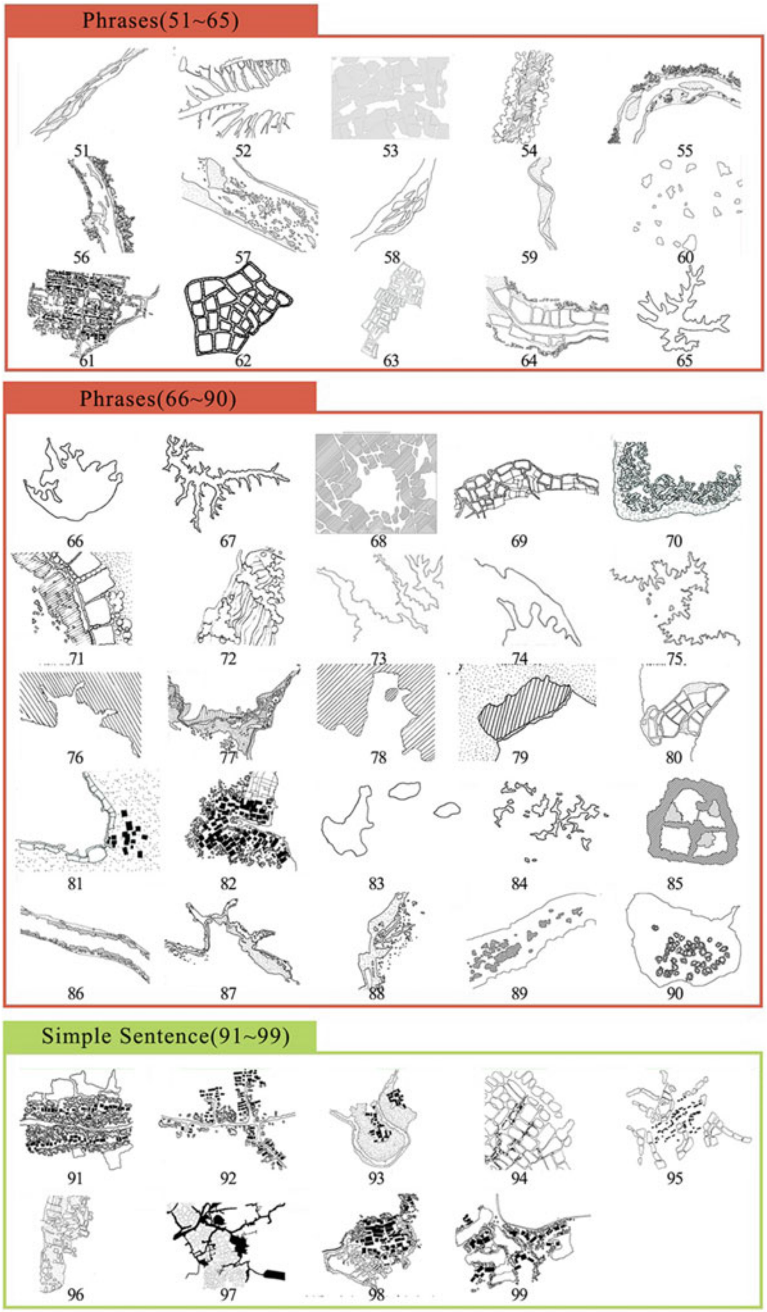


Fig. 6.3 (continued)

6.2.2.2 Characteristics and Laws

For combination patterns of dwelling and ecological spaces, most of ecological spaces were formed related to rivers which are away from villages and locate between spaces of dwelling and river with plants communities serving as a buffer. Dwelling space keeps a certain distance from river and locates at the inner side of river bend. Sometimes, dwelling spaces locate by the water and connected to river directly at the end of river in low hierarchy, but the main rivers are covered by ecological spaces of plant community on both sides.

For combination patterns of dwelling and production space, dwelling spaces are generally the dominant surrounded by production spaces extending outward at all directions with the configuration of explosive radiation. However, some combination spaces are also dominated by production spaces which expand and sprawl outward maximumly, and living spaces interspersed inside and scattered randomly with the configuration of packing.

For combination patterns of ecological and production spaces, ecological spaces are the center attached to production spaces distributed along the edges and intermeshed into ecological spaces. Productive activities usually utilize the good ecological conditions at the edge of ecological spaces. Sometimes ecological spaces dominated with waterbody intersperse in production spaces, the ponds as production spaces would emerge in the central area, and farmlands would be formed around waterbody extending radiantly when waterbody forms a closed space.

For combination patterns of ecological, production, and dwelling spaces, dwelling spaces and ecological spaces formed by plants are intermeshed and integrated to form the central space surrounded by small and segmented production spaces which are next to a layer of ecological spaces. Sometimes ecological spaces with ponds act as the center and the dwellings scattered among ponds which are surrounded by production spaces at the out layer.

6.2.3 Pattern Vocabulary

6.2.3.1 Construction of Pattern Vocabulary

Landscape pattern language of water habitat is constructed by words as basic space units and phrases as spatial combinations which act as ecological patterns of water habitats corresponding to ecological processes (Fig. 6.2). A large number of patterns have been summed up through the comparative study of pattern vocabularies within the same type of water habitats, which represent the common features of water habitats. Designers could grasp the necessary characteristics to establish ecological patterns by using pattern language determined by the key ecological processes when the common features are determined.

6.2.3.2 Features of Pattern Vocabulary

The words of water habitats are rich and have a wide range of practical applications due to rich types and variable forms of water body with diverse habitats. It is easier to form the convergence of three kinds of spaces with ecological, productive, and dwelling because ecological spaces are easier to form around waterbody than other places and additionally the propensity of human to waterbody and productivity of waterbody itself. So for water habitat, it could be easy to form pattern language especially suitable for dwelling, which also could be applied to landscape planning and design. Water habitats often contain diverse interfaces formed by waterbodies themselves and other elements with edge effects of richer biodiversity and more obvious processes, which are consistent with the understanding of edge and boundary in ecology. It is more vivid for the form of pattern vocabulary of water habitat because of the liquidity of water body in natural environment which is incomparable with other type of elements. Pattern vocabularies of different habitats are constructed even within a same type of waterbody due to the difference in speed and direction of water flows.

6.2.4 Application of Pattern Language

6.2.4.1 Situations and Problems

The site with landscape feature of *'living and farming with water'* covers an area of 61.8 km^2 and locates at Maoyang Village, Shaoxing County in Zhejiang Province, which is mainly composed of ponds, farmlands, rivers, and other elements of landscape. The area of fishery ponds is about 8 km^2, natural water area is about 6.8 km^2, and the ratio of waterbodies accounts for 24% of the total area. Fishery ponds are concentrated at southwest of the site, river is wide in the center, and several ponds are scattered in the west side. The area of agricultural land is about 46.6 km^2 accounting for 75.4% of the total area, and the area of constructed land is about 0.4 km^2 accounting for 0.6% of the total area. The site currently is facing some challenges which are inconvenient for land transportation, monohabitats, and fragile ecological environment, unabundant vegetations, and simple community structure.

6.2.4.2 Pattern Vocabulary and Application

Based on the characteristics and ecological process of the site, the applications of pattern language in design with the theme of *'living and farming with water'* are analyzed and selected from three scales of holistic, aggregated, and basic pattern of landscape.

Holistic landscape pattern of the project selected a cracking pattern as pattern language corresponding to water habitat in patch and river network of the site in the

Fig. 6.4 Pattern vocabulary and application of holistic landscape pattern

South of Yangtze River (Fig. 6.4), which has a very typical pattern of rural culture landscape and its context. In this pattern, streams are interlaced, and some streams are wide enough to form small lakes, the network looks like several patches of land floating on a large area of water. Streams would divert into farmland patches on both sides and to end in them. The configuration of total landscape is separated and stitched with linear water spaces and appears in the texture of cracking.

There are abundant waterbodies in west of site with the potential of being a central lake, design ponds in southwest, streams running through from west to east, and more natural ponds in northwest according to current situations of land resources, as well as the connection between landscape space units and land use forms. The following patterns are selected (Fig. 6.5):

The shape of natural lake is a radial configuration with a large central area of water and many rivers spreading out all around the lake in the South of Yangtze River. The configuration and form of lakes in the plain area with a pattern No.68 (Fig. 6.3) were used in planning and design of site with the theme of *'living and farming with water'*. According to the characteristics of rivers and streams in southern region of the Yangtze River, dwelling space and ecological space are combined to construct a harmonious and intermeshed pattern No.92 of residential and natural space (Fig. 6.3). Combined with the configuration of existing fishery ponds in the site, it was constructed and designed with a pattern No.62 of pond for production

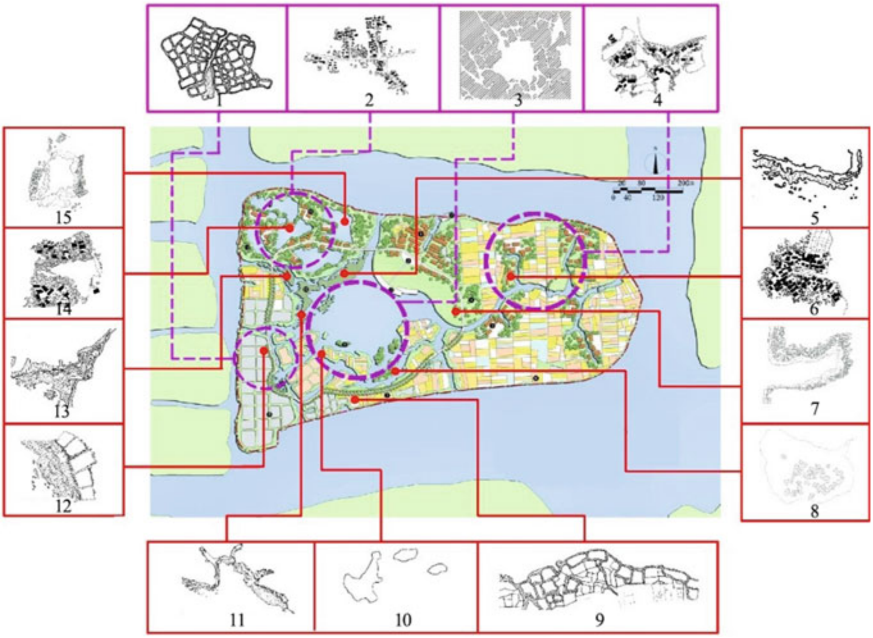


Fig. 6.5 Pattern vocabulary and application of landscape units in water habitat. 1 Ponds for production, 2 Ecological-living space combination, 3 Master plan in plain area, 4 Ecological-living-production space combination, 5 Lake revetment: wetland, 6 Lakebay, 7 Revetment: forest-grass type, 8 Wetland: scattered type, 9 Revetment: field-pond type, 10 Central island in lake, 11 Wetland: band-like distributed along the shore, 12 Revetment: pond-wetland, 13 Lake bay, 14 Pond for living type, 15 Lake pattern: natural type

in network of grid (Fig. 6.3). It needed a reasonable arrangement for a combination pattern No.99 of ecological, dwelling, and production space (Fig. 6.3), in which dwelling space and ecological space with plants next to river are intermeshed each other and integrated to form a central space. A certain area of production space is formed around the periphery, which is combined with current agricultural land.

There are various landscape elements in the site, and the dominant elements of water habitat include wetlands in lake bay, artificial lake bay, natural ponds, ponds for daily use, lake islands, lake revetments, and wetland habitats. Based on regional environment of the site, landscape patterns applied in design (Fig. 6.5) are patterns No.77 and No.82 of bay (Fig. 6.3), a natural pattern No.21 of pond (Fig. 6.3) and a pattern No.22 for daily use (Fig. 6.3), an island pattern No.83 (Fig. 6.3) and a pattern No.34 of lake revetment (Fig. 6.3), a pattern No.69 of field-fishery pond revetment (Fig. 6.3), a pattern No.71of fishery pond-wetland revetment (Fig. 6.3), a pattern No.70 of forest-grassland revetment (Fig. 6.3), a pattern No.87 of coastal strip (Fig. 6.3), and a pattern No.90 of scattered distribution (Fig. 6.3). Here, a total of 11 patterns in 5 categories have been selected to construct 4 types of habitats including lakes, rivers, wetlands, and ponds. The types of water habitat are relatively rich in the area upholding the landscape theme of *'living and farming with water'*, in which not only are various types of habitats interspersed and connected with each other, but also the habitats of woodland, grassland, and farmland are intermeshed with each other.

6.2.5 Verification of Pattern Vocabulary Application

From the selected spaces of typical water habitats, a total of 90 basic patterns on 5 types and 9 combination patterns on 4 types are extracted (Wang et al. 2012). Each type of pattern has its own characteristic but also has some common features. A pattern prototype database of ecological interface was established through obtaining, analyzing, and interpreting remote sensing images of typical water landscape space using the platform of Google Earth and AutoCAD. It is feasible to select a typical space or an optimal space among different combinations within the same type of water landscape from the pattern prototype database, and abstract and extract these spaces to form landscape pattern language of water habitat and apply to design the case reflecting the theme of *'living and farming with water'*. The research on pattern language of water habitats is currently in its infancy, and a lot of practical works need to be done on the basic framework proposed in this section, which include further improving the prototype database of water habitat, studying the compatibility with ecological flows in the process of pattern selection and practice (Wang and Cui 2015).

6.3 Public Open Space in Traditional Villages

6.3.1 Basic Pattern

6.3.1.1 Basic Types

The pattern of public space around plaza includes two types of entrance plaza and node square, which consists of 34 types of simple pattern as words and 24 types of single-component or multi-component patterns as phrases. Patterns of public space around water are classified into linear and patchy patterns of waterbody, which consists of 27 basic patterns and its main components as words and 18 multi-component patterns as phrases. Patterns of public space centered on green space are classified into urban park green space and ecological green space, which consists of 11 types of environmental components as words, such as water system, temples, ancestral halls, and bridges, and 22 patterns of various green spaces as phrases.

6.3.1.2 Characteristics and Laws

The plaza in village provides public places through connection to other units.

of landscape, such as fishery ponds, green spaces, ancestral temples, and religious temples. Plaza at the entrance has a large area with relatively regular shape, which enclosed by plants, buildings, and other elements and connected closely with main roads inside and outside a village. Squares locating at intersections of roads, gaps between buildings, and open space at bridgehead have small area with relatively flexible layouts and often in irregular-polygon shape.

The characteristics and laws of basic patterns of public space around waterbody are of rich forms, flexible functions, and diverse components with their own shapes in different regions and villages. The scale of public space surrounding the linear water system is small, scattered relatively, and decentralized in linear tandem shape. The transitional water system in neighborhood always occupies a large area of space with a flexible layout, which often combined with infrastructure components such as ports, small squares, and public buildings and also kept same direction with linear elements like roads in village. Small waterfront squares and water source at the border are most typical spaces of transitional water system, among which squares are combined with components of water ports and waterfront platforms, and water sources always clustered with important infrastructure components of archway, bridge with gallery, ancestral temple, and appeared in complex space forms. They always have special roles in village. Spaces centered on water patch have relatively concentrated layout, which combine with infrastructure components of squares, green space, ancestral temples, and forests of ***Fengshui***. Among them, water spaces at the center of village have small area and in regular shape, but at the border, they have larger area and in more natural shape.

6.3.2 Aggregated Patterns

6.3.2.1 Aggregated Types

The location and organization of public space in traditional village are the dominant factors to form and influence spatial structure of a village, by which this research classified the combined spaces of public space into four types of entrance, center, boundary, and composite space and are summed up to 30 types of phrases for aggregated landscape pattern.

6.3.2.2 Characteristics and Laws

Combination patterns of entrance, center, boundary, and composite space are all composed of spatial elements like plazas, green space, waterbody, and various infrastructure components like ancestral temples, religious temples, bridges, water ports, and *Fengshui* forests and formed patterns of open space with balanced elements, densely or loosely layout, and rich forms. According to the various forms of combination, combination pattern of the entrance space could be classified into 3 types of the block group, belt extension, and surrounding rings. Combination patterns of the center space are classified into types of the block group and belt extension. Combination patterns of the boundary are mainly in form of belt. Combination patterns coalesce the above types of open space, which are classified into types of strip extension, radiation, and surrounding.

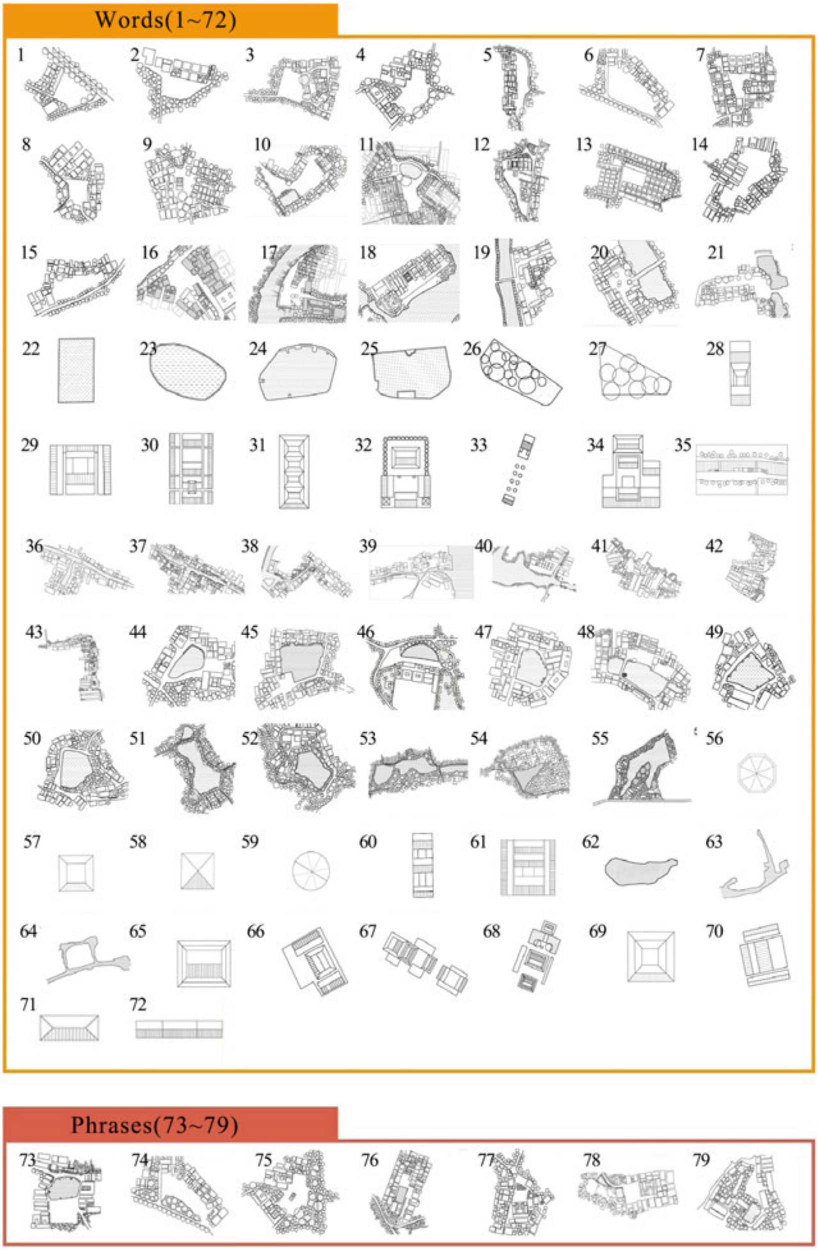
6.3.3 Pattern Vocabulary

6.3.3.1 Construction of Pattern Vocabulary

Landscape pattern language of public spaces in traditional village is constructed by words as space units and phrases as space combinations, by which patterns of public space are formed according to the corresponding natural and socio-ecological process (Fig. 6.6). The text above summarizes a large number of pattern vocabularies and describes their respective characteristics. Through the comparative study on pattern language within same type of public space in village, designers could grasp the essence in using landscape pattern language in practice as long as the common features of such spaces are determined definitely.

6.3.3.2 Characteristics of Pattern Vocabulary

Public spaces of traditional village are the important parts of rural cultural landscape, of which the composition and meaning are the microscopic epitome of human ecology. It needs the specific methods and paradigms of socio-ecological design to guide planning and design of public space in order to ensure the rationality of spatial composition and structure. It is of a huge number and abundant types of spatial elements and environmental components of public spaces in traditional village with value of widely practical application due to the common essence in different regions. Traditional villages have special context both in natural environment and historical culture in different regions, behind which the reasons and mechanisms are also very complicated. Combination patterns of public space are more random than pattern languages of other combination types. It is necessary to fully study the regional context, the geographical and cultural characteristics of village, take the characteristics and needs of human activities into account, then make targeted and flexible choices in the practical application of landscape pattern language.


Words(1~72)
Phrases(73~79)

◀**Fig. 6.6** Pattern language of public space in traditional villages. 1~6 Entrance plaza, 7~12 Road and square intersection, 13~17 Square with building retreats, 18~21 Bridgehead expansion square, 22~34 Component in the square, 35~40 Neighborhood transformative linear water system, 41~43 Boundary transformative linear water system, 44~46 Water patch at the entrance, 47~52 Central waterbody system, 53~55 Water patch at the boundary, 56~61 Water system components, 62~72 Components of green space, 73~75 Entrance plaza with single component, 76~78 Entrance plaza with several components, 79~81 Road intersection square with single component, 82~84 Road intersection square with several component, 85~87 Building retreats after square with single component, 88~90 Building retreats after square with several components, 91~93 Bridgehead expansion square with single component, 94~96 Bridgehead expansion square with several component, 97~99 Boundary transformative linear water system with several components, 100~102 Neighborhood transformative linear water system with several components, 103~108 Plane water system at the entrance with several components, 109~111 Central plane water system with several components, 112~114 Plane water system at the boundary with several components, 115~120 Fengshui forests, 121~122 Cultural park, 123~126 Public park, 127~130 Forests with religious meaning, 131~136 Natural forests, 137~139 Aggregated block at the entrance, 140~142 Band-like blocks at the entrance, 143~145 Enclosed blocks at the entrance, 146~148 Central aggregated blocks, 149~151 Band-like type at the center, 152~154 Band-like type at the boundary, 155~157 Integrated band-like type, 158~160 Integrated radial type, 161~166 Integrated enclosed type

6.3.4 Application of Pattern Vocabulary

6.3.4.1 Current Situation and Problems

The village of Jiguanlazi is a small one with the area of 829 km^2 in Changbai County, Jilin Province, which locates at the narrow development zone of Yalu River in southern part of the county. The landmark is a crescent lake around the village formed by natural process of the Yalu River in history, and on which the village works as an eco-tourism area integrated sightseeing, leisure, rafting, and scientific investigation. Several small lakes formed in most parts of the ancient waterway surrounded a gentle hill, and just a small part of waterway was dry and cultivated as agricultural land. The topography of village is high in the north and low in the south to form a gradient change of mountain, lake, hill, village, and river from north to south. Public spaces for activities in village mainly include the committee and entrance plaza, unused space, and wildness. With challenges of limited connection between waterbody, green space, farmlands, and other elements, the harsh environment for dweller, the scarce space for public activities, and irrationally use of the wildness around residential buildings, it is necessary to shape the holistic pattern of landscape and design public spaces for village in order to ensure the sustainable development of natural and socio-ecological environment and also to meet the needs of tourism development (Wang and Han 2014).

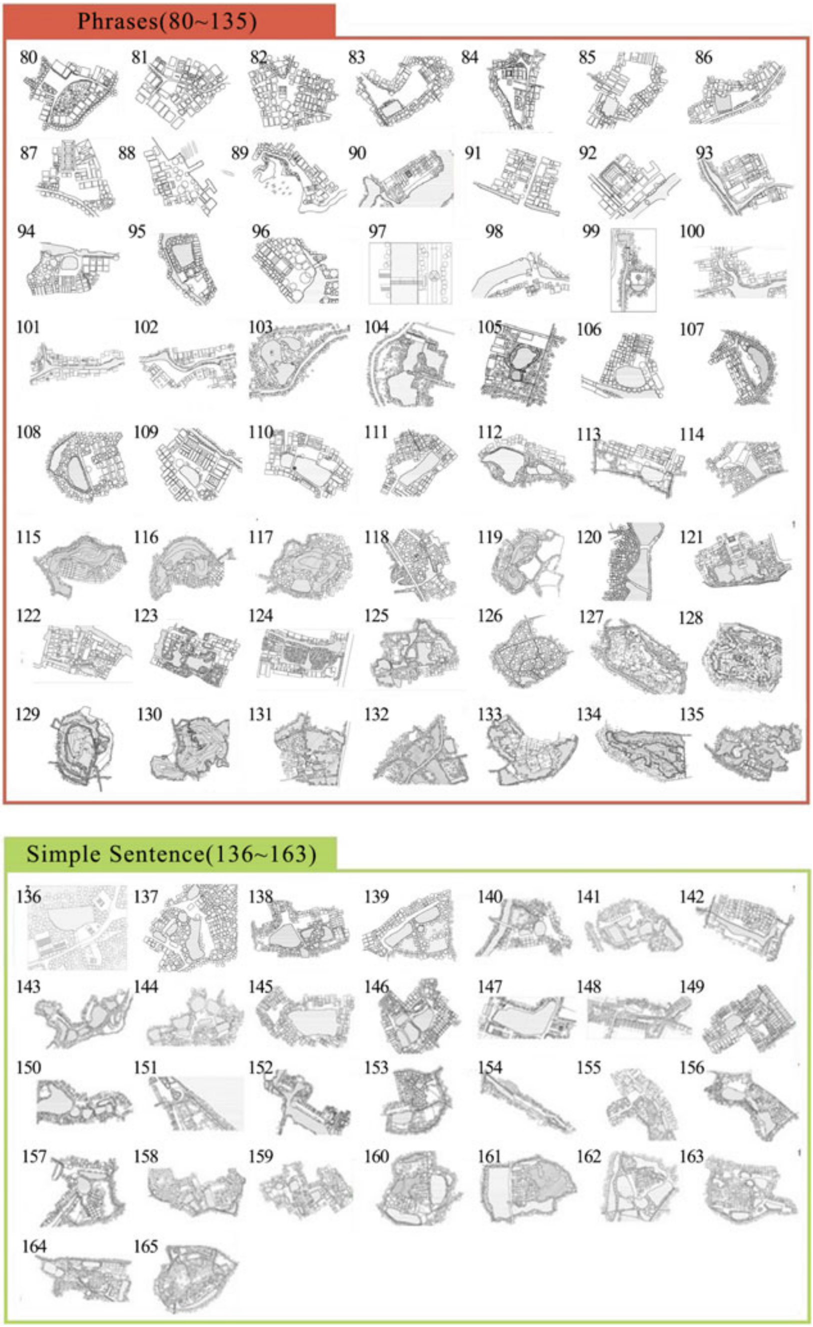


Fig. 6.6 (continued)

6.3.4.2 Application of Pattern Vocabulary

For the integrity and humanity at a macroscale, it needs to respect local natural and socio-ecological landscape through considering the method of human ecological design as the basic standard, matching the planning for village construction to the master plan of rural development, regarding public space planning of village as an important part of the master plan. At a medium scale, the construction of public space should be regarded as an extension and refinement of the planning at macroscale, and paid attentions to the connection between public space and master plan, and protected the original layout of local spaces and landscape characters through rational planning of function, layout, land use from perspectives of metrics and morphological features. At a microscale, the specific design of public space should be centered on human, and the activities of requirements and features of residents in public space should be fully understood before planning. The degree of openness and scale of public space should be determined according to people's requirements, and the elements should be chosen according to specific behaviors and their location, public spaces should be updated with the continuous change of behavior.

Patterns of holistic landscape should be selected on the basis of spatial characteristics of the integrated public spaces which are composed of the interior public spaces and surrounding parts of the residential area. Public spaces in residential area are classified into four categories of daily life, tourism service, commercial leisure, and ecological recreation according to the needs of residents' activities, reasonable classification and organization, and surrounding eco-environment. Public spaces around residential areas are classified into the area of holiday and leisure, ecological forest sightseeing, agricultural activity, and park recreation, which are based on the planning of ecological space, industries, and land construction to meet the needs of residents and external tourism activities.

For the design of vocation and aquaculture group, a complete system of landscape spaces was formed with planning and arranging tourist routes and related projects directed by the theme of culture experience, ecological education, and natural cognition. The sequence of juxtaposed and progressive relationship in space was showed by the combination of integration and independence in linear space of ancient waterway which formed a functional sequence of park recreation, culture experience, distinctive accommodation, ecological fitness, ecological fishing, and agricultural sightseeing combined the characteristics of site and recreational needs. The space sequence with waterbody as landscape context and landscape center in open spaces was planned and organized, which include three open spaces of the combination between island and surrounding waterbody, polders with waterbody, and the open lake. At the same time, public open spaces at small scale are nested in the form of squares and block in each open space.

Combined with landscape context and characteristics of landscape pattern, pattern vocabularies of public space were selected in form of words as public spaces around plaza, public space around water, and public space centered on green space. It mainly selected 6 patterns of 4 types to fit pattern vocabularies of public space around plaza, which are the types of village entrance, partial corridor intersection, building retreatment, and bridgehead expansion. It selected 5 patterns of 3 types to fit pattern vocabularies of public space around water, which are linear water system, patchy water system in center, and patchy water system at boundary. It selected 3 patterns of 2 types to fit pattern vocabularies of public space centered on green space, which are public green space and natural woodlands. As phrases of pattern language, combination patterns of public space are formed according to spatial characteristics correspondingly, in which the center, boundary, and composite patterns are selected according to site characteristics and activity requirements, and adjusted correspondingly to specific nodes. Patterns are coupled at different scales with each other and formed a complete, continuous, and healthy public space system driven by the natural and cultural processes in village (Fig. 6.7).

6.3.5 Verification of Pattern Language Application

Landscape pattern language is a new perspective and method for exploring the spatial composition and laws of landscape in ecological design, of which the establishment for public space in traditional villages is aimed to provide framework for ecological planning and design practice to protect and inherit traditional cultural landscapes. A pattern prototype database of public space was established through obtaining, analyzing, and interpreting remote sensing images of typical public space in village using the platform of Google Earth and AutoCAD, from which typical spaces or optimal spaces among different combinations at multiple scales were selected within a same type of public space.

Landscape pattern language of public space in village was classified into two parts of basic patterns and combination patterns as form of words and phrases, which include 72 types of words of 3 categories, 64 types of phrases of 3 categories, and 30 types of simple sentences of 4 categories. It had been verified feasible to apply pattern language to its planning in Jiguanlazi Village where a complete and abundant public spaces were designed finally (Zou 2014). It is necessary to continuously expand pattern vocabularies and its application scope of open space in village and conduct the comparative study of public space in traditional villages as well as in modern villages to increase the universality of landscape pattern language and form a complete landscape language (Wang 2006, 2013).

Fig. 6.7 Pattern language and its application of public space in village. 1 Planar water system pattern 1: boundary type, 2 Planar water system pattern 2: central type, 3 Linear water system type 1, 4 Planar water system pattern 3: boundary type, 5 Planar water system pattern 4: boundary type, 6~8 Combination pattern 1: integrated type, 9 Combination pattern 3: boundary type, 10 Node square pattern 5: building retreats after square, 11 Square at the entrance, 12 Node square pattern 4: bridgehead expansion square, 13 Node square pattern 3: building retreats after square, 14 Node square pattern 2: intersection square, 15 Green space pattern 3: park, 16 Green space pattern 2: natural woodland, 17 Green space pattern 1: park

6.4 Ecological Network

6.4.1 Basic Patterns

6.4.1.1 Basic Types

This study classified the basic networks of landscape ecological space into plain network and mountainous network at large scale, which are composed of three spatial types of corridor, node, and basic unit of mesh, such as corridors of roads, waterways, linear vegetation spaces and nodes of settlements, patchy waterbodies, and vegetation nodes, as well as basic units of road networks, water systems, vegetation, and buildings. A total of 56 patterns from No.1 to No.56 of 10 basic types as words and 29 aggregated patterns from No.57 to No.85 of 3 aggregated types in plain networks as phrases reflecting the pattern of living networks and production networks, as well as 13 aggregated patterns from No.86 to No.98 of 3 aggregated types in mountainous networks as phrases reflecting patterns of living network, production network, and ecological network (Fig. 6.8).

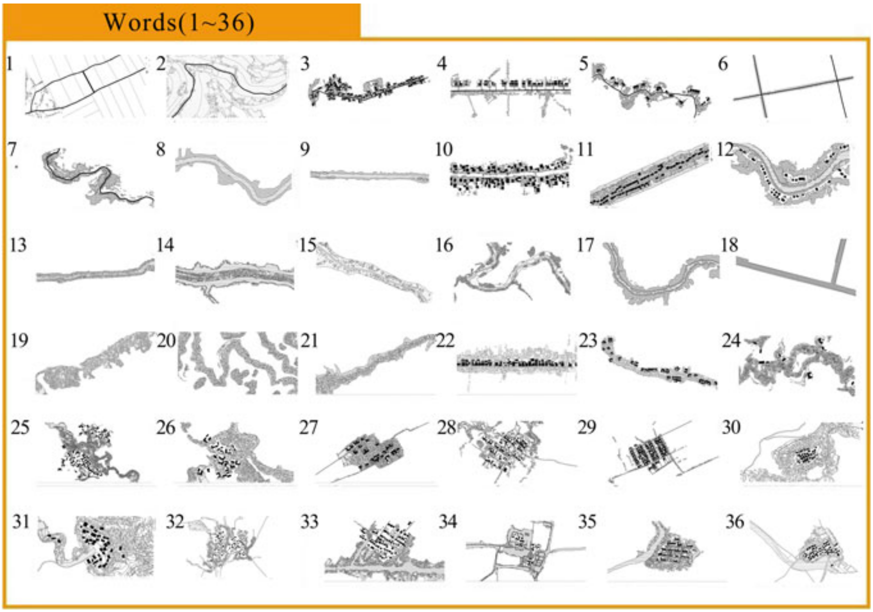


Fig. 6.8 Basic pattern vocabulary of landscape ecological network. 1~7 Road corridor, 8~17 Water system corridor, 18~24 Vegetation corridor, 25~32 Building-vegetation-settlement node, 33~39 Building-water-vegetation-settlement node, 40~42 Water barely node, 43~47 Water-vegetation node, 48~50 Vegetation node, 51~56 Units type, 57~61 Road and settlements network, 62~67 Water and settlement network, 68~70 Productive road network, 71~73 Protection forest network, 74~79 Water system for production, 80~82 Natural vegetation network, 83~85 Natural water system network, 86~91 Road and fundamental living network for settlements, 92~94 Production land network, 95~98 Vegetation network, 99~104 Road-settlements network and vegetation production network, 105~108 Road-settlements network and water system for production network, 109~110 Road-settlements network and water ecological network, 111~112 Road-settlements network and vegetation ecological network, 113~114 Vegetation production network and water ecological network, 115~118 Road-water-vegetation network, 119~120 Road-settlements and production land network, 121~124 Road-settlements and vegetation ecological network, 125~126 Vegetation production and ecological network, 127~128 Road-settlement-terrace-production-vegetation-ecology network

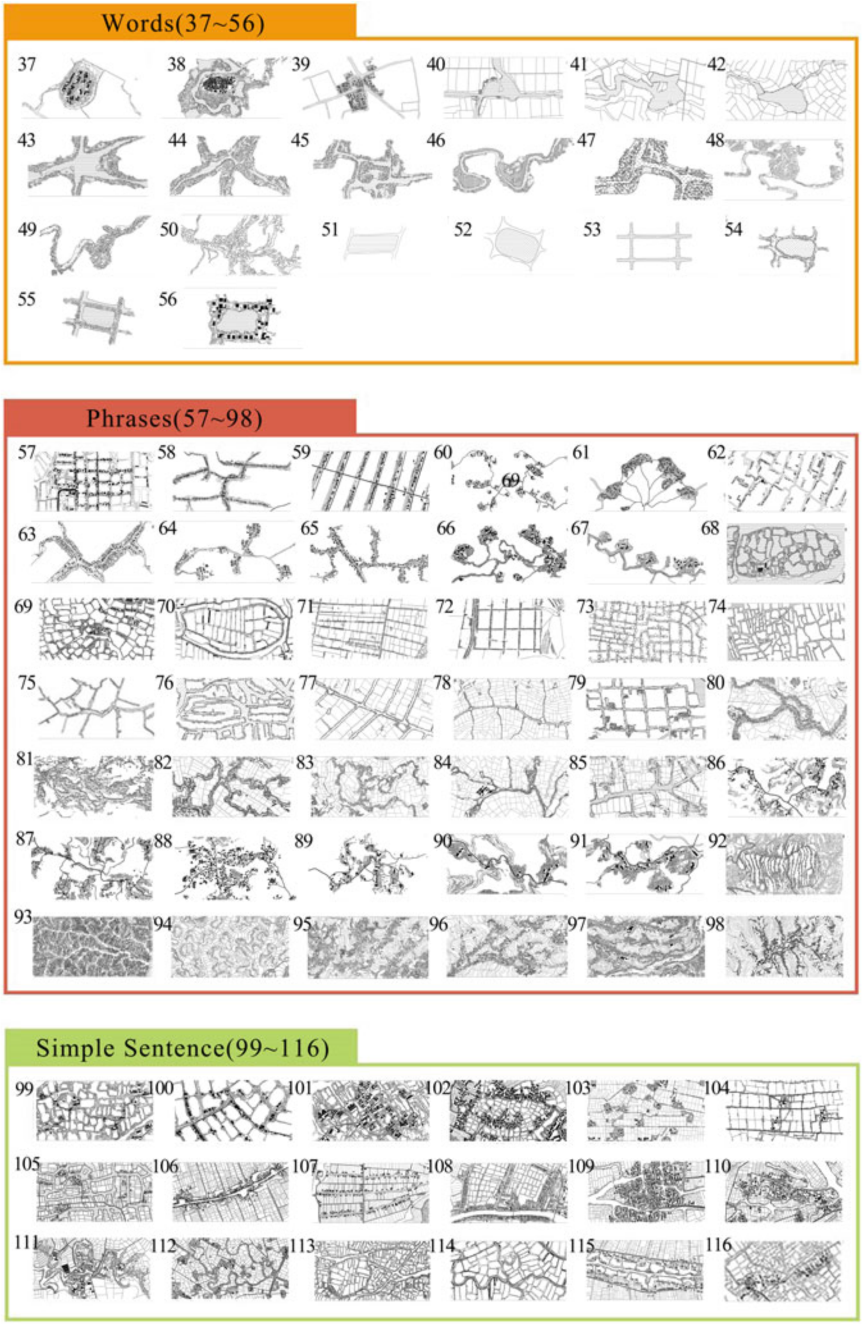


Fig. 6.8 (continued)

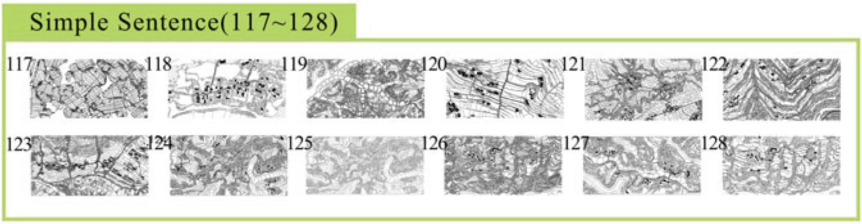


Fig. 6.8 (continued)

6.4.1.2 Characteristics and Laws

The diversity of corridor, node, and their form of landscape ecological network is influenced by the diversity of landscape elements, and their combinations although landscape elements are relatively limited, which mainly include the corridor such as forest belt, rivers, streams, roads, and others, and the node such as forest, grassland, lakes, ponds, settlements, farmland, and others. Basic space units of network are formed with nodes, corridors, and mesh enclosed by corridors, which are reflected by 56 words of pattern vocabulary for planning and design of landscape ecological network. The main determinants of pattern words are the types of landscape elements and the abundance of landscape environment. From perspective of the basic network types, 42 patterns basic network as words are dominated mainly by the degree of variability and the ductility of basic network based on rich compositions. In the process of space growth, basic network would adapt to certain changes of landscape, such as size, porosity, shape, and others (Wang and Lv 2014).

6.4.2 Aggregated Pattern

6.4.2.1 Types of Aggregated Pattern

Landscape ecological network is classified into networks of dwelling, production, and ecological spaces corresponding to functions so as to decompose and research the complex networks based on three functional attributes of landscape. According to the coupling modes of landscape ecological space, this research classified landscape ecological network into 4 types which are the coupling network pattern of dwelling with production, the coupling network pattern of dwelling with ecological space, coupling network pattern of production with ecological space, and coupling network pattern of dwelling, production with ecological space, each of which was classified into types in plain and mountainous area according to geographical environment with a total of 30 aggregated patterns from No.99 to No.128 (Fig. 6.8).

6.4.2.2 Characteristics and Laws

For the coupling network pattern of dwelling with production, generally, it is centered on dwelling space with a large area of production space and interspersed ecological space inside. According to specific environmental conditions, patterns integrated dwelling with production space each other are classified as three ways of living and production space distribution alternately, the group of dwelling space enclosed with a large area of production space, and dwelling space scattered in a large area of production space.

For the coupling network pattern of dwelling with ecological space, generally, dwelling space locates in a cluster or an organic layout, which attaches to ecological spaces. Sometimes, ecological space locates in the center and dwelling space distributes on both sides with the dotted or concentrated layout. Sometimes with the vegetated space as context, ecological space integrates with dwelling space which is adjacent to waterbody without buffer (Wang and Meng 2016).

For the coupling network pattern of living, production with ecological space, generally, production space is located on one side of dwelling space, ecological spaces intersperse inside dwelling space, or dwelling space is attached to ecological space such as rivers and slopes. Sometimes, patterns are dominant with production space with large area and integrate production spaces, dwelling spaces, and ecological spaces together, in which dwelling and ecological spaces are dotted. Sometimes dwelling spaces are dotted distribution inside ecological space in the pattern with same proportion of ecological and production spaces. Sometimes, the pattern is dominant by dwelling space with large areas, supplemented with eco-space, and surrounded with production space.

6.4.3 Pattern Vocabulary

6.4.3.1 Construction of Pattern Vocabulary

Landscape pattern language for network of ecological space is constructed by words as basic parts of networks and phrases as networks (Fig. 6.8), in which the vocabularies such as words and phrases have their own characteristics, and the essences of network design vocabulary are established through the deep and detailed analysis and comparative study on the prototypes. From the perspective of pattern-process in landscape ecology, the common and universal laws were summarized and generalized to guide landscape ecological planning and design through scientific and appropriate ways to express them professionally. The ultimate goal of landscape ecological design could be realized through the using of ecological patterns determined by the key ecological process and to achieve the macroecological goals by the microapproaches.

6.4.3.2 Characteristics of Pattern Language

The words and phrases of landscape ecological network are abundant with a wider range of practical applications corresponding to the rich types and variable forms of ecological space, on which it is easier to form an ecological network than other spaces of landscape network.

Network of ecological space is easier to form ecological, productive, and dwelling spaces which inlaid with each other as a mosaic, so as it is easier to form a rich and diverse design vocabulary which suit the needs of ecological planning and design and could be well applied to modern landscape ecological planning and design.

Network formed by nodes, channels, and their enclosures has rich and varied combination patterns which integrate the effects of center and edge, channels and their connection, nodes, and source-sink and create rich and diverse habitats, landscape types, biodiversity, and more obvious landscape ecological processes (Wang et al. 2015).

Network of landscape ecological space is composed of stable ecosystems with rich compositions, patterns, processes and perception of landscape, and characteristics of biodiversity, of which design vocabularies are more various to construct diverse forms of pattern language.

6.4.4 Application of Pattern Vocabulary

6.4.4.1 Situation and Problem

The site of Gushanzi Village locates at Changbai County, Jilin Province, with the area of 8.3km^2 and 619 population, of which the Korean population accounts for about 1/4, and the other is Han nationality. The village was planned uniformly in 1980s in layout of regular grid which is surrounded by mountains in the east, north, west, and the Yalu River in the south and lies a good foundation of landscape environment with flourish vegetation, abundant seasonal rivers, and irrigation networks. On the contrary, the integrity of the village was damaged by unreasonable constructions and agricultural land use, which is planned in a pattern of regular checkerboard-like with scarce and boring space form with extremely low ratio of green space. It is necessary to restore and protect the ecological resources in and around the village to improve the greening environment. The proportion of migrant workers is too high to provide enough vital labors, so it is an urgent to ensure the healthy development for scientific and systematic planning and renovation (Han 2017).

6.4.4.2 Pattern Vocabulary and Its Application

Basic network pattern as words and aggregated network pattern as phrases are selected from pattern language of landscape ecological network according to targets of the project and features of the site integrated with landscape elements such as mountains, grasslands, forests, farmlands, streams, pools with green facilities, hedgerows fitting the slope, and Korean traditional dwellings.

The village is planned with a pattern of alternative distribution of dwelling space, green buffer, production space, green buffer, and ecological space, which established the nested structure of total landscape, to ensure the individual needs for villages and various functional spaces and coordinate landscape values and ecological value based on the analysis of situation, evaluation of ecological quality, and landscape suitability gradient.

Total ecological network could be constructed through coupling the multiple networks such as waterbodies, roads, woodlands scattered in the field, and woodlands of extending forest belt of village. The harmonious coordination in dwelling space was established relying on the central waterbody, waterways or wedge-shaped green belt, and idyllic park spaces. The requirements of storm storage, waste treatment, soil erosion, and water purification in production space were met with the construction of green sponge facilities, and hedgerows combined with water treatment center of village.

Corridors were connected into a complete system, in which corridors strengthen the ecological connections between mountains and waterbodies relying on multiple tributaries of the Yalu River and strengthen the horizontal ecological process relying on roads and village alleys along the river. The strategic ecological nodes were strengthened by building stepping stones using the existing ponds and groves to purify agricultural pollution.

Landscape ecological network is not only highly complex but also different in various environmental units. Therefore, it is necessary to apply a rich vocabulary to match diversified and multi-level spaces to design the coupling network patterns which adapt fully to the natural conditions and fully matches the characteristics of current environment, which includes diversified components, basic patterns, and aggregated patterns of network for design vocabulary (Fig. 6.9).

Basic patterns of network include 6 types on landscape elements of vegetation node, water-vegetation node, vegetation-settlement integrated nodes, road-vegetation corridors, roads-settlement corridors, and waterways-vegetation corridors and include 8 basic patterns on network of vegetated production network I and II, production-water system network I and II in plain, and vegetated-ecological network I and II, vegetated network I and II distributed along contour in mountain area.

Aggregated patterns include 4 types of combinations between road-settlement network and water system ecological network, combinations between road-settlement network and vegetated production network, and combinations between patterns of networks I and II in mountain area, among which the coupling network pattern I matches the natural environment and topographical conditions of village with many valleys and waterways. Nested patterns of dwelling-production-ecological space build the connections through multi-directional and multi-type corridors. Network pattern II in mountain area matching the rich vegetation network links closely spaces of dwelling, production, and ecological space together, by which it

Fig. 6.9 Application of network pattern language in holistic landscape planning. 1~2 Vegetation production network in the plain, 3~4 Water system for network in the plain, 5 Vegetation node, 6~7 Vegetation network in the mountainous area, 8~9 Vegetation corridor along the contour, 10~11 Integrated network in the mountainous area, 12 Road-settlement and water ecological network, 13 Vegetation-settlements intersection node, 14 Water-vegetation node, 15 Natural water-vegetation corridor, 16 Living network of road and settlements, 17 Curved road-vegetation corridor

would improve the isolated and unconnected layout of the existing living, production, and ecological spaces in village.

6.4.5 Application and Verification

Pattern language is a new method for portraying the nested characteristics and scaling of complicate eco-spaces. It is to provide basic vocabularies and expression ways for the ecological planning and design through the building of landscape pattern language. From perspective of landscape ecological network, it would provide bases for establishing complete language system combined with patterns of water habitat, ecological interfaces at small and medium scale, land forms, and public open spaces in village (Lv 2017).

The system of pattern language on landscape ecological space network with words, phrases, and simple sentences, which include 56 patterns of 3 categories of words, 40 patterns of 3 categories of phrases, and 30 patterns of 4 categories of simple sentences. The significance is obvious for guiding the planning and design through applying pattern language of network, but it needs to receive feedback and make corrections during the process of research which is currently just in its infancy (Wang et al. 2011).

6.5 Land Form

6.5.1 Basic Pattern

6.5.1.1 Basic Types

Land form is classified into three categories of cultivated land, horticultural land, and fishery pond. There are 31 basic patterns as words and 49 aggregated patterns as phrases corresponding to the basic types of cultivated land including flat paddy field, flat dry field, sloping paddy field, and sloping dry field. There are 22 basic patterns as words and 27 aggregated patterns as phrases corresponding to the basic patterns of fishery ponds including farmland fishery ponds, river–lake fishery ponds, and dike-pond system. There are 11 basic patterns as words and 13 aggregated patterns as phrases of horticultural land including tea gardens and orchards according to topographical characteristics and planting crops.

6.5.1.2 Characteristics and Laws

The configuration of paddy field in plain is classified into types of tree branches, networks, blocks, and river networks. Paddy fields in tree branch locate mostly in valleys and ravines surrounded by mountains or hills. Paddy fields in network locate mostly in hilly areas, especially in areas with small and densely distributed hills. Paddy field in block locate generally in the plain with large and continuous area. Paddy fields in river networks locate in areas with dense waterways, where rivers intersect into the fields and divide into lots of field units, of which the shape, size, and density of paddy field units are also different according to different shape and width of water network.

The configuration of dry fields in plain is classified into types of tree branches, networks, blocks, curvilinear, and woodlands networks. Dry fields in tree branches locate in valleys and ravines with mountains or hills around. Dry fields in networks locate in hilly areas with small and densely distributed hills. Dry fields in blocks distribute in plain with flat terrain and broad fields. The residential areas distribute generally in clusters at the nodes of dry fields. Dry fields in woodlands networks consist of woodlands rows between fields with various shape and spatial rules, some woodland belts distribute regularly on the footpath among basic units, but some distribute on the footpath of aggregated units.

The configuration of paddy fields on slope area is classified into types of field with single-core, multi-cores, and non-core. The terraces with single-core are in a ring shape and enclosed edge of terrace which around a center from high to low. Some residential groups or vegetation clusters would distribute on the wide table of terrace according to the slope and the different widths of terraces. The terraces with multi-cores are in a ring shape and enclosed edge of platform which around two or more centers from high to low. The terraces with non-core are not enclosed and generally parallel to each other, of which the table of terrace would extend straight to the boundary.

The configuration of dry fields on slope is classified into types of fields with single-core, multi-cores, and non-core which are similar to that of paddy fields on slope, and many rows of woodlands distribute on the footpaths, and the settlements in clusters or in rows distribute at the broader fields. The difference between dry fields and paddy fields on slope area is that edges of the non-core terraces are often irregular, curved, and unsmooth enough. The terrace table changes in width and separated by shallow trenches in the terrace.

The configuration of fishery ponds in farmland is classified into types of tree branches, linear, fingers, and scattered points. Fishery ponds in tree branches distribute in farmlands, or next to farmland, or in shallow ditch. Fishery ponds in linear space are neatly spliced into single or multiple rows. Fishery ponds in scatter disperse in farmlands without connection to each other or close to each other. Fishery ponds in finger generally have a larger area and regular shape, of which the bottom is mostly connected with rivers and lakes and enlarge the area of each pond with irregular shape.

The configuration of fishery ponds attaching to river and lake is classified into types of linear, scattered, and block. Fishery ponds in linear space are mostly rectangular and generally attached to the banks of rivers or lakes. Fishery ponds in scattered points are irregularly distributed and scattered in the river and lake network and mostly distributed in areas with developed networks which are of different sizes and irregular shapes with varying intervals, but they are much smaller than fishery ponds scattered in farmland. Fishery ponds in block mostly locate in the South of the Yangtze River with developed water network, which are mostly arranged in a cell shape, and the dike is generally planted with crops or expanded into a residential group. The dike-pond is different from the other two types of fishery ponds, which is an eco-agricultural system with mulberry, sugarcane, fruit trees, and other crops on dike in the Pearl River Delta.

Horticultural land is summarized in two categories of tea garden and orchard, of which tea garden is classified into three types of oval ring, fan shape, and linear shape, and the orchard is classified into rectangular, arc, curved, and irregular shapes.

6.5.2 Aggregated Pattern Vocabulary

6.5.2.1 Aggregated Pattern Types

The combinations with same components refer to the different combinations of land form composed of same elements, which include combination of cultivated lands, fishery ponds, and gardens. Combinations of cultivated land include 3 categories and 12 subcategories of splicing, repeated, and surrounding type. Combinations of fishery pond include 2 categories of river–lake fishery pond and dike-pond system. Combinations of garden include one category of tea garden.

Combinations with different elements include combination of farmland and fishery pond, combination of farmland and horticultural land, combination of horticultural lands, farmland, and fishery pond, and combination of farmland, fishery pond, and horticultural land. Combination of farmland and fishery pond includes 3 major categories and 12 subcategories of surrounding, scattered, and splicing with block type. Combination of horticultural land and fishery pond has 1 category. Combination of farmland and horticultural land has 3 categories, and combination of garden, farmland, and fishery pond includes 4 types.

6.5.2.2 Characteristics and Laws

The planar form of land use in same type varies with environments, which would be combined together and resulted in diverse integrated spaces. The combinations of cultivated land are classified into types of splicing, surrounding with multiple types and repeated with single type.

Splicing type refers to cultivated land on slope or in flat spliced together with various land units, of which the configuration is in diversity depending on the topography, such as the combination of terraces and flat farmland in plain areas and combination of sloping terraces and flat farmland at the bottom of valley. Surrounding type mostly distributes in hilly areas where mostly were cultivated on slopes. Landscape of cultivated lands in configuration of net structure on dam fields in hills is enclosed with terraces and forms a concentric circle. Landscape with combination of flat cultivated land distributes in river bend surrounded with terraces on slope. Repeated type is more common in cultivated land on slope with configuration of repetition of the same kind of terrace units. Combination of fishery ponds includes two categories with different forms of fishery pond and dike-ponds. Both of them are composed of regular and irregular fishery ponds. Garden combinations are mainly generated by repetition of same units.

The combination of cultivated land and fishery ponds is classified into types of surrounding, scattering, and splicing with block. Surrounding type is mostly in clusters of cultivated land in terrace or flat surrounded by fishery ponds which are generally in rectangular units and layout in row. Scattering type means fishery ponds are scattered in cultivated land with various shapes, sizes, and density. Splicing with block refers fishery ponds are distributed in blocks spliced with cultivated land, or block fishery ponds are surrounded by cultivated land and spliced together.

The combination of cultivated land and horticultural land is mostly the combination of cultivated land and tea gardens which are distributed on slopes or small hills and in mononuclear or linear configuration. Cultivated lands around gardens are distributed on dam field or shallow ditches in configuration of branch or net.

The combination of horticultural land and fishery pond is mainly the combination of tea gardens and fishery ponds which are mostly in tree branch configuration and distributed around tea gardens which distributed on low hills like mononuclear terraces.

The combination of cultivated land, garden, and fishery pond includes the combination of cultivated land, orchard, fishery pond and the combination of cultivated land, tea garden, and fishery pond. For the combination of cultivated land, orchard, and fishery pond, fishery ponds locate at the edge of water body with wide dike, on which regularly planted with rows of fruit trees, and there are cultivated lands. For the combination of cultivated land, tea garden, and fishery pond, tea gardens are mostly in form of mononuclear terraces, which differs from the other two elements and their combinations. One of which is that fishery ponds are interspersed inside tea gardens and spliced with farmlands in configuration of tree branches, and the other is that fishery ponds combined with tea gardens are scattered in cultivated lands as spots or blocks.

6.5.3 Pattern Vocabulary

6.5.3.1 Pattern Vocabulary Construction

Pattern language of land form is composed of basic units as words, aggregated units as phrases, and spatial relations at multiple scales as grammar and geographic landscape as context (Fig. 6.10), which corresponds to the spatial system and ecological process of the interactions between human and nature. The vocabulary system of land form describes the basic vocabulary of land form and its characteristics, of which the common characteristics could be obtained by comparing pattern language of the same type of land form. Designers could grasp the necessary features through using landscape pattern language and establish a design concept derived from the characteristics of land form.

6.5.3.2 Features of Pattern Language

Land forms are rich in types and planar shapes, and their corresponding words and phrases of landscape pattern language are also abundant. Various combination patterns acting on as phrases are generated by combining with basic spaces of vegetation, farmland, and residential clusters, which also derivate rich combinations of


Words(1~69)
Phrases(1~7)

◀**Fig. 6.10** Pattern language system of land forms. **Words**: 1~9 Flat irrigated field, 10~18 Flat dry farmland, 19~27 Irrigated terrace land, 28~36 Dry terrace farmland, 37~45 River-lake fishery ponds, 46~51 Ponds in cultivate land, 52~60 Pond with dike, 61~63 Orchard, 64~69 Tea garden. **Phrases**: 1~2 Tree branch-like irrigated flat land, 3~5 Irrigated flat land in water network, 6~8 Network-shape irrigated flat land, 9~11 Block-shape flat irrigated field, 12~14 Tree branch-like dry flat farmland, 15~17 Block-shape flat dry farmland, 18~26 Woodland network dry farmland, 27~29 Mononuclear irrigated terrace field, 30~31 Multi-nuclear irrigated terrace field, 32~40 Non-nuclear irrigated terrace field, 41~43 Dry terraced farmland with nuclear, 44~48 Non-nuclear dry terraced farmland, 49~51 Linear river and fishery pond, 52~54 Scattered fishery pond along river, 55~57 Blocked river and fishery pond, 58~59 Branch-like pond in the field, 60 Linear dike-pond, 61~63 Scattered fishery pond in the field, 64~66 Finger-like river and fishery pond, 67 Finger-like fishery pond in the field, 68~69 Linear dike-pond, 70~74 Blocked dike-pond, 75 Grid tea garden, 76~77 Blocked dike-pond, 78~79 Ring-shape tea garden, 80~82 Grid tea garden, 83 Ring-shape tea garden, 84 Non-nuclear dry farmland on the terrace, 85~87 Grid orchard, 88~90 Linear orchard. **Simple sentences**: 1~6 Combination of splicing cultivated land, 7~9 Repeated cultivated land combination, 10~12 Enclosed combination of combination, 13~15 Combination of farmland and pond, 16~17 Combination of pond and garden, 18~20 Combination of garden and pond, 21~32 Combination of farmland and pond, 32~35 Combination of farmland-pond-garden

land form. The changes of land form are closely related to local climate because land is the important resources of production which is also closely related to local approaches, customs, and historical evolution of agricultural production.

Cultural heritage and ecological continuity reflecting from land form should be fully respected in the process of ecological landscape planning which shape the form of land, and the design should be based on the characteristics of various land forms. It could manifest the most reasonable state of land resources and could solve ecological problems in local practice, as well as form an ecological community beneficial to local development according to local conditions through landscape planning and design.

6.5.4 Pattern Language Application

6.5.4.1 Current Situation and Problems

The site locates at the South of Luhun Lake in Song County, Luoyang, Henan Province with the area of 2981 km^2 by length of 62 km long from east to west and 86 km width from north to south. Farmland is the dominant landscape with the elevation gradually decreasing from south to north, and the waterfront area is narrow but with gentle slope. The planned area is 88.3 km^2 with many residential areas scattered in the site and mostly concentrated in valley, where the dominant landscape is mainly farmland with few vegetation types. Traffic system is inconvenient because of only one urban expressway next to the site and with few connected secondary roads. The ecosystem is composed of single crops and few vegetation with simple community structure and weak ecological stability and landscape attraction.

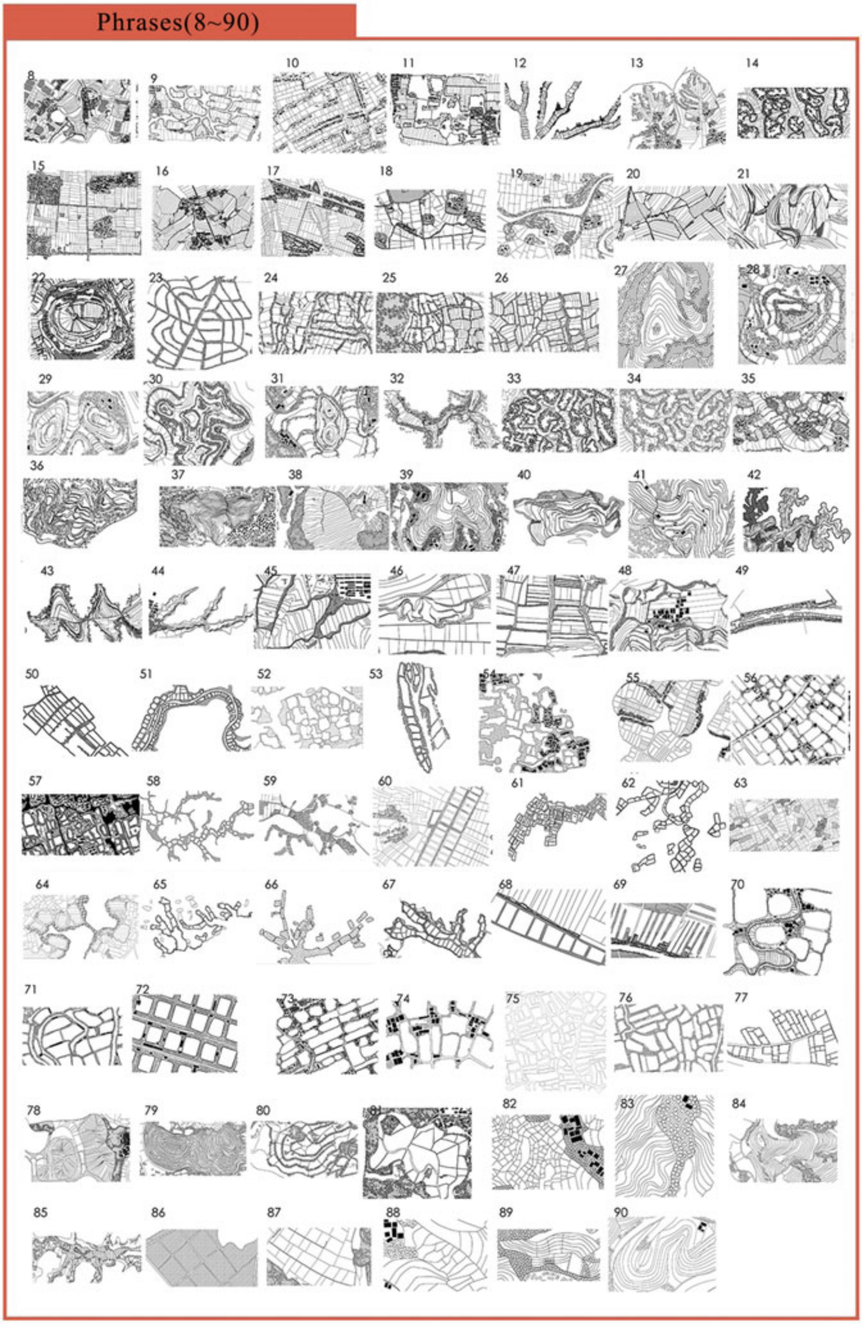


Fig. 6.10 (continued)

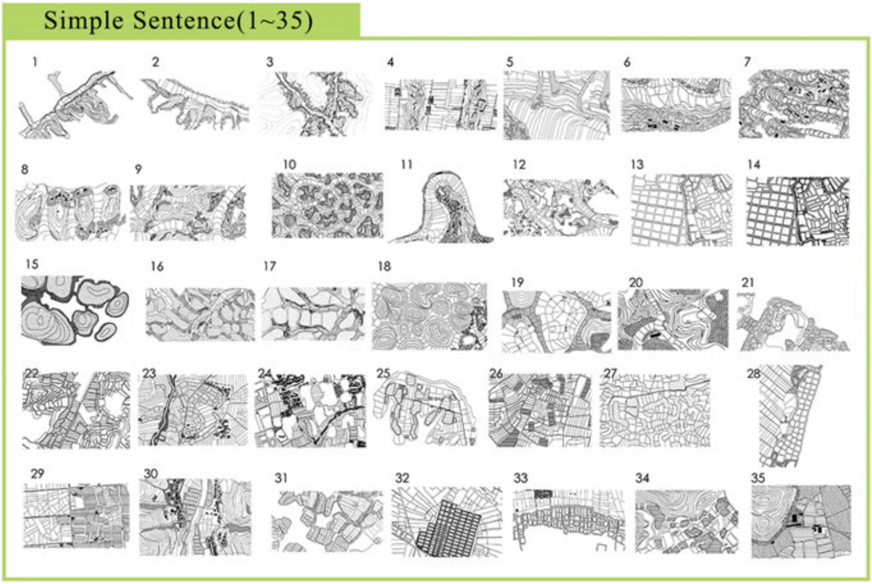


Fig. 6.10 (continued)

6.5.4.2 Pattern Selection

The goal is to plan an experience park dominated by productive landscapes with open viewing and good prospective. The topographical features should be fully utilized and strengthened for transformation and improvement the distinctive and various features of topographical landscape. The function orientation of this project is a productive landscape experience park by emphasizing the characteristics of hilly terrain in north, enriching landscape types, increasing vegetation types and ecological stability, and planning the productive landscape for tourists to experience, so it should make full use of landscape pattern language of land form in design.

Landscape pattern determines the overall structure of the park, and landscape space determines the spatial connections between different areas in the park. The holistic pattern is a combination of small hills and dam fields according to the analysis of topography, therefore, patterns of aggregated space with dry terraces and flat land in pattern language were adopted, of which combination pattern of spliced cultivated land and combination pattern of surrounding cultivated land are integrated in master planning.

It is necessary to fully consider the pattern facing a river while surrounded by mountains in space building to make full use of landscape advantages. Combination patterns of flat cultivated land, cultivated land and fishery pond, flat paddy land, flat dry field and residents, flat dry field, and fishery pond are adopted in the planning of total landscape. It mainly involves basic spaces of fishery ponds and cultivated lands, among which the pattern I and II of flat field in block and dry field, pattern of terrace with single-core and terrace without nuclear, pattern I and II of flat paddy field, pattern I and II of fishery pond in river–lake type are used in site planning and design.

6.5.4.3 Pattern Vocabulary and Application

The park is dominant with various productive landscapes and production modes for tourists to experience, in which mainly includes landscape of terraced field, rose flower, flat farmland, fishery ponds, and wetlands. The park is zoned into the terrace, fishery pond, flat farmland, rose flower, and wetland landscape function areas, which could meet the needs of tourists at multiple levels with various functions and landscape features and form the total structure with five centers and two belts. The five centers are, respectively, experience garden of fisherman, leisure farm, wetland maze, sea of roses, and a terraced farmhouse. The two belts are landscape belt along the lake and landscape belt in flat farmland, which could be enjoyed and felt the charm of large-scale farmland and the sea of flowers by tourists along landscape belt.

The construction of terraced landscapes mainly relies on three basic patterns of single-core and non-core types, one of which is a flat curve type, and the other is arranging community groups and residential groups on a broad field, among them the residential group serves as an experience farm garden. The flat farmland area includes 4 landscapes of farmland on waterfront, farmland surrounding, sea of rose and wetlands, in which the sea of rose adopted a pattern of farmland surrounding residential clusters. Wetland garden refers to patterns of flat paddy fields which are scattered in water area and connected by plank roads to form an interesting wetland maze.

Fishery ponds landscape refers to patterns of river–lake fishery ponds and makes full use of the waterfront advantages. Individual fishery ponds are in cell-shaped and without connection to each other. Fishing experience ponds are distributed in groups as important nodes of fishery pond landscape with plant communities to create stable and diverse leisure spaces.

Aggregated landscape includes the combination of terraced and flat farmland and combination of fishery pond and farmland. The overall layout of the park is in circle-shaped with flat farmland landscape surrounding terraced landscape, of which it forms a landscape belt with broad fields and rich landscape types at the junctions. The combination of fishery pond and farmland refers to patterns of splicing combination, which are connected by ecological spaces, and could direct tourists to enter farmland landscape after experiencing fishery pond landscape (Fig. 6.11).

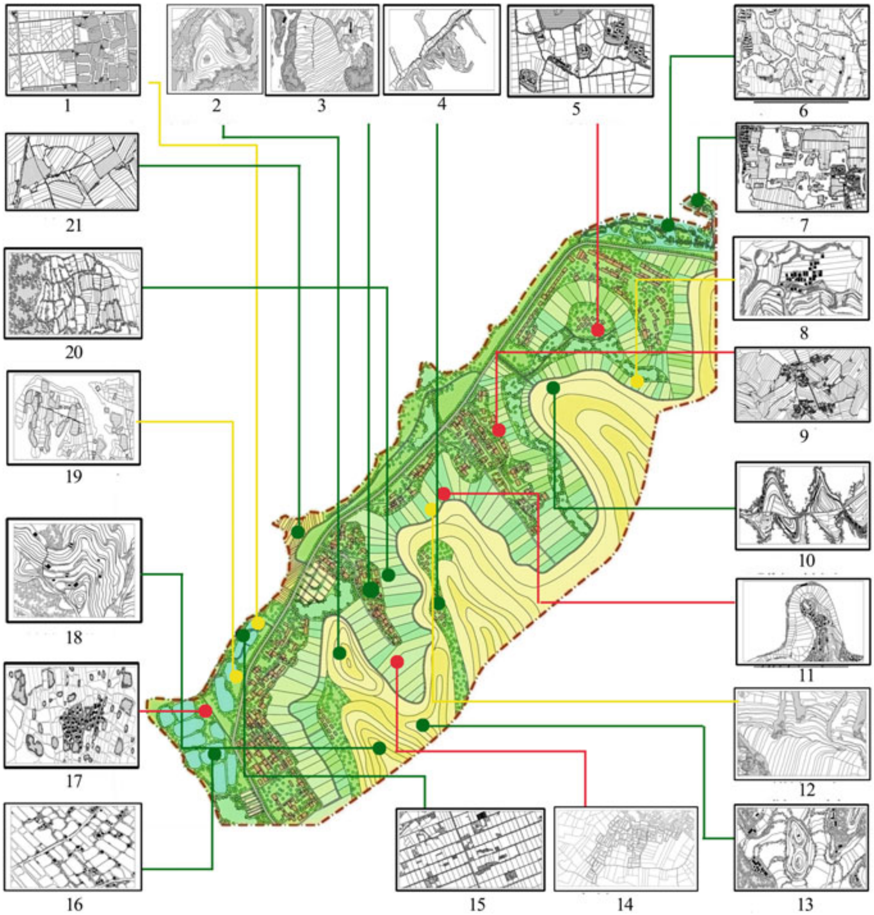


Fig. 6.11 Pattern language application of land forms. 1 Combination of cultivated land and fishery pond, 2 Mononuclear field on the terrace, 3/8 Non-nuclear field on the terrace, 4 Combination of cultivated land, 5 Settlements, 6~7 Flat irrigated field, 9 Settlements, 10/13 Non-nuclear field on the terrace, 11 Combination of cultivated land, 12 Combination of cultivated land, 14/15/17 Fishery ponds, 16/18 Settlements, 19 Mononuclear terraced field, 20 Combination of cultivated land and fishery ponds, 21-22 Flat dry farmland

6.5.5 Verification of Pattern Language

6.5.5.1 Recording Historical Human–land Interactions

As human cultural landscape, land form is a historical record of human–land interaction, which not only reveals the unique geographical characteristics but also reveals human and cultural characteristics of the places as important parts of landscape. The diversity of land forms is determined by various land types and local culture landscapes, which manifests a horizontal mosaic structure under landscape processes and vertical nested structure of land form units at different scales (Hu and Wang 2015).

6.5.5.2 Library of Pattern Vocabulary

The prototypes of land form were analyzed and compared based on principles of landscape linguistics, landscape morphology, and landscape ecology, and the unique patterns of land form were studied in different environments and at multiple scales based on natural and human processes. The categories of land forms and their spatial relationships were discussed systematically, and further, basic design vocabularies of words and phrases were obtained from landscape components to the combinations of spatial units based on the theory of landscape pattern language of land form, which include 3 categories, 9 subcategories, and 64 words, 3 categories, 9 subcategories, and 89 phrases, and 2 categories, 7 subcategories, and 35 simple sentences.

6.5.5.3 Integrating Process with Land Form

It can be seen from the applications of landscape pattern language which could be applied at levels of holistic pattern, combination pattern, basic unit, and landscape elements to create total landscape, various types, and unified landscape based on site conditions, reasonable combination pattern selection, conversion of design vocabulary for land form, and choice of nested structure of landscape space at multiple scales. In the actual case, a combination pattern of surrounding cultivated land was adopted to shape the configuration of holistic landscape, in which landscape spaces include fishery pond, terraced space, flat farmland, and their combination space. Landscape elements include fishery pond and cultivated land, etc. Different types of land forms are combined and nested with each other, and the final design is to form a park with strong experience based on productive landscape integrating sightseeing, experience, and production (Wang et al. 2016).

6.5.5.4 Context Dependence and Production Mode

Land form is greatly affected by the geographical environment and production modes, which shows extremely fragile characteristics with the development of social-economic and technological changes. Some land forms with distinctions have become the common cultural heritage for human beings, of which the protection and continuation are the important values of pattern language research and application. The locality and diversity of landscape pattern language of land forms, as well as the laws of scaling and nested structure of pattern language, have become important domains for further researches on landscape pattern language of land form (Wang and Cui 2015).

6.6 Landscape Axis

Landscape pattern language provides an alternative framework and approach for cognizing, analyzing, expressing, and experiencing landscape space. As an important characteristic of landscape, pattern language of landscape axis could be established according to the classification of axial space as the attributes of ecological, productive, and dwelling space in total human ecosystem based on the horizontal and hierarchical structure of linguistics, as well as the horizontal splicing and vertical nested structure in landscape pattern depended on the theory of human ecology and methods of planning and design through classification of typical patterns at multiple dimensions and multiple levels, which includes the axis elements and axis patterns acting on as words, phrases, and simple sentences (Wang 2009).

6.6.1 Pattern of Landscape Node

6.6.1.1 Types of Node Pattern

The various node patterns are composed of different spatial elements acting on as the core or sequence space in traditional culture landscape, which could be classified into three spaces of natural and productive combination, natural, and human combination and human construction space based on space elements, functions, and forms.

The natural and productive combination patterns include 4 types and 10 patterns of vegetation and arable land combination, water system and paddy field combination, water system, vegetation and arable land combination, and road system and arable land combination. The human combination patterns include 5 types and 26 patterns of architectural nodes, multi-architectural nodes, buildings and courtyard combination, buildings and road combination, and public open space. The natural and human combination patterns include 4 types and 11 patterns of combination between building, road and waterbody, combination between building and vegetation, combination between building, vegetation and road, and combination between building, road, water system, and vegetation.

6.6.1.2 Characteristics and Laws

The natural and productive combination patterns could be classified into combination of vegetation and farmland, combination of water system and paddy field, combination of water system, vegetation and cultivated land, and combination of road and cultivated land according to different types and combinations of spatial elements, which have their own forms suitable to geographic features and production modes. Combination patterns of vegetation and cultivated land are common in rural settlements at different regions, of which landscape forms reflect the spatial relationships as spaces interlaced, separated, or sandwiched with the change of topography and geomorphology. Combination patterns of water system and paddy field are common too in inland river waterfronts or coastlines, of which landscape forms of water interface in plain are linear spaces centered on river channels, and fishery ponds, polder areas, and paddy fields are irregularly surrounded by shorelines on both sides. Combination patterns of water system, vegetation, and cultivated land are common in plains or hilly areas centered with linear water systems with vegetation and cultivated land on one or both sides. Combination patterns of road and cultivated land are widely distributed in plain areas with single-linear or multiple linear roads crossing through farmland or cultivated land.

The construction node patterns of landscape axis could be classified into 5 categories of building node, multiple buildings node, building and courtyard combination, building and road combination, and public open space according to multiple scales and element relationships. Small square courtyard is an independent unit of landscape axis node reflecting the cultural concept of family in traditional village. Multiple nodes patterns are common in traditional settlements of defense, patriarchal clan, religion, and culture, in which the former reflects distribution of several large courtyards in a circle pattern, and the latter reflects distribution of nodes in finger pattern along the stepped terrain strengthening the importance of spiritual and cultural characteristics in space. It is a common pattern for building and courtyard combination with the large public courtyard, family ancestral hall, religious site, and residential courtyard, which usually has an important position in dominating patterns with concentrated area of cultural beliefs reflecting on the ideas of patriarchal clan.

Combination patterns of building and road include 3 types of free layout of residential buildings along road, buildings keeping away from the road, and building group enclosing the road to form a bazaar, of which the first type exists in various terrain environments, the second type exists in undulating terrain such as mountains and hills, while the third type is suitable for market-oriented landscape located at the road cross. Patterns of public open space include the aggregated spaces with a center of ancestral halls, green spaces, temples, and waterbodies, respectively, which act as an event space for public activities in settlement accompanied usually by spaces of religion, festive activities, daily communication, and other important functions related to the production and life of residents.

6.6.2 Basic Pattern

6.6.2.1 Types of Basic Pattern

Basic patterns of landscape axis refer the spaces formed under the influence of single spatial component based on node pattern, which could be classified into 2 types of single axis with mono-element and multi-axis with mono-element according to the number of axis.

Basic patterns of single axis with mono-element are classified into five categories of road-settlement, water system-settlement, vegetation-settlement, topography-settlement, and human inducement-settlement. Basic pattern of road-settlement includes two types of straight line and enclosed circle. Basic pattern of water system-settlement includes artificial linear, natural curve, and enclosed types. Patterns of vegetation-settlement are in linear spaces with the different configuration of linear nested and linear wrapped. Basic patterns of topography-settlement include three types of the settlement paralleled along terrace, settlement vertically crossing the terrace, and settlement surrounding terrain. Basic patterns of human inducement-settlement include 3 types of the extension with cultural building, extension with market orientation, and extension with defense.

Basic patterns of multi-axis with mono-element are classified into three categories of road-settlement, water system-settlement, and vegetation-settlement. Basic patterns of road-settlement include three types of parallel, vertical, and staggered configuration. The vertical and staggered patterns include 3 types and 2 types, respectively. Basic patterns with multi-axis of water system-settlements include two types of the parallel and vertical staggered configuration, of which the latter includes 2 subcategories of natural staggered and geometrically vertical configuration. Basic patterns of vegetation-settlement are just 1 type of the staggered configuration.

6.6.2.2 Characteristics and Laws

The shape of a pattern with monoaxis and single element is relatively simple in linear, curved, or enclosed type under the influence of artificial or natural factors. For patterns of landscape axis dependent on road, spatial patterns of residential buildings distributed along a road are determined by the shape of road with linear feature as landscape axis clearly, which can be classified into axis patterns of settlement prolonged with road and settlement circled with road according to road shape and relationship with settlement. For patterns of landscape axis under the influence of water system, they are mostly distributed in areas with abundant water systems, which could be classified into patterns of artificial linear space and natural curvilinear space according to the process and shape of water system. For patterns of axis combined vegetation with settlement are commonly in various landscape, they are greatly influenced by the form of vegetation corridors which generally include natural forest belts and artificial economic forest belts. For patterns influenced deeply and directly by topography and landform as the main components of human settlements, they could be classified into types of settlement with parallel terrace, settlement with vertical terrace, and settlement surrounding the terrace according to the construction model of settlement on the terrace. Patterns induced by human have the feature of self-organization in different shapes and sizes, which could reflect the primary and secondary rhythms created by the ancestors in space construction and could be classified into types of induction with cultural building, with rural market and with defense according to historical functions of landscape.

Landscape patterns with multi-axis present more complicated morphological features of parallel, perpendicular, and staggered configuration. For patterns of settlement with multiple axis based on road, they locate in traditional settlements with mature road networks in parallel, vertical, or staggered configuration corresponding to the settlement form in clumps or finger shape. For patterns of settlement with multiple axis based on water system, they distribute in areas with well-developed water networks in parallel and vertically staggered configuration according to the structure of water system and the degree of residents depended on water resources. For patterns of settlement with multiple axis along vegetation, forests are closely related to the environment of traditional human settlement, of which the strips of contiguous forests form a parallel and staggered relationship with settlements and play a role of shelterbelts for settlements and farmlands.

6.6.3 Aggregated Pattern

6.6.3.1 Types of Aggregated Pattern

Spatial patterns of landscape axis are often the result of various elements combination. Aggregated patterns of landscape axis are classified into two types of mono (multiple) axis with dual elements and mono (multiple) axis with multiple elements. Patterns of mono (multiple) axis with dual elements are classified into combination of public space with road and settlement, combination of vegetation with road and settlement, combination of terrace land with road and settlement, combination of landform with vegetation and settlement, combination of water system with road and settlement, combination of water system with topography and settlement, and combination of water system with vegetation and settlement. Axis pattern of public space, road with settlement combination could be classified into types of overlapping, vertical, radiating, and enclosing configuration. Axis pattern of vegetation, road with settlement combination is classified into aggregation fitting single-linear space and aggregation-related multi-linear space. Axis pattern of terrace land, road, and settlement combination is classified into type of terrace enclosing road and settlement, type of road perpendicular to terrace settlement, type of road and settlement along the terrace. Axis pattern of topography, vegetation with settlement combination includes two categories of single curve and multi-curve enclosed aggregations. Axis pattern of water system, road, and settlement combination is classified into parallel, vertical, enclosed configuration, and interface fitted configurations in flat area. Axis pattern of water system, topography, and settlement combination is classified into interface aggregated to mountain area and interface aggregated to water system. Axis pattern of water system, vegetation, and settlement combination is classified into types of water system and vegetation surrounding settlement and water system and vegetation paralleled settlement.

Patterns of mono (multiple) axis with multi-elements include 6 categories of terrace land, road, vegetation, and settlement combination, water system, road, vegetation, and settlement combination, water system, road, topography, and settlement combination, water system, vegetation, topography, and settlement combination, public space, road, vegetation, and settlement combination, and terrain, roads, water system, vegetation, and settlement combination. For axis patterns of topography, road, vegetation, and settlement combination, they include 3 types of interface along a linear space in mountain area, single-linear space enclosure in mountain area, multiple linear spaces paralleled in mountain area. Patterns of water system, road, vegetation, and settlement combination are classified into types of single-linear space paralleled in plain area, single-linear space surrounding in plain area, multiple linear spaces paralleled in plain, single-linear space wrapped in mountainous area, multiple linear spaces paralleled in mountainous area. Patterns of water system, roads, topography, and settlement combination mainly appear as types of double-wrapped linear configuration in mountain area. Patterns of water system, topography, vegetation with settlement combination appear as 2 types of multiple linear spaces paralleled and double-wrapped linear space in mountain area. Patterns of public space, road, vegetation, and settlement combination include 2 types of the star and land enclosed configuration in flat area. Patterns of topography, road, water system, vegetation with settlement combination include 5 types of single-linear double-wrapped interface, multi-linear double-wrapped interface, single-linear paralleled interface, and multi-linear staggered interface.

6.6.3.2 Characteristics and Laws

Landscape axis patterns of settlement combined with other two elements include 7 types of public space, road, and settlement combination, vegetation, road, and settlement combination, terrain, road, and settlement combination, terrain, vegetation, and settlement combination, water system, road, and settlement combination, water system, topography, and settlement combination, and water system, vegetation, and settlement combination.

Public culture spaces are the spatial expression of human and socio-ecological characteristics of landscape space. The combination models of various elements in axis patterns of public space with road and settlement can be classified as types of overlapping, vertical, dispersal, and enclosed configuration (Ye 2012). Axis patterns composed of vegetation and roads are typical patterns of linear residential space in landscape, which could be classified into types of single-linear fitting space and multi-linear connecting space according to the relationship of vegetation belt and combination of road and settlement. Axis patterns of topography, road with settlement combination exist in mountain and hilly area at multiple scales, which are classified into 3 types of combination road with settlement wrapped with terrain, combination of perpendicular to the terrain, and combination along the extension of terrain. Axis pattern of topography, vegetation, and settlement combination with less area of productive space is based on the background of steep and rugged hilly terrain and dense vegetation, of which the cultural characteristic tends to be larger than that of ecological function. Axis pattern of water system, road with settlement combination includes types of parallel, vertical, and enclosed configuration in flat area and interfaces of waterway fitting the mountain. The axis of linear waterways and the axis of linear road act together on spatial form of settlements. Axis pattern of waterway, topography with settlement combination includes types of interface aggregated near the mountain and interface aggregated near waterways according to the distance between settlements and mountains or rivers. Axis pattern of waterway, vegetation with settlement combination often shows as a long and narrow land inside the river, which includes combination of waterway and vegetation surrounding settlement and combination of waterway, vegetation, and settlement paralleled each other with considering the ratio of waterways in total area, extension of buildings, and spatial relationship of vegetation belt.

Axis patterns of settlement combined with multiple elements are classified into 6 types of terrain, road, vegetation, and settlement combination, waterway, road, vegetation, and settlement combination, waterway, road, topography, and settlement combination, waterway, vegetation, topography, and settlement combination, public space, road, vegetation, and settlement combination, and terrain, road, waterway, vegetation, and settlement combination. The socio-ecological characteristics of axis patterns in most areas could be expressed with pattern language of topography, road, vegetation, and settlement combination which covers all interfaces between mountains, hills, plateaus, and other topography with the configuration of interface with single-linear space along the extension of mountain, single-linear space enclosed mountain, and multiple linear space paralleled the direction of mountain extension. Patterns of waterway, road, vegetation, and settlement combination exist in areas such as water network in plain areas with an extensive wide distribution and a variety of types, which are classified into types of linear space paralleled, linear space surrounded, and multiple linear spaces paralleled in plain, linear space wrapped, and multiple linear spaces paralleled in mountainous area. Axis pattern of waterway, road, and settlement combination exists in the valleys, canyons, and gullies of plateaus and mountainous regions, which is relatively close and grows along the waterfront of river and the slope with the configuration of linear space double-wrapped with mountain. Aggregated patterns of waterway, vegetation, and settlement with specific terrain are mostly distributed in hills, mountainous, and interfaces of river valleys with configuration of linear space double-wrapped. Aggregated patterns of public space, road, vegetation, and settlement distributed in traditional culture landscape, which include the star and enclosed configuration in flat area. Aggregated patterns of road, waterways, vegetation, and settlement with specific terrain locate in areas with rich natural geographical resources, which include interface enclosed with linear space, interface enclosed with multiple linear space, interface paralleled waterway, and interface with multiple linear apace staggered in mountain area.

6.6.4 Vocabulary of Landscape Axis

6.6.4.1 Construction of Pattern Vocabulary

The dwelling, production, and ecological spaces are combined with five basic spatial elements of settlements, vegetation, waterways, roads, and terrain, which act on as the material basis and spatial background of landscape axis (Wang 2015). According to the complexity of spatial composition, form, process, and their driving forces, and following the logic of *'from less to more'* and *'from simple to complex'*, patterns language of landscape axis are composed and nested with *'words'* as basic patterns, *'phrases'* as aggregated patterns, and *'simple sentences'* as holistic patterns corresponding to spaces hierarchically, which are assembled together to build a landscape pattern language of axis providing an effective reference for the identification of landscape axis and protection of spatial patterns (Fig. 6.12).

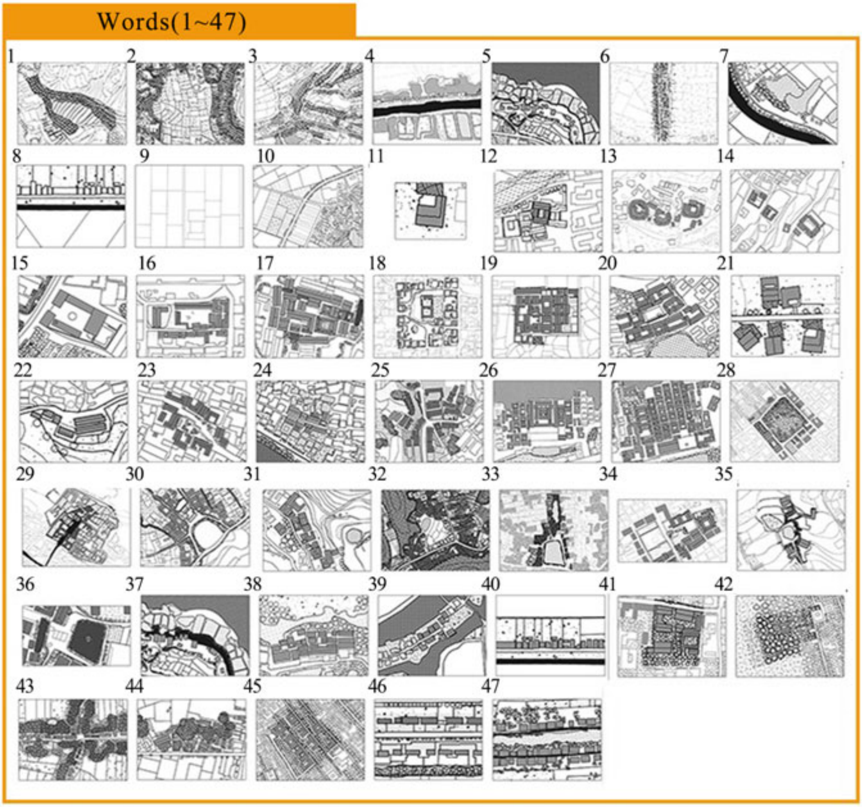
6.6.4.2 Features of Pattern Vocabulary

Landscape axis is an important carrier for the intangible culture of traditional villages, which determines the spatial sequence and development direction of space and provides a channel for flows of material, energy, and information in landscape space. The method and paradigm of axis design are the prerequisite for the regeneration of landscape space with clear structure and integral pattern. The formation of axis space is a process of coupling the natural and human factors organically in landscape space with distinct characteristics of scale. It is the key to the design of landscape axis and the protection of overall landscape pattern through understanding this process. It has certain laws to follow to shape axis spaces with the orientation of unique natural environment and social or cultural background in different areas. Broadly, it is necessary to take into account the specific characteristics of the site and consider the production, dwelling, and ecological factors of space comprehensively for the selection and utilization of patterns improvise under the limitation of complexity, randomness, and flexibility of formative mechanism of landscape axis in actual application (Yang 2015b).

6.6.5 Application and Verification

6.6.5.1 Characteristics and Problems of Site

The Nanhu Village of Xuancheng in Anhui Province locates at the North of Nanyi Lake with the area of 15.3 km^2 and surrounded by waterbodies on other three sides with humid climate, distinct seasons, beautiful landscape, and harmonious environment, where the terrain is various in the trend from highland in the northwest to


Words(1~47)
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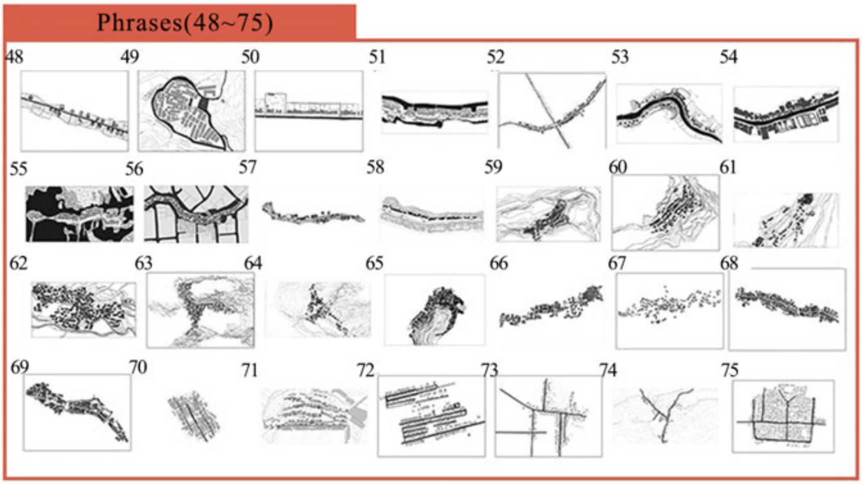
Phrases(48~75)
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◀**Fig. 6.12** Pattern language system of axis spaces. 1~3 Node pattern of vegetation and farmland, 4~5 Node pattern of water and irrigated farmland, 6~8 Node pattern of water, vegetation, and farmland, 9~10 Node pattern of road and farmland, 11~12 Node pattern of building, 13~14 Node pattern of buildings, 15~20 Node pattern of building-courtyard, 21~25 Node pattern of building-road, 26~36 Node pattern of open space, 37~40 Node pattern of building-road-water combination, 41~45 Node pattern of building-vegetation-road combination, 46~47 Node pattern of building-vegetation-road-water combination, 48~49 Pattern of single axis road-settlement, 50~56 Pattern of single axis water-settlement, 57~58 Pattern of single axis vegetation-settlement, 59~65 Pattern of single axis settlement-terrain, 66~69 Pattern of single axis road-settlement caused by human factors, 70~77 Pattern of multi-axis road-settlement, 78~81 Pattern of multi-axis water-settlement, 82~83 Pattern of multi-axis vegetation-settlement, 84~90 Combination of cultural space-road-settlement, 91~96 Combination of vegetation-road-settlement, 97~103 Combination of terrain-road-settlement, 104~105 Combination of terrain-vegetation-settlement, 106~114 Combination of water-road-settlement, 115~116 Combination of terrain-water-settlement, 117~120 Combination of water-vegetation-settlement, 121~129 Combination of terrain-road-vegetation-settlement, 130~135 Combination of water-road-vegetation-settlement, 136~140 Combination of water-terrain-vegetation-settlement, 141~142 Combination of water-terrain-road-settlement, 143~144 Combination of public-space-road-vegetation-settlement, 145~152 Combination of terrain-road-water-vegetation-settlement

lowland in the southeast, along which the section is composed of the mountain foot, interfaces between hills and valley intermeshed, and interfaces between hills and lake intermeshed. The central market formed by the crossing of township roads and county roads from north to south in the village acts on as north–south axis of total landscape with the configuration of fish bone in the middle and southern regions conforms to interfaces between valley and hill and the distinctive feature of hilly woodland cluster pattern in southern Anhui.

Nanmuzui is a natural village under the government of Nanhu Village with the population of less than 80 people and 20 buildings, most of which are traditional residential buildings with brick-timbered structure and high value of heritage in the configuration of obvious axis pattern of peninsula shape. The big challenge of the village for local government is to provide resettlement and employment for fishermen under the restriction of water resource and other natural spaces conservation. The interface in shape of peninsula between mountain and lake is steep and covered by natural forests which surround the fishing village in cluster. The cultivated land is mostly the private plots around houses with limited agricultural industry value (Yang 2015). The industry of extensive aquaculture on west side of the village was gradually developed through building ponds at the edge of lake, which impacted severely on natural landscape.

6.6.5.2 Selection of Pattern Vocabulary

On the basis of master planning and interpretation of axis patterns in residential area, the goals of planning and design are to coordinate socio-ecological axis as a corridor system to protect the authenticity of landscape personality and spatial

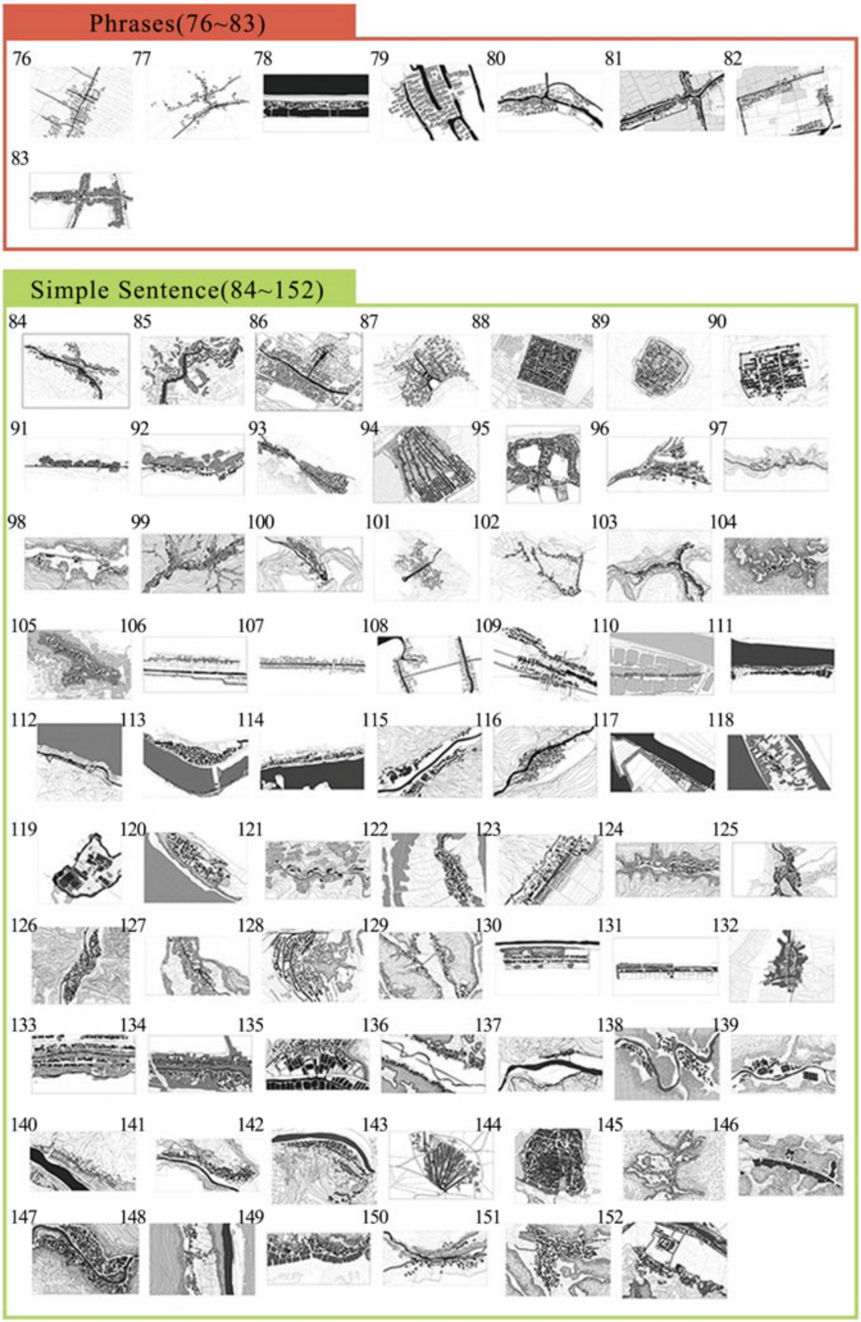

Fig. 6.12 (continued)

patterns dominant the landmarks of traditional village and develop a model of intensive and efficient eco-agricultural industry and industry of vacation tourism based on ecological agriculture and cultural resources of traditional village, which is help to solve problems in the process of long-term sustainable conservation and utilization of water-related resources of the lake. The target of fishery village integrated function of lake sightseeing, culture-based fishery, and recreation or vacation would accelerate the integration of income growth approaches of fishery transformation, rural recuperation, and tourism, which is to solve the problem of industry output, resettlement of residents, and conservation of landscape.

In order to strengthen landscape character and functions of culture and economy, total landscape was planned as 7 distinctive zones which include tourist service center, traditional cultural street, settlement pattern protection, leisure resort, traditional agriculture, culture-based fishery, and natural vegetation community conservation, which are organized with three landscape axis for modern tourism development, traditional socio-ecological landscape conservation, and traditional agricultural enhancement combined with ecological landscape. Because of rural landscape as a mosaic of multiple elements with distinctive characteristics of local context and intangible human driving factors, the multiple elements coupling pattern was applied in planning as expression of landscape pattern language, which is similar in topographic and geomorphic elements. In addition, the coupling network of village would be reconstructed through the adjustment of spatial pattern of landscape axis (Fig. 6.13).

6.6.5.3 Application of Pattern Vocabulary

The village was planned as 4 function areas of traditional cultural landscape protection, development of tourism and vocation, experimental base of lake aquatic species cultivation and development of culture-based fishery with the total spatial structure of three axes, dual centers, and two bases, among which the dual centers are the comprehensive service center for tourism and demonstration center of industries transformation, and the two bases are the experimental base for aquatic production and the cultural-show base. The axis of traditional cultural landscape was regenerated along the road distribution 20 traditional houses on both sides in order to comply with tourism development and fishery production. The axis of agricultural resort settlement on the lakeside was improved by using the pattern paralleled with axis of settlement to ensure the widest viewing of landscape based on basic patterns of landscape axis.

According to situations of the village in peninsula shape and location at the interface between slope and lake, spatial forms of roads, vegetation, and other spatial elements are conducive to the formation of traditional landscape axis. The pattern vocabularies as words of landscape axis are selected from basic patterns of single element and single axis to eliminate messy spatial forms and elements, grasp the main spatial form and pattern, and create ecological patterns of traditional fishery village. Settlement axis dependent on road with traditional buildings should be planned on high terrain for tourists to enjoy the scenery which could be displayed in front of

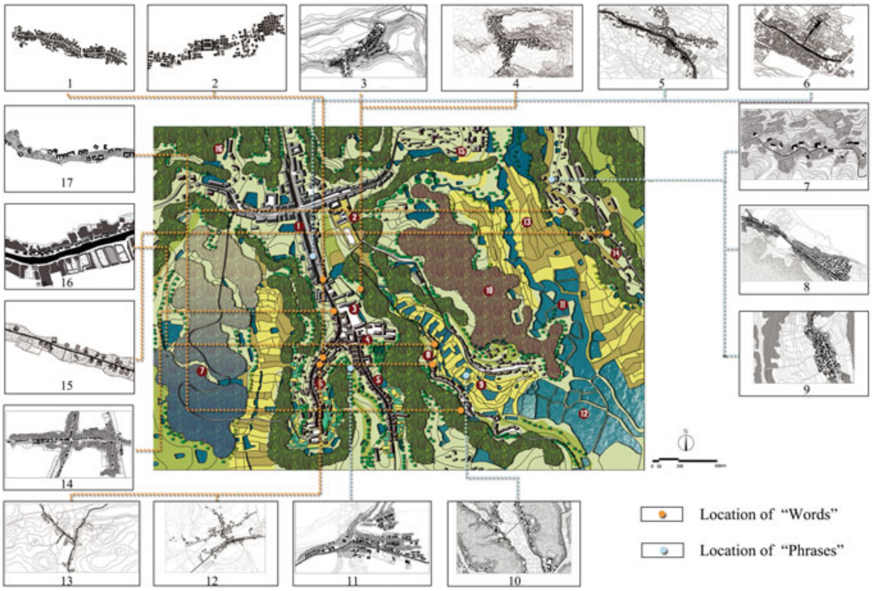

Fig. 6.13 Pattern vocabulary application of landscape axis. 1 Pattern of single axis settlement caused by human factors, 2 Pattern of single axis settlement caused by human factors, 3 Pattern of landform settlement single axis caused by topography, 4 Coupling of public cultural space, road, and settlement, 5 Coupling of public cultural space, road and settlement, 6 Coupling of terrain, road-vegetation, and settlement, 7 Coupling of vegetation, road, and settlement, 8 Coupling of terrain, vegetation, and settlement, 9 Pattern of single axis settlement caused by vegetation, 10 Pattern of single axis settlement caused by river, 11 Pattern of single axis settlement caused by road, 12 Pattern of multi-axes settlement caused by vegetation, 13 Pattern of multi-axes settlement caused by vegetation, 14 Pattern of multi-axes settlement caused by road, 15 Pattern of multi-axes settlement caused by road, 16 Coupling of vegetation, road, and settlement, 17 Coupling of terrain, road, vegetation, and settlement

different people with high opportunity. Small resort village dependent on the polders should be paralleled to the traditional fishery village. Compound words as basic patterns with single element and multiple axis including the multi-axis basic pattern of settlement based on road and the multi-axis basic pattern combined water system and road could meet the needs of space transformation and provide design reference to spatial patterns (Zhang 2013).

For pattern vocabularies as phrases of landscape axis, the single-linear wrapped axis of vegetation, road, and settlement combination driven by terrain could be suitable for tourism reception and service of fishery village, which is also more conducive to tourists for enjoying the scenery according to the survey on natural resources.

For pattern language of landscape axis used in village planning, a total of 5 types of 9 pattern vocabularies of single element with single axis were selected at the level of simple words, which includes pattern vocabulary of settlement based on road, water system, vegetation, topography, and cultural buildings, respectively. 2 types and 3

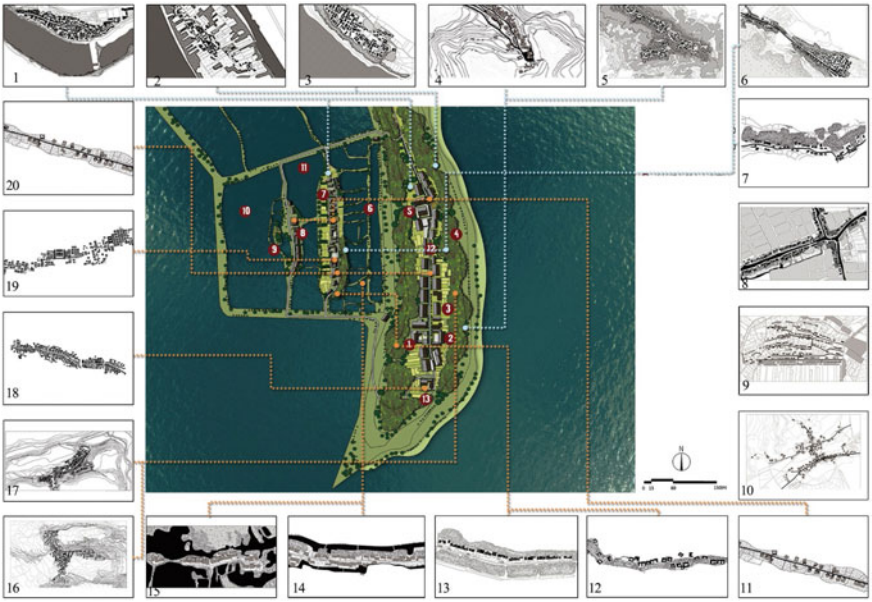

Fig. 6.14 Pattern language application of landscape axis in Nanmu Village. 1 Combination of water, roads, and settlements, 2 Combination of water, vegetation, and settlements, 3 Combination of water, vegetation, and settlements, 4 Combination of terrain, roads, and settlements, 5 Combination of terrain, vegetation, and settlements, 6 Combination of vegetation, roads, and settlements, 7 Combination of vegetation, roads, and settlements, 8 Basic pattern of multi-axis settlement and waterbody, 9 Basic pattern of multi-axis settlement and road, 10 Basic pattern of multi-axis settlement and road, 11 Basic pattern of single axis settlement and road, 12 Basic pattern of single axis settlement and vegetation, 13 Basic pattern of single axis settlement and water, 14 Basic pattern of single axis settlement and waterbody, 15 Basic pattern of single axis settlement and waterbody, 16 Basic pattern of single axis settlement and terrain, 17 Basic pattern of single axis settlement and terrain, 18 Basic pattern of single axis settlement caused by human factors, 19 Basic pattern of single axis settlement caused by human factors, 20 Basic pattern of single axis settlement and road

pattern vocabularies of single element with multi-axis were selected at the level of compound words, which includes the pattern of settlement based on water system and on road, respectively. A total of 4 types and 7 pattern vocabularies with dual elements coupling were selected at the level of phrases including combination of vegetation, road, and settlement, combination of terrain, road, and settlement, combination of terrain, vegetation, and settlement, and combination of water system, vegetation, and settlement (Fig. 6.14).

6.6.5.4 Verification of Pattern Vocabulary

Landscape pattern language is a new approach and method for exploring the composition and laws in socio-ecological design of landscape, which aims at providing a basis for socio-ecological planning and design practice in the protection of landscape axis and spatial pattern, and the inheritance of intangible culture heritage. Pattern vocabularies of landscape axis are divided into three parts of basic pattern of space node, basic pattern of axis, and aggregated pattern of axis and act on correspondingly as words and phrases of landscape pattern language from the classification of linguistics, landscape language, and morphology. Among them, it has 8 categories, 25 medium categories, and 69 subcategories acting on as words, 3 categories, 6 medium categories, and 14 subcategories acting on as simple phrases, and 7 categories, 17 medium categories, and 37 subcategories as compound phrases, as well as 6 categories, 17 medium categories, and 32 subcategories as simple sentences. Landscape pattern language of axis had been verified effectively in the application of village planning to protect spatial patterns and landscape axis of traditional village, the inheritance of intangible cultural heritage, and the development of ecotourism industry. It is necessary to further explore the internal mechanism of pattern formation, study the individual landscape characters of sample space and common features in regional design, strengthen the applicability and pertinence of axis pattern language, and enrich pattern language of local landscape (Wang 2009, 2011, 2017).

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Chapter 7
Spatial Relationship and Pattern Language Lexicon

Landscape space units could be classified into basic unit, aggregated unit, and holistic unit with different characteristics of spatial relationship at multiple scales (Wang 2011, 2017). Basic units could be classified into independent and related landscape basic space, and aggregated units could be classified into combination of fused space, parallel space, superposition over-space and networks. Among them, the superposition space combination has three forms of nested, overlaid, and overlapping. Networks include five forms of intersecting, interweaving, interlocking, continuous, and interrupted spaces (Table 7.1).

7.1 Spatial Relationship of Basic Space Unit

7.1.1 Lexicon of Independent Landscape

Independent basic spaces of landscape are basic units often appearing in relatively small-scale patterns with independent structural characteristics, of which the elements are relatively simple and easy to identify, the forms of space usually manifest the shape of cluster with a certain sense of enclosure and the weak expansion capacity of elements to the periphery.

Basic spaces meeting the requirements of independent landscape are mainly the patterns of settlement location influenced by daily life and leisure. However, not all patterns of settlement location meet the requirements of basic space, only some cluster-shaped independent settlement patterns are more in line with the basic space characteristics of independent landscapes (Fig. 7.1).

Cluster settlements could be classified into two basic types without considering the environment around settlements, one is the settlement surrounded only by vegetation, and the other is the settlement surrounded or passing by waterbodies besides vegetation. Among them the vegetation-enclosed settlements could be classified into

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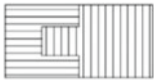
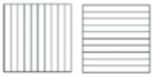
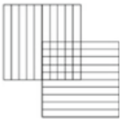
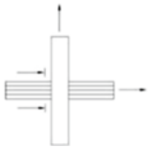
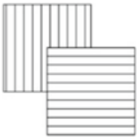
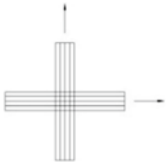
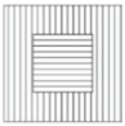
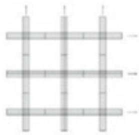
https://doi.org/10.1007/978-981-19-6430-5_7

Table 7.1 Spatial relationship mode of landscape space units

No	Type	Space relationship	Pattern	No	Type	Space relationship	Pattern
1	Fused	Fused		6	Network	Interlocking	
2	Parallel	Parallel		7		Continuous	
3	Overlaid	Overlaid		8		Interrupted	
4		Overlapping		9		Intersecting	
5		Nested		10		Interwoven	

two types of full-enclosed vegetation and semi-enclosed vegetation, such as settlements fully enclosed by vegetation in pattern 132, pattern 134 and pattern 140, and settlements semi-enclosed by vegetation in pattern 154 and pattern 137. Waterbody enclosed settlements could also be classified into two types of fully-enclosed water bodies and semi-enclosed water bodies, such as settlements fully enclosed by water bodies in pattern 141 and pattern 145 and settlements semi-enclosed by water bodies in pattern 139, pattern 152, and pattern 133.

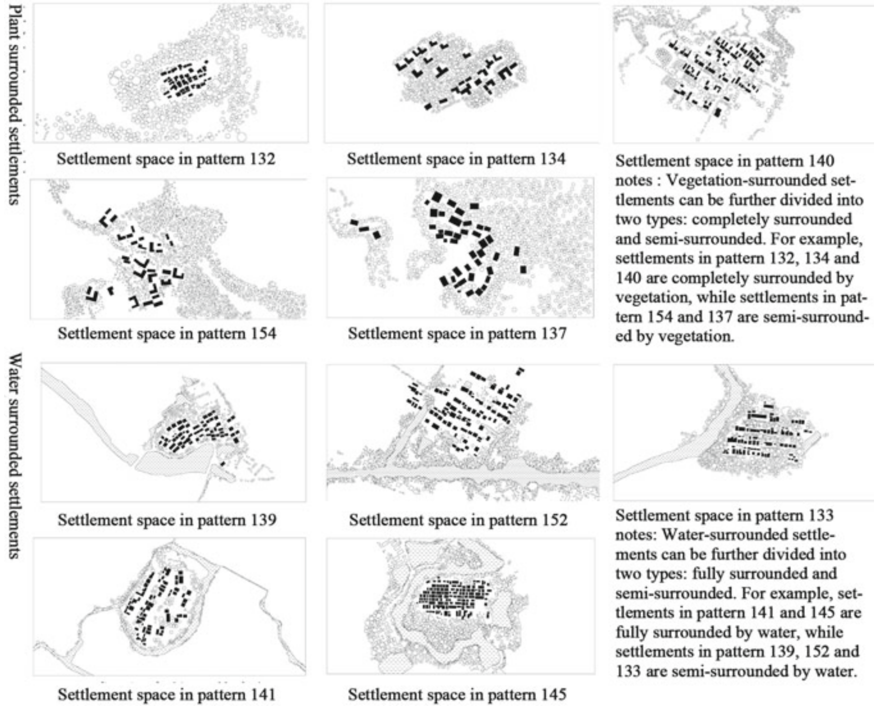


Fig. 7.1 Basic space of independent landscape

7.1.2 Lexicon of Related Landscape

7.1.2.1 Contingent

Basic space of contingent related landscape means the relationship is not inevitable between elements of space, which needs to be produced under certain conditions, but it does not mean this kind of space could be produced even meeting the conditions. For example, some spaces without uniform pattern to follow are formed incidentally in a specific environment.

Basic space of contingent-related landscape usually has a close relationship to the surroundings, but weak inevitable connection between the inner components, of which the combination would not produce necessarily this kind of space with the character of contingency. Basic space of contingent landscape generally does not have a fixed pattern in random form to express.

Settlement pattern formed at the nodes of water system with the configuration of radiation (Fig. 7.2) appears with the characteristic of contingency, which was formed on a central island with radial water systems as a result of erosion and deposition and surrounded by settlements which gradually become a larger settlement. First of all, the conditions for construction of settlements need to be met. For example, the

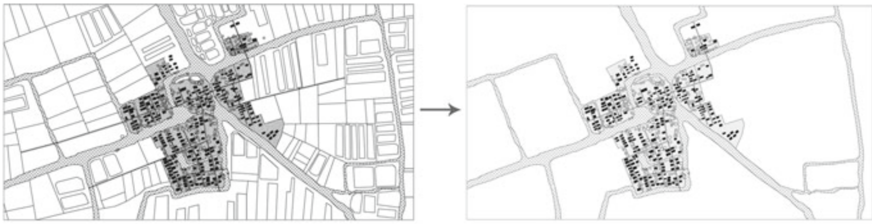


Fig. 7.2 Basic space of contingent and related landscape

central island formed by sediment is strong enough to withstand the pressure brought by the construction of settlements, and the surrounding farmland, water source, and transportation meet the daily needs of residents. On the contrary, settlement pattern might not be produced if these conditions are not met, but even if all these conditions are met, settlement pattern might not necessarily be produced, which is contingent completely.

7.1.2.2 Coordinated

Coordination refers to matching and harmonizing spatial relations through the adjustment between spaces and elements of space, which is to coordinate and adjust the interrelationship between systems or elements of the system to reduce the contradiction and form a virtuous circle in the process of evolution.

In terms of space scale, basic space of coordinated landscape is usually observed at a small scale, which is relatively diverse and complex with abundant changes in components, and among which there is often an internal coordination in landscape.

The pattern of *Fengshui* forests in village formed by cultural beliefs in pattern No.183 is the coordinated symbiotic relationship between forest and village (Fig. 7.3), in which there is also a coordinated symbiotic relationship between the flaky terraces and vegetation in the terraced fields formed by production activities in pattern No.7, pattern No.11, and pattern No.26.

7.1.2.3 Subordinated

Subordination refers to the distinction between components at the hierarchy of the primary and secondary in space with the dominance of the primary elements and the secondary without obvious characteristic and performance. For example, public open space in a village is a part of the whole village space and serves dominantly to the daily leisure needs of village residents (Fig. 7.4).

Basic space of dependency-related landscape usually is small in terms of space scale, which is subordinate to large space with the upper scale and is a subordinate

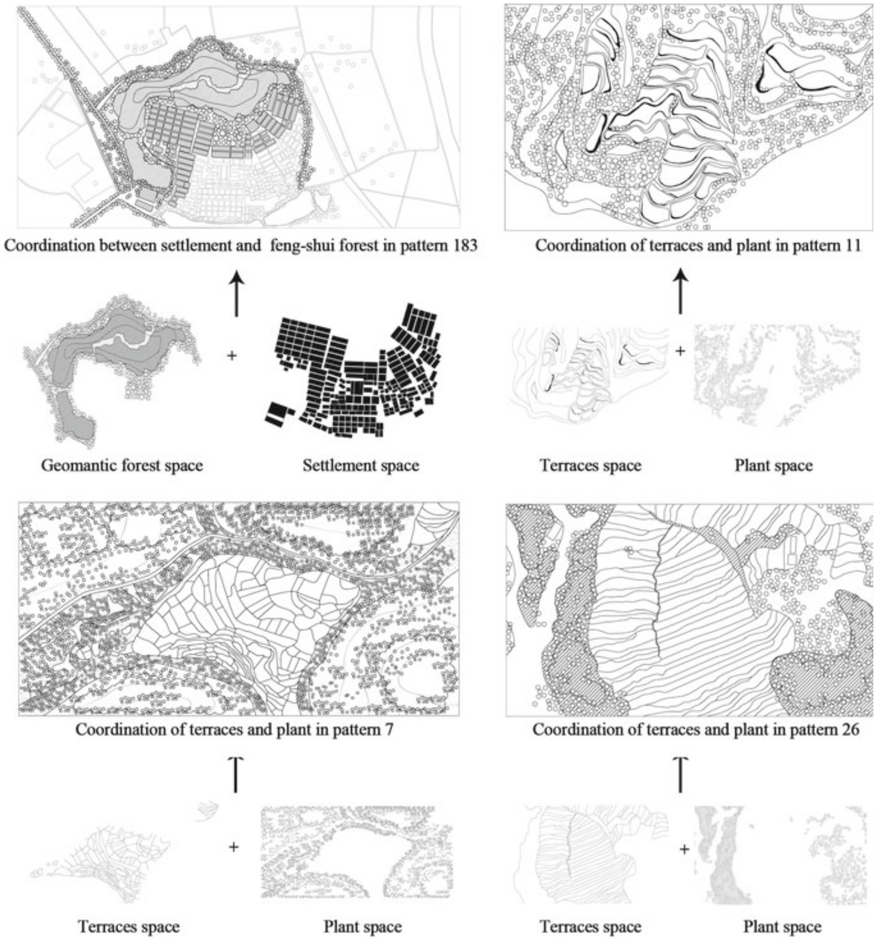


Fig. 7.3 Basic space of coordinated and related landscape

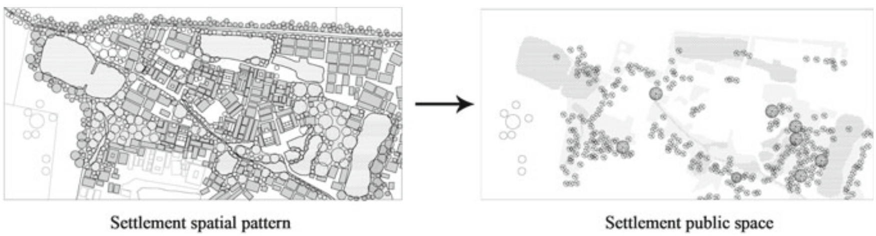


Fig. 7.4 Basic space of subordinated and related landscape

part of large space in terms of spatial relationship. The form is relatively rich and diverse but without fixed pattern, which changes with the change of spatial nature in terms of the internal structure of basic space.

7.2 Spatial Relationship of Aggregated Space Unit

7.2.1 Fused Space

Space fusion is a refinement of overlapping form of space, which specifically refers to interactions between components and elements of various types of space, of which they break through the boundaries, and as a result space, fusion often produces new space types under the interaction. For example, the polder is a unique type of farmland formed by spatial fusion of water-pond system and farmland (Fig. 7.5). In addition, patterns with the dike of mulberry and fishery pond are also the unique landscape with water-pond system utilization produced by the fusion of mulberry dike around fishery pond.

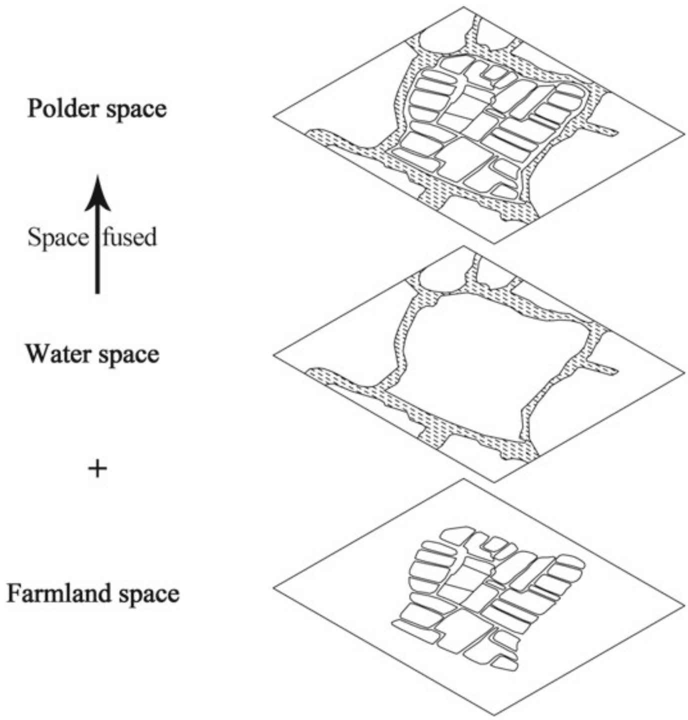


Fig. 7.5 Fused composite space unit

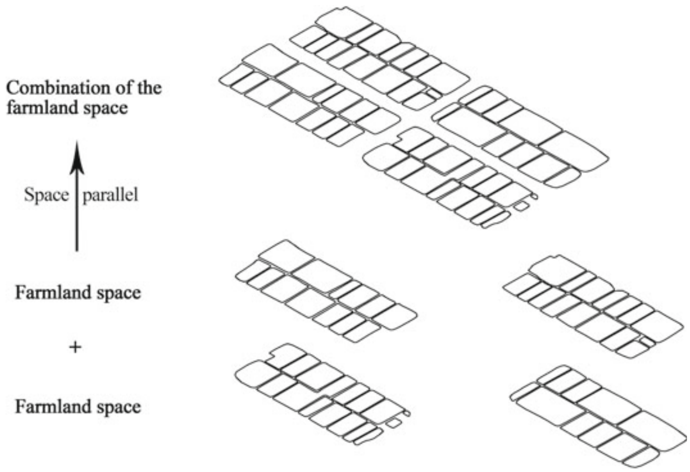


Fig. 7.6 Parallel compound space unit

Fused composite space of landscape usually has certain connections between basic space units which fused with each other, and it is the fusion between basic spaces that could create new space types with the longitudinal compound relationship, which often presents the characteristics of repeating the certain features of form at a large scale.

7.2.2 Paralleled Space

Paralleled space is the parallel relationship of two or more similar spaces with same status regardless of priority. For example, the relations between dikes in the polder and the relations between various fishery ponds are both a composite space type formed by the parallel of similar spaces (Fig. 7.6). Paralleled landscape composite spaces usually are the recurrence of a space repetition without intersection between the recurring space units under a space compound relationship of horizon.

7.2.3 Over-Space

7.2.3.1 Space Nested

Nested space is an issue of spatial scale, of which generally small-scale spaces are nested into large-scale spaces with a relationship of big space embracing small space, which could also be understood that the characteristics embodied at small scale still show the same characteristics at large scale, no matter how the scale changes. The

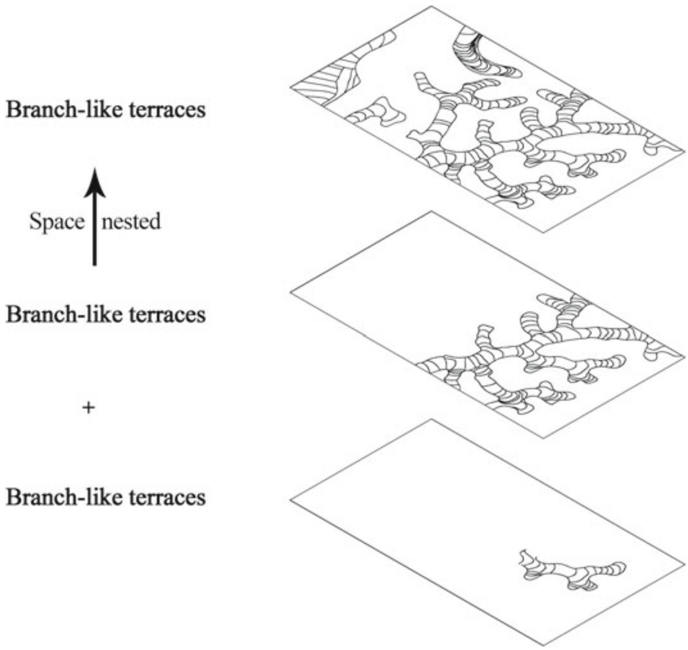


Fig. 7.7 Compound space unit with nested structure

terraced combination space has typical features of nested space showing branch-like features from small to large scales (Fig. 7.7). It is easy to show network characteristics and combination form at multiple scales for landscape composite space with the same spatial characteristics crossing scales.

7.2.3.2 Space Overlaid

Space overlaid could be understood as landscape with the respective attributes of two or more spaces after overlapping with a longitudinal space compound relationship and forming a new space based on two or more space attributes. The tidal zone is a good example of space overlaid, which is a way to make use of the interface between waterbody and land and produce a new type of farmland with strong function of production and with dual attributes of waterbody-land interface and farmland (Fig. 7.8).

7.2.3.3 Space Overlapping

Space overlapping means that one space covers another space without intersection between spaces, which is just a simple overlap in space and does not produce new

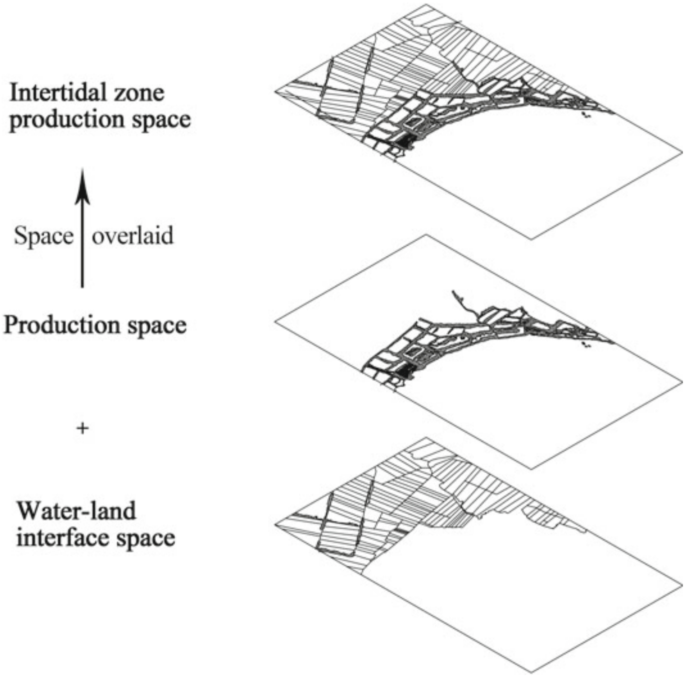


Fig. 7.8 Space overlaid compound space unit

attributes. The covering space is dominant, and the attributes of the space being covered are weakened. The overlap of mulberry and buildings on it in the pattern of mulberry with fishery pond results in residential function (Fig. 7.9). The construction on the dike planted mulberry would not change the original agricultural circulation system but only add a residential function to the production function, which is also a subsidiary function as the result of the development of mulberry with fishery ponds. Space overlapping is a longitudinal space compound relationship without generation new space types but retaining their own characteristics.

7.2.4 Network Space

Landscape is a space complex which carries various activities such as communication, production, leisure and recreation, and festival celebrations, so landscape space could be understood as living space, production space, and ecological space in terms of spatial attributes and their key landscape services. Landscape elements including buildings, roads, vegetation, water bodies, and farmland are organized into three functional spaces according to certain laws and mechanisms and finally form a highly complex system under the combined forces of man and nature (Wang et al. 2009). As

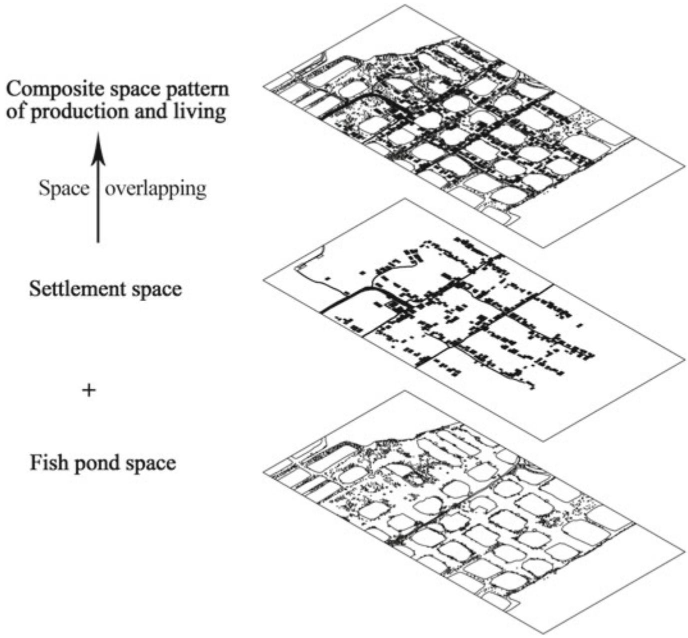


Fig. 7.9 Space overlapping compound unit

a way to understand the complex structure of group or system, network provides a comprehensive analysis framework which is helpful to understand the integrity and complexity. The flows of material, energy, and information are basic functions of the network which connects different ecosystems and is the most common structure in landscape. The function of network lies not only in the movement of species, but also in its impacts on landscape matrix and patch communities.

The connotation of landscape network is to understand the complex system of landscape space and interpret the form and spatial pattern of landscape ecological elements based on basic principles of network, on which the research is to deconstruct their complexity and analyze the internal laws, external space forms, comprehensive effects, and application values (Wang et al. 2015).

Basic elements of landscape network mainly include vegetation, water bodies, buildings, roads, and farmlands, among which the vegetation includes all kinds of trees, shrubs, and land cover vegetation, as well as artificially planted crops, protective vegetation, and landscape vegetation. Water bodies include river systems, lakes, and ponds, as well as artificially excavated irrigation water systems, fishery ponds, and reservoirs. Buildings include houses, ancestral halls, temples, and archways. Roads include streets and lanes inside settlements, as well as the traffic roads between settlements and production roads such as field ridges in production space. Farmlands include non-irrigated farmland, paddy fields, and fishery ponds. These basic elements of human landscape are further combined to form the basic spatial components of landscape network, including corridors, nodes, and units (Wang and Wang 2011). Corridors are the basic components formed by the linear arrangement of basic elements, which could be composed of a kind of elements or mainly by one element and supplemented by other elements (Wang and Cui 2013). Nodes are basic components of network in which basic elements are aggregated into patches. The unit is the basic mesh of networks, and some of which are special components of production network. These components are organized into multiple functional networks in space with certain rules, and the multiple functional networks are finally coupled into a complex network (Han and Wang 2014).

Combination pattern of network spaces is the most common form among all types (Wang and Lv 2013). Basically, spaces are always in the process of connectivity with the characteristics of network as long as it reaches a certain scale. Space intersection exists between the same two linear spaces, which forms the space interwoven form after being nested each other spatially, and space interwoven appears in multiple identical spaces. Space continuity is the continuousness of space type, in which the form of expression may change but landscape character remains unchanged (Wang and Wang 2013). Space interrupted is that one space is interrupted by another, and the two spaces have different properties. Space interlocking is the interlocking of two different types of space.

7.2.4.1 Space Intersecting

Space intersection is the intersection between several linear spaces of the same type, which often constitutes a part of cyberspace. Space combinations of the windbreak forest belt are only parts of a whole network of windbreak forest belts, and patterns of spatial relationship formed by the intersection of two forest corridors (Fig. 7.10). Space intersecting of landscape aggregated space usually has the same characteristics with a horizontal relationship of space aggregation, sometimes it is the basis of space interwoven, especially appears as space intersection at small scales while space interwoven at large scales.

7.2.4.2 Space Interwoven

Space interwoven is the interwoven of multiple identical linear spaces to form a relatively complete network. The combination is a complete network of windbreak forest belt at certain scale, which is formed by interwoven multiple horizontal and vertical forest belts (Fig. 7.11). Space interwoven of landscape composite space usually is a horizontal relationship of space composition with same characteristics and basis for the formation of network spaces.

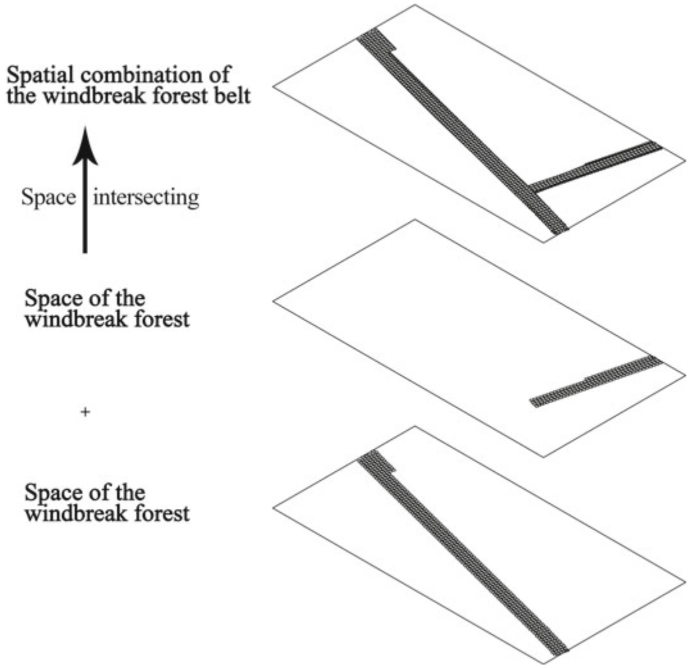


Fig. 7.10 Unit of composite space with spatial intersecting

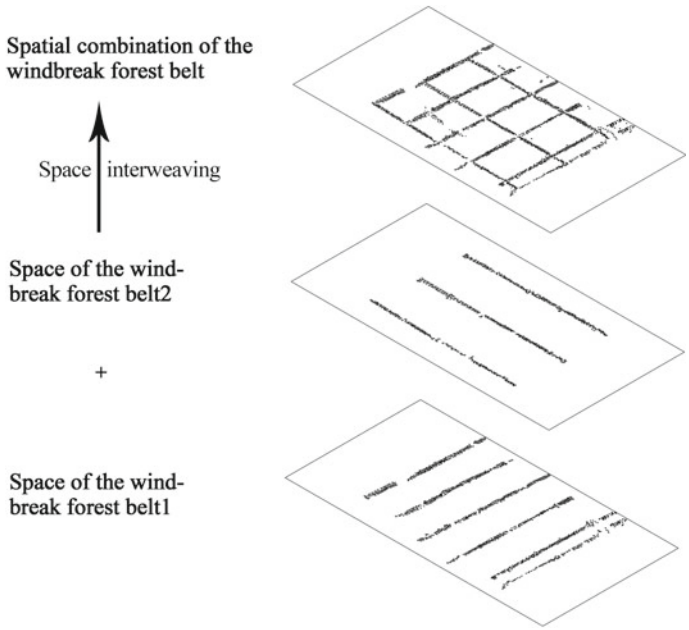


Fig. 7.11 Unit of composite space with spatial interwoven

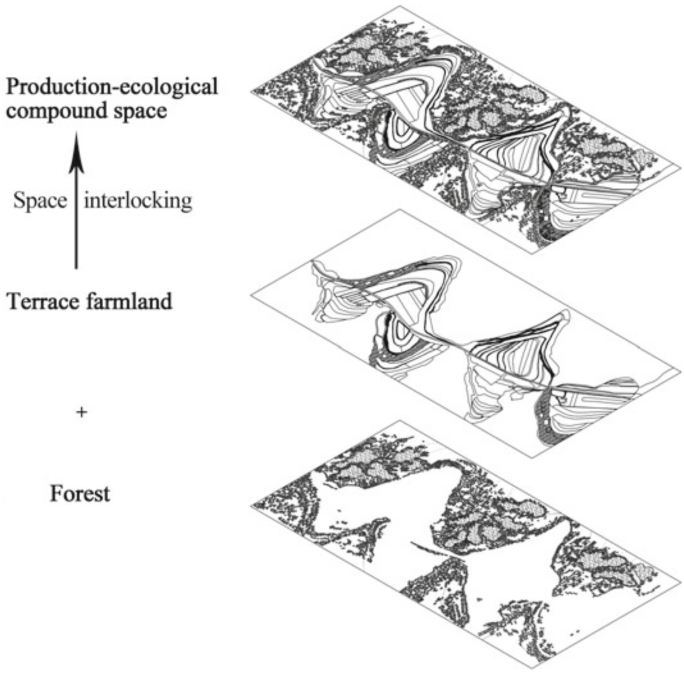


Fig. 7.12 Unit of composite space with spatial interlocking

7.2.4.3 Space Interlocking

Space interlocking is a close connection between two spaces with different characteristics. The productive-ecological composite space is formed by interlocking between forests and terrace farmlands (Fig. 7.12), in which one belongs to production space, and the other belongs to ecological space. Finger-like interlocking between these two types of space combination is a very typical form of space interlocking. Basic spaces of landscape usually are formed by interlocking tending to show a dentate shape with a horizontal relationship of space combination.

7.2.4.4 Space Continuous

Space continuity is spatial series without interruption by other space, but among which there may be different forms of expression. For example, the combination of farmland space is a continuous combination, and the expression form of farmland has changed from dry land in plain to terraced field due to the change of topography (Fig. 7.13). Therefore, farmland space combinations have changed adaptively according to the different environmental conditions, and the form of expression has changed although the attribute of farmland as a production space has not changed.

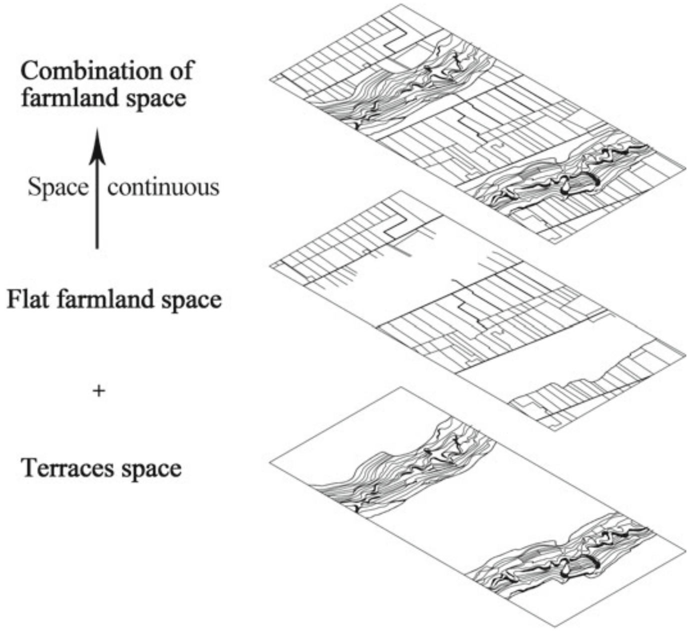


Fig. 7.13 Compound space unit with spatial continuity

Space continuity is a horizontal relationship of space compound, of which the spaces often have the same characteristics, but sometimes have different forms or forms of expression, and its elements are often relatively single.

7.2.4.5 Space Interrupted

Space interrupted refers to the temporary interruption of a space due to intervention of different kinds of spaces. For example, in some types of farmland, there would suddenly be a dense forests in the middle; here, the forest space is a cause of interruption of farmland space (Fig. 7.14). However, after the interruption of forests space, farmland space is still continuing. As could be seen from above description, it is the continuity of two same space types, while space interrupted is a spatial pattern in which one space type is interrupted by another but continues after the interruption. Landscape composite space with interruption usually has horizontal relationship of compound space formed by the intervention of spaces with different characteristics, of which the shape formed by space interrupted is often similar, and a large area of same space is interrupted by a linear space.

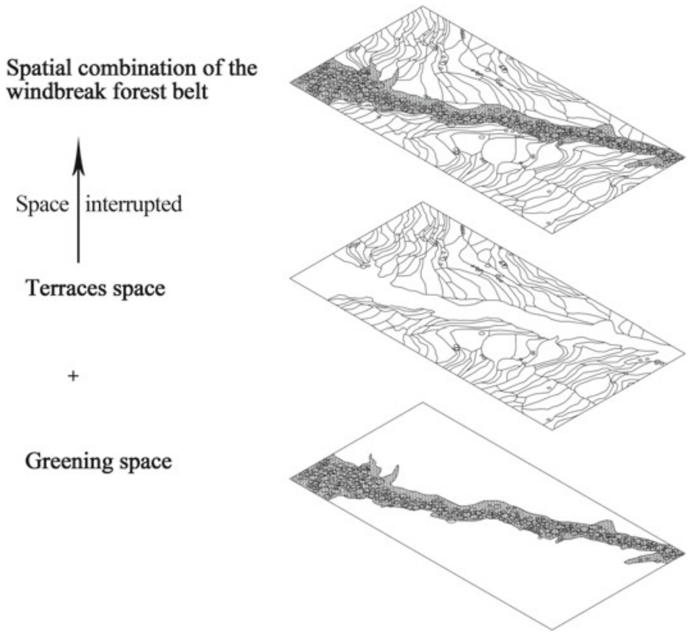


Fig. 7.14 Compound space unit with spatial interruption

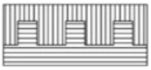
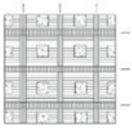
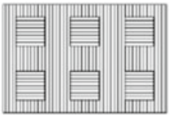
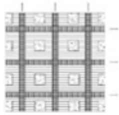
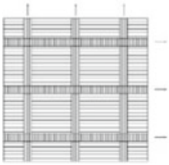
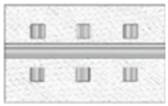
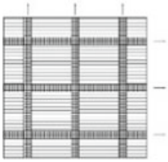
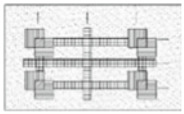
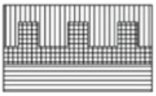
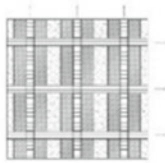
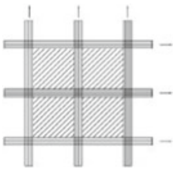
7.3 Composite Lexicon of Space Unit

It could be seen that most patterns are often combinations of multiple space units except for the relatively simple ones, such as the polder system and agro-ecosystem integrating mulberry dike and fishery pond. In general, the composition relationship of space unit is a combination of two, three, or four types of spaces, which includes combinations of space fusion, parallel, overlapping, and network (Table 7.2). It is rarely in one pattern that two or more expressions of one type of space combination would appear under a certain scale, so that the relationship of space pattern would be more disordered except for the nested structure of overlapping, in which there may be two overlapping relationships at different scales because of scaling. In addition, in the process of combination through various space relationships, it would also produce a complex pattern with spatial relationship in different configuration when the combination refers to different types of space.

7.3.1 Space Paralleled and Interlocked

Spaces compounded with spatial parallel relation and spatial interlocking are generally in jagged shape or finger shape. Composite spaces of woodlands and terraces

Table 7.2 Spatial relationship models of aggregated space

Serial number	Spatial relationship compound	Diagram	Serial number	Spatial relationship compound	Diagram
1	Parallel, interlocking		7	Parallel, interwoven, overlapping	
2	Parallel, overlaid		8	Parallel, interwoven, overlaid	
3	Interwoven, overlapping		9	Parallel, interrupted, overlaid	
4	Nested, overlaid		10	Parallel, interwoven, overlaid, fused	
5	Parallel, interwoven, interlocking				
6	Parallel, interwoven, fused		11	Parallel, interwoven, nested, fused	

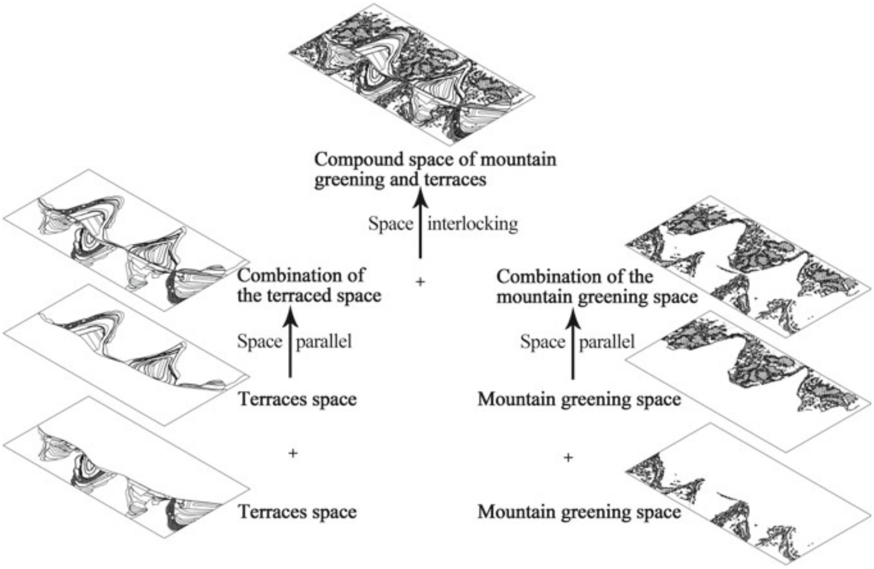


Fig. 7.15 Composite space with paralleled and interlocked relationship

in mountain area are combinations of two relationships of space paralleled and space interlocking, among which combinations of terraced spaces are formed by single terraced spaces paralleled each other, combinations of mountainous woodlands spaces are formed by single mountainous woodlands paralleled each other, and combinations of terraced space and mountainous woodlands form a composite space (Fig. 7.15).

7.3.2 Space Paralleled and Overlapped

Spaces compounded with the paralleled and overlapped relationship are generally expressed as the new space pattern produced by space paralleled after superimposing landscape space (Fig. 7.16). Paralleled combination of single fishery pond in space creates a combination of multiple ponds which have possibilities of multiple functions instead of monofunction of irrigation system without designated environmental background. Therefore, a composite space of farmland and multi-pond was formed as a typical production space pattern with the function of irrigation by overlapping with farmland spaces.

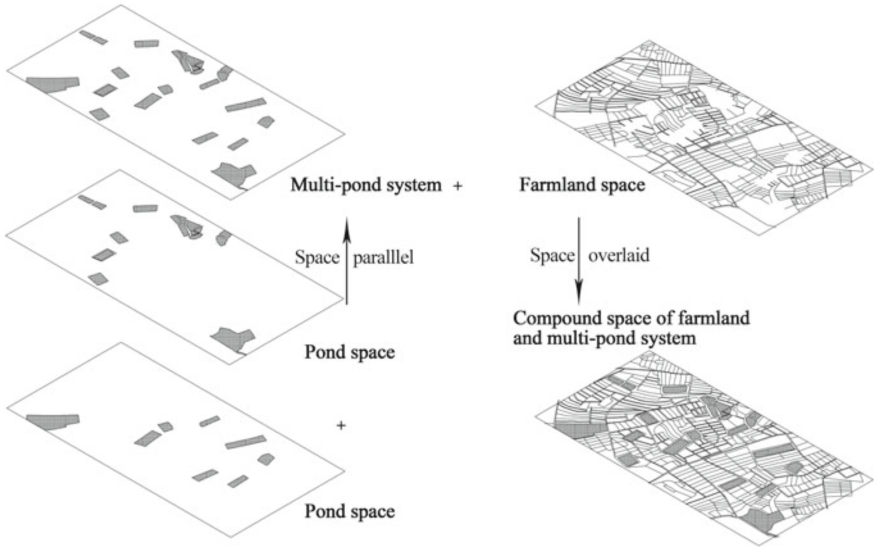


Fig. 7.16 Composite space with paralleled and overlaid relationship

7.3.3 *Space Interweaved and Overlaid*

Spaces compounded with interweaving and overlaying are generally manifested as the complex relationship between landscape matrix and corridors. It would not create a new type of space through combination produced by space interwoven and matrix overlaying each other. As shown in a pattern of farmland windbreak composite space (Fig. 7.17), green spaces combined at latitudinal and longitude directions interweaved to form a green space network which overlaid farmland spaces each other to produce a pattern of farmland windbreak (forests) composite space.

7.3.4 *Space Nested and Overlapped*

Spaces compounded with the nested and overlapped relationships are generally expressed as the superimposed relationship between landscape matrix, corridors, and patches, which are superimposed with new space attributes. As shown in Fig. 7.18, branch-like farmland spaces at small scale are nested with each other to form a branch-like farmland space combination at larger scale. In fact, it is difficult to distinguish the type of branch-shaped farmland as terrace from the graphical representation, however, the characteristics of branch-shaped farmland of terraces are fixed after overlapping the matrix of mountainous woodlands. Therefore, it could be identified that nested structure is the mutual spatial relationship between terraced spaces, which was given the topographical attributes of farmland space.

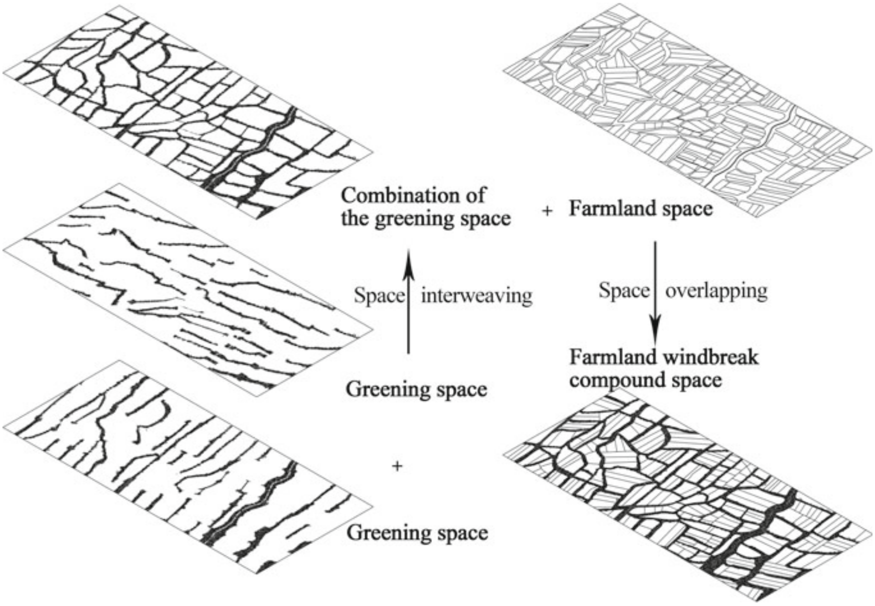


Fig. 7.17 Composite space with interweaved and overlapped relationship

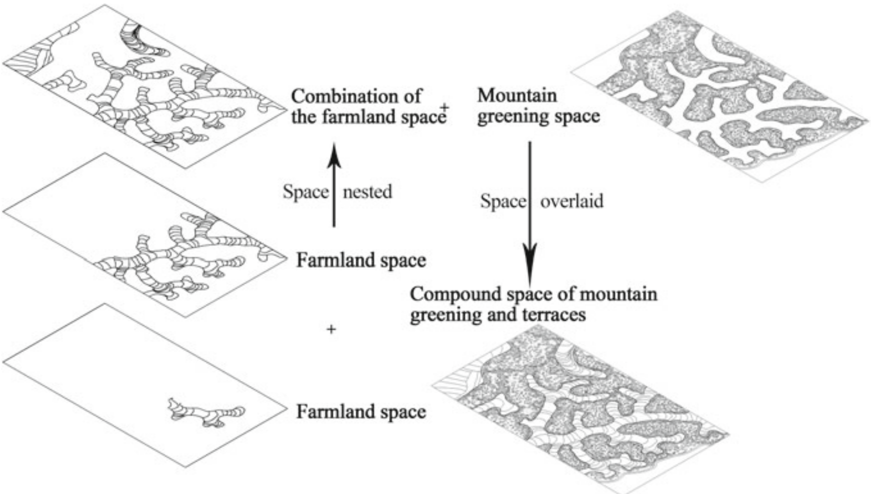


Fig. 7.18 Composite space with nested structure and overlapping

7.3.5 Space Paralleled, Overlapped, and Interlocked

It is difficult to distinguish landscape patch, corridor, and matrix in a composite space combined with the paralleled, overlapped, and interlocked spatial relationships, because the classification would be different from various angles, and space types could not be distinguished only as three configurations. As shown in Fig. 7.19, space combination of tidal flat was formed by tidal flat units with the paralleled relationship, and space combination of farmland was formed by farmland units with the paralleled relationship, based on which a new combined space was formed by overlapping between tidal flat spaces and farmland spaces, and finally, a productive-ecological complex space was formed through space interlocking between the combination of cultivated spaces and waterbodies. It would also be seen from the above analysis that three spatial relationships of paralleled, overlapping, and interlocking are in order and could not be inverted. If the relationship between waterbodies and farmland spaces was analyzed firstly, it would be difficult to determine what the real relationship of combination is between the two spaces. Similarly, if the relationship between tidal flats and waterbodies was analyzed firstly, it is also difficult to describe it clearly and would cause confusion in analysis. Therefore, the order and sequence of these spatial relationships must have the strict rules to be followed.

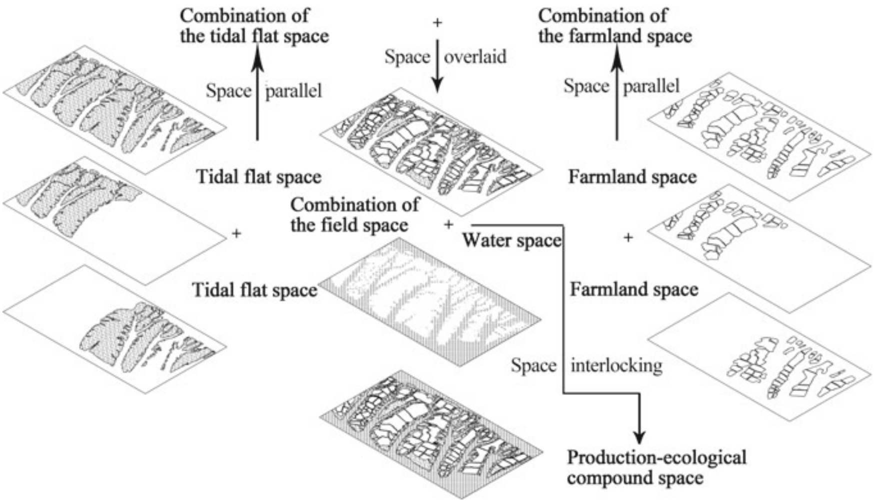


Fig. 7.19 Composite space with overlaid and interlocked relationship

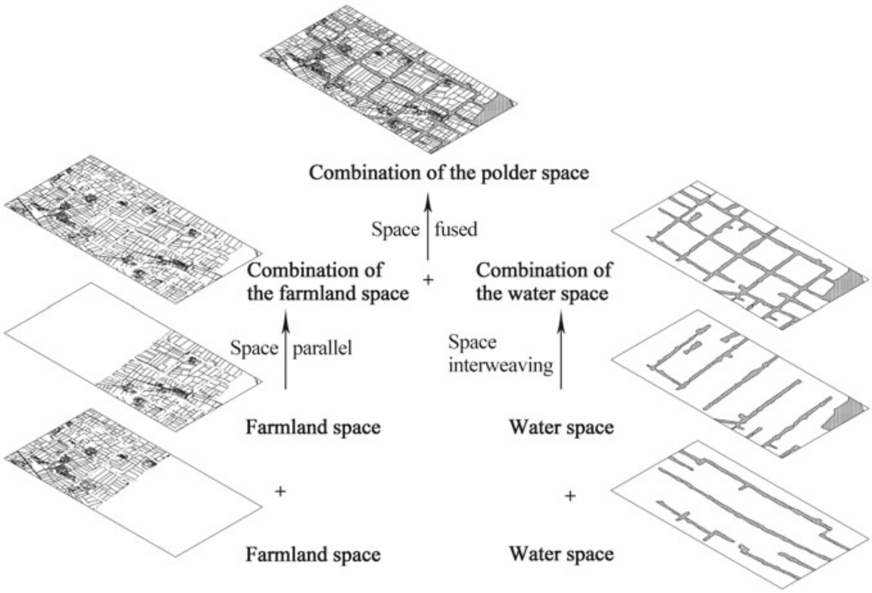


Fig. 7.20 Composite space with paralleled, interweaved, and fused relationship

7.3.6 Space Paralleled, Interweaved, and Fused

Spaces with the paralleled, interweaved, and fused spatial relationships are generally expressed as the fusion relationship between landscape matrix and corridor. The form of a new space was produced through mergence into the matrix with combination of space interwoven. As shown in Fig. 7.20, a combination of farmland spaces was formed with the paralleled relationship between farmlands, a combination of waterbodies was formed with the intertwined relationship at two directions of waterbodies, and a combination of polder space was formed with the integrated relationship between combinations of farmland spaces and network of waterbodies, which is a new space form generated by the integration of farmland spaces and waterbodies.

7.3.7 Space Paralleled, Interweaved, and Overlaid

Spaces with the paralleled, interweaved, and overlaid relationships are generally expressed as the overlapping relationship between landscape matrix and corridor. It would not create a new space type or change the original properties of the matrix except for only adding a new function with overlapping between matrix and combinations generated by space interlacing. As shown in Fig. 7.21, combinations of mulberry dike and fishery pond were formed with the parallel relationship between mulberry

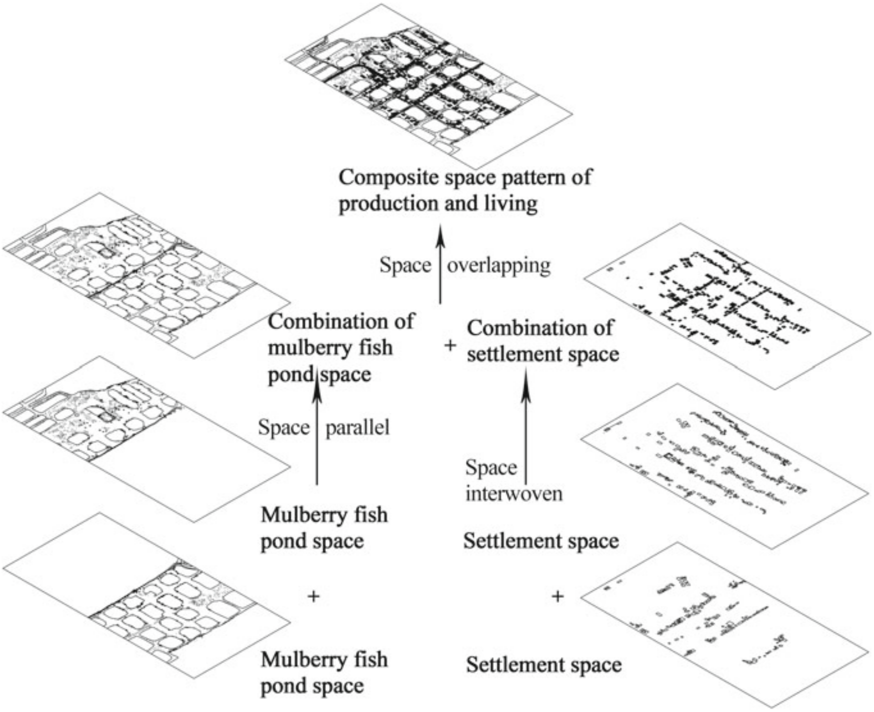


Fig. 7.21 Composite space with paralleled, interweaved, and overlapped relationship

dike and fishery pond, combinations of settlement were formed with the relationship of interweaving by settlement spaces at latitudinal and longitude directions, then the composite patterns of production and living were formed with the relationship of overlaying between combination space of mulberry dike–fishery pond and combination space of settlement, in which the ecological process and attributes of the mulberry dike—fishery pond combination have not changed fundamentally.

7.3.8 Space Parallel, Interweaved, and Overlapped

Spaces with the paralleled, interweaved, and overlapped spatial relationships are generally difficult to distinguish spaces of landscape patch, matrix, and corridor because of various results from different perspectives, so space types could not be simply distinguished just according to three landscape elements. As shown in Fig. 7.22, the parallel relation dominates the combination among green spaces in mountain area, farmland spaces are intertwined to form a farmland combination, and then, a composite space was formed with the relationship of overlapping between green space combination and the farmland combination, which is somewhat similar

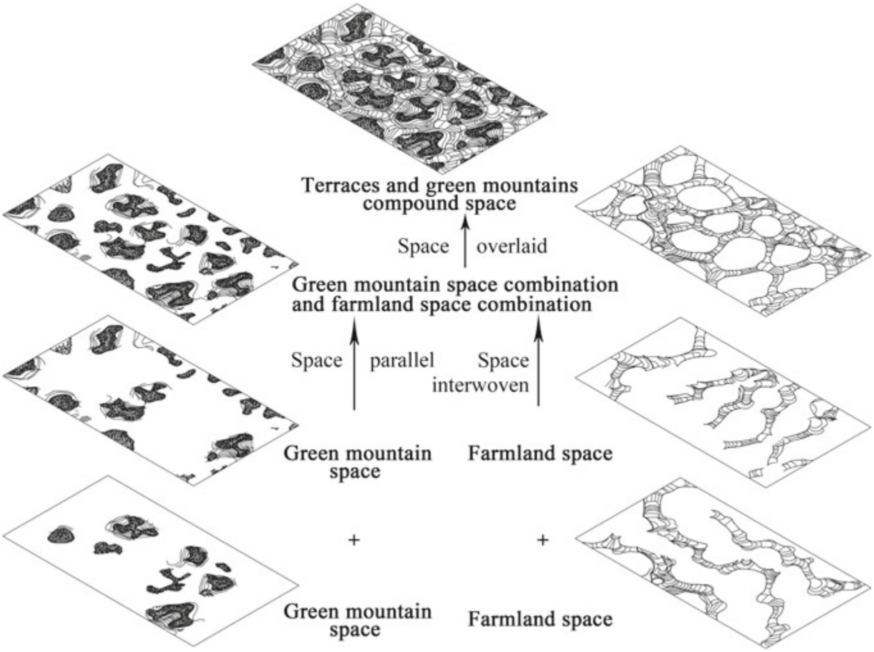


Fig. 7.22 Composite space I with paralleled, interweaved, and overlaid relationship

to spaces nested and overlapping (Fig. 7.18), but the spatial relationship is essentially different except for the spatial relationship of overlapping which endows the attribute of space terrain to farmland. As shown in Fig. 7.23, a composite space pattern of production and life was created through overlapping by waterbodies combination dominated with paralleled relation, settlements combination dominated with interweaving and farmlands, in which it could be analyzed from the figure that farmland spaces acted on as landscape matrix, linear settlement space combination as corridors, waterbodies combination as patches.

7.3.9 Space Paralleled, Interrupted, and Overlapped

Spaces with the paralleled, interrupted, and overlapped relationships are generally able to distinguish space types referred to landscape matrix, corridors, and patches. As shown in Fig. 7.24, a composite pattern of production and living was formed with the relationship of overlapping by the paralleled settlement combination and combination of farmlands interrupted by waterbodies. It could be analyzed from the figure that farmlands act as landscape matrix, linear waterbodies act as corridors, and settlements act as patches.

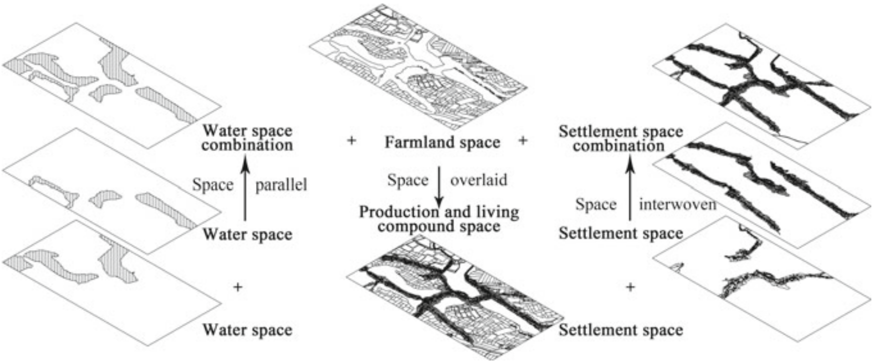


Fig. 7.23 Composite space II with paralleled, interweaved, and overlaid relationship

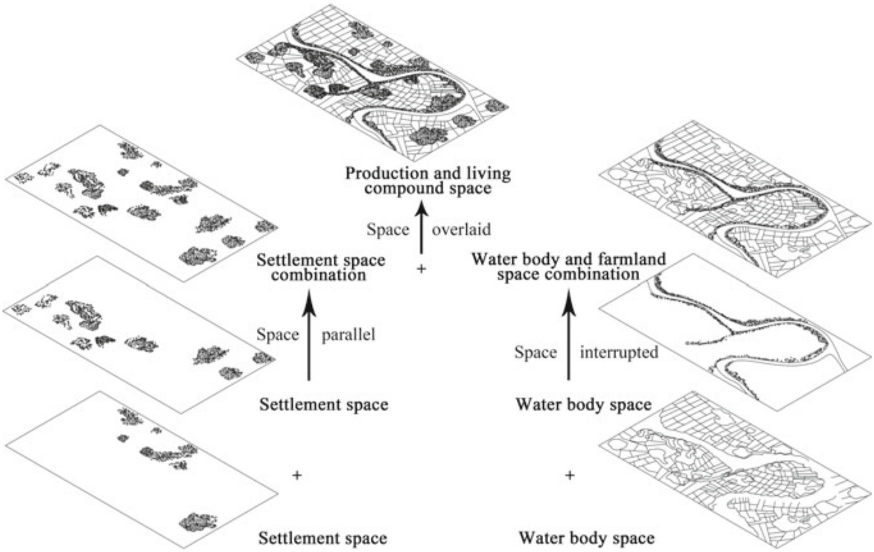


Fig. 7.24 Composite space with paralleled, interrupted, and overlaid relationship

7.3.10 Space Interweaved, Paralleled, Fused, and Overlapped

Spaces with the paralleled, interweaved, fused, and overlapped relationship generally refer to being well distinguished from landscape matrix, corridors, and patches. As shown in Fig. 7.25, combination spaces of traditional water village were created with the relationship of fusion between waterbodies combination intertwined by linear water spaces and settlements combination paralleled by basic settlement spaces. Based on this, a composite pattern of production and living spaces was created with the relationship of overlapping between the combination spaces of traditional

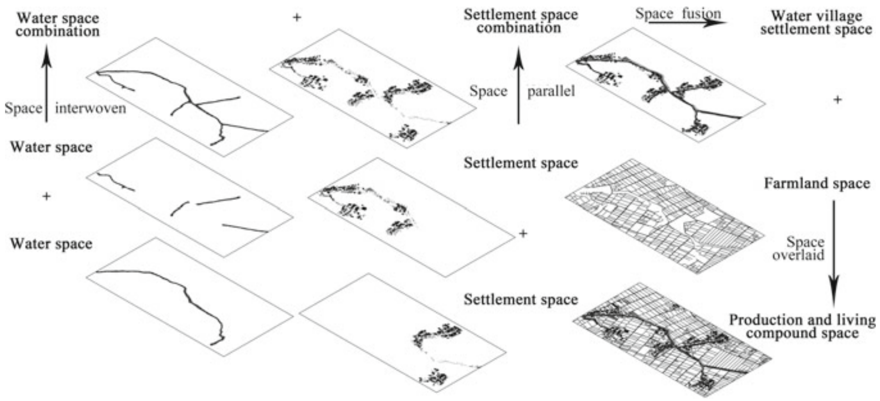


Fig. 7.25 Composite space I with paralleled, interweaved, fused, and overlaid relationship

water village with nested structure and farmland spaces. It could be analyzed from Fig. 7.25 that farmlands act as matrix, linear water spaces act as corridors, and settlement spaces act as patches, which are organically nested together and form a typical composite pattern of water town in Southern China. Of course, in this case, the fusion relationship between waterbodies and settlements is identified ahead of the identification of nested structure with farmlands to form the final composite pattern of production and living spaces.

It is argued that there may be another order of spatial analysis, which is a composite pattern of production and living was formed with nested structure by settlement combination composed of the paralleled basic settlement spaces, waterbody combination interwoven with linear water spaces and farmlands. In this way, the relationship between settlement combination and waterbody combination is not thoroughly analyzed because there is a kind of spatial fusion instead of nested relationship between waterbody combination and settlement combination. So it is more reasonable to analyze the order of space with the interwoven, paralleled, fused, and nested relationships in order to fully reflect the relationships between various space units and composite patterns of production and living spaces combination.

As shown in Fig. 7.26, it produces a space of traditional water village with the integration of waterbodies and settlements, which is arranged side by side to form a combination space, and the linear green spaces are interweaved to form a combination of green space network. Based on these, a typical composite pattern of production and living spaces was formed by the combination of settlement spaces, green spaces network, and farmlands.

It could be analyzed from Fig. 7.26 that farmland spaces act as matrix, linear waterbodies act as corridors, and settlements act as patches, which are organically nested together to form a typical composite pattern of production and living spaces. Compared with the compound space in Fig. 7.25, different types of composite space are formed with combination of different types of basic space although based on the same spatial relationship. As shown in Fig. 7.25, it is different that the corridor is a

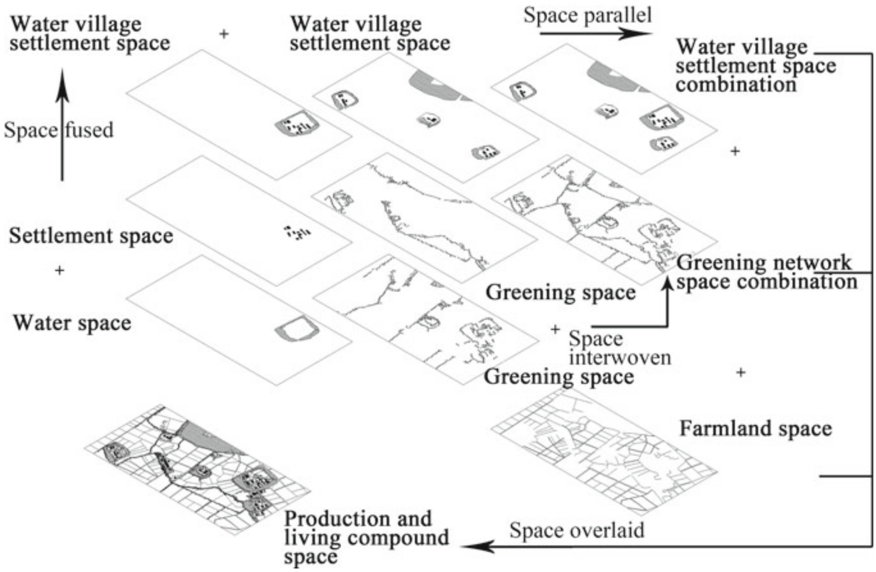


Fig. 7.26 Composite space II with interweaved, parallel, fused, and overlaid relationship

linear waterbody, and patches are settlements before combination but the corridor is linear greening space, and the patches are waterbodies and settlements in composite space, in which the spatial types of patches and corridors are different although with the same matrix of farmland.

7.3.11 Space Paralleled, Interweaved, Fused, and Nested

Spaces with the paralleled, interweaved, fused relationships, and nested structure are often more regular in the shape of spatial pattern, which are mainly due to the nested structure of spatial relationship. As shown in Fig. 7.26, the pattern appears totally as a relatively regular polder space. Regular spaces of farmland are juxtaposed each other at the same scale to form spatial combinations of farmland and waterbodies are interweaved at the directions of longitude and latitude to form spatial combinations of waterbody (Wang and Lv 2014). The combination of farmlands and combination of waterbodies merged to form a polder combination space which is integrated with nested structure and transformed from a small scale to a large scale. As the prototypes of typical pattern were selected at similar scales, the spatial relationship of nested structure could not be reflected intuitively, but the polder space pattern in Fig. 7.27 would be more obvious with the area growing bigger to reflect the nested structure at larger scale.

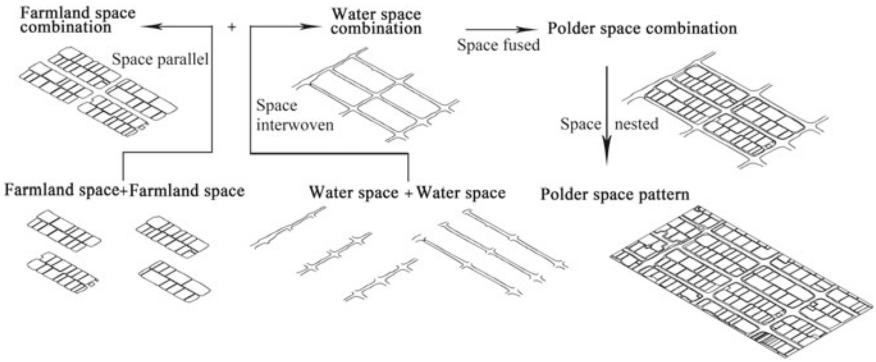


Fig. 7.27 Composite space with paralleled, interweaved, fused, and nested relationship

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Chapter 8
Syntax and Scaling of Landscape Pattern Language

8.1 Scaling of Pattern Language

8.1.1 The Objectivity and Subjectivity of Scale

The ontology-based essence of landscape architecture is landscape space and its formative mechanism, of which scale is the basic feature and becomes a spatial attribute determined by the spatial ontology and has the objectivity of space. The objectivity of scale is reflected in space parameters, such as area, size, extent, grain, quantity, dimension, and so on, which could be used to describe the scale characteristics of space. Also it is determined by the ontological characteristics of space and does not change with other factors. However, there are two characteristics of absoluteness and relativity in the objectivity of scale, which is determined by the characteristics of absoluteness and relativity of space which should be both considered when understand the spatial characteristics of landscape scale (Arganaraz and Entraigas 2014). Sometimes, the relative characteristics of space always have important effects and determinant significance to scale.

Taking an island as an example, the area of an island is a decisive character, which determines some absolute characteristics of island; however in the process of spatial cognition, some islands have large area but their ecological characteristics reflect some similar characteristics of island with small area, and the relativity of scales determines these characteristics at small scales compared with that of the mainland. In other words, among the characteristics of scale, some characteristics are determined by absolute features, while some characteristics are strongly dependent on the relativity of space, and their characteristics are determined by the relativity. Landscape space is the subject of space perceived by users, whose perception on spatial scale varies according to different individuals (Kaplan and Kaplan 2008). Landscape has the common characteristics of subjectivity and objectivity.

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https://doi.org/10.1007/978-981-19-6430-5_8

8.1.2 Scale Determined by Spatial Effect

From the perspective of subjectivity and objectivity of space scale, landscape space could be described by basic parameters which are important indexes reflecting the absolute characteristics of space scale. In addition, a space is coupled with other spaces to form a new integral space and the scale characteristics of space both depended on their relativity characteristics (Kienast et al. 2009), moreover depended on the perception of users, therefore scales of landscape space have the characteristic of systematic complexity.

What determines the scale of space? For landscape space, what extent of space is small scale or large scale? The questions are very difficult to answer. The scale is determined by spatial effects under the mechanism of working together of absoluteness, relativity, and perception of landscape (Fig. 8.1). Landscape space has the characteristics of scale and scale effects, and it means that spatial scale would change obviously and hierarchically only when the scale effect changes greatly corresponding to the changes of landscape scale. The big change indicates that landscape space jumps from one scale to another and also indicates the difference of ecological characteristics and ecological processes at different scales (Lautenbach et al. 2011). It could be understood that the changes and characteristics of landscape space are acted at the same scale level if the scale effect does not change greatly, therefore, it is an important technique to define the characteristics of spatial scale through discussing the scale effect of landscape space.

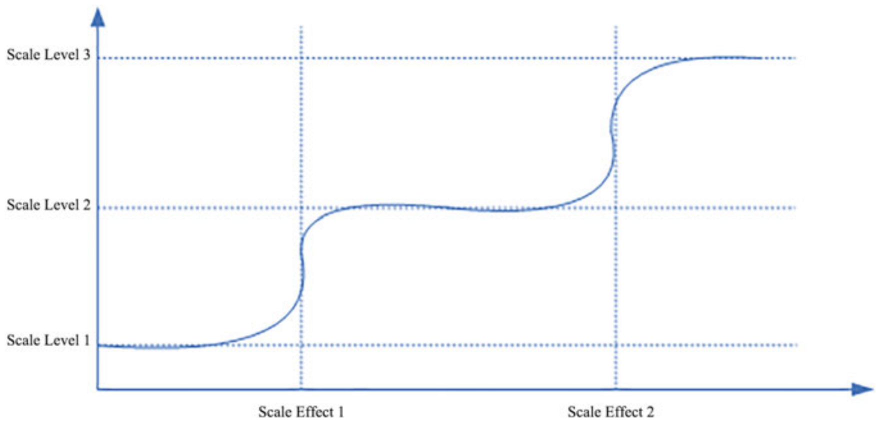


Fig. 8.1 Mechanism of spatial scale determination

8.1.3 Scale Nested and Scaling

Holistic landscape space is a body with nested structure, and the vocabulary and spatial logic of pattern language come from spaces at multiple scales corresponding to the characteristics of ecological space. Therefore, landscape pattern language is also a nested system completely composed of vocabulary and spatial logic at multiple scales through scaling. On one hand, it is difficult to realize the transformation and application across scales due to the strong dependence of pattern vocabulary and spatial logic on scale; on the other hand, it is easy to realize the transformation and application across scales because some of them have a relative dependence on scale (Priemus et al. 2004). Therefore, it needs to clarify the scale characteristics and scale dependence in the application of pattern vocabulary and spatial logic so as to determine the basis and conditions of scale nested structure and scale transformation. It has two processes of scaling up and scaling down in scale transformation basically, which are important processes to determine the scale mechanism.

8.1.4 Scaling as Syntactic Rule

From perspective of the grammar of landscape pattern language, the shaping of landscape space is a process in which basic spaces are nested into a total landscape space corresponding to the changes of scale, landscape ecological pattern, and process. Scale mechanism determines the logics of pattern language and is an important syntactic rule of pattern language. Spatial network is the realistic feature of landscape ecological pattern in which landscape patches and corridors are only the basic components of ecological space, and landscape ecological network is the mosaic and space complex with fusion of landscape patches and corridors.

The syntax of landscape spatial network contains the mechanism of network organization, formation, and integration under the process of single scale and scaling crossing the scales. Under the condition of single scale, the syntax consists four types of site-matching, transferred-epithet, orderly, and modifying. Under the condition of scaling crossing the scales, the network syntax is characterized by network contraction and nested mechanism.

8.2 Syntax of Landscape Spatial Network

The research on lexicon of landscape spatial network is focus on simple and composite networks, of which the results are used to explain the organizing rules and inner processes among spatial units in simple and composite networks. The core is to summarize systematically the overall laws of simple and composite networks in typical network pattern. Therefore, the syntax of network pattern is the key context to integrate various patterns of ecological network.

8.2.1 Site-Matching

Site-matching refers to network integration and coordination based on adaptation to the geographical environment, which is the essential connotation for landscape space and landscape network space (Freeman and Ray 2001). The main components of landscape ecological network are the factors with important ecological niches, which are different between the networks dominated, respectively, with functions of settlement, production, and ecological spaces. Through the analysis of typical network patterns extracted at the early stage, it is found that adaptation to the special geographical environment makes the spatial organization with high coordination between production space, living space, and ecological space within landscape, which is reflected in the formative process of the complete network system (Rodenburg and Nijkamp 2004) (Figs. 8.2, 8.3 and 8.4).

The close relations from the part to the whole could be established through combination between living space and ecological network space with settlements as the main body. The production space, such as terraces, dams, and other production network types, also reflect the organization mechanism of site-matching. Therefore, it is considered that the network integration process based on the site-matching is

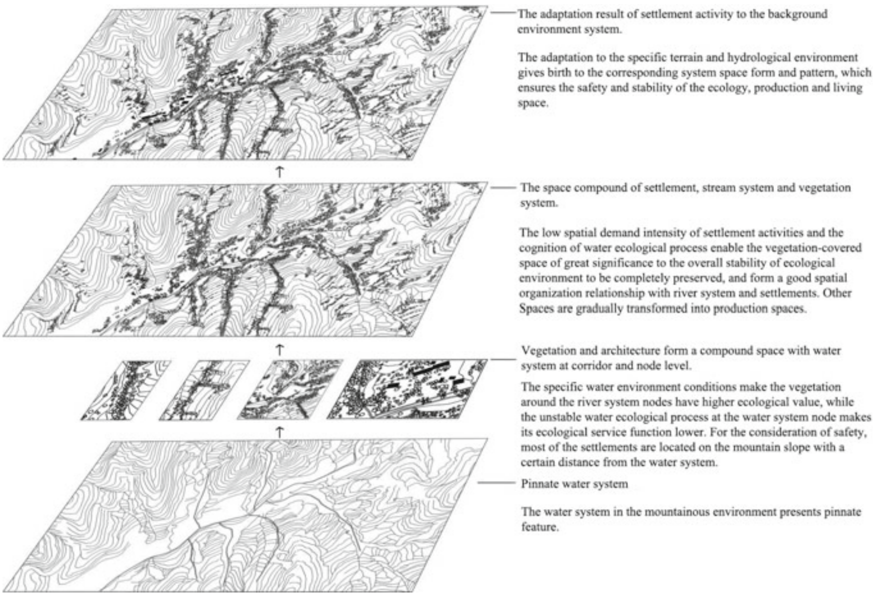


Fig. 8.2 Integration and organization of network pattern in mountain environment

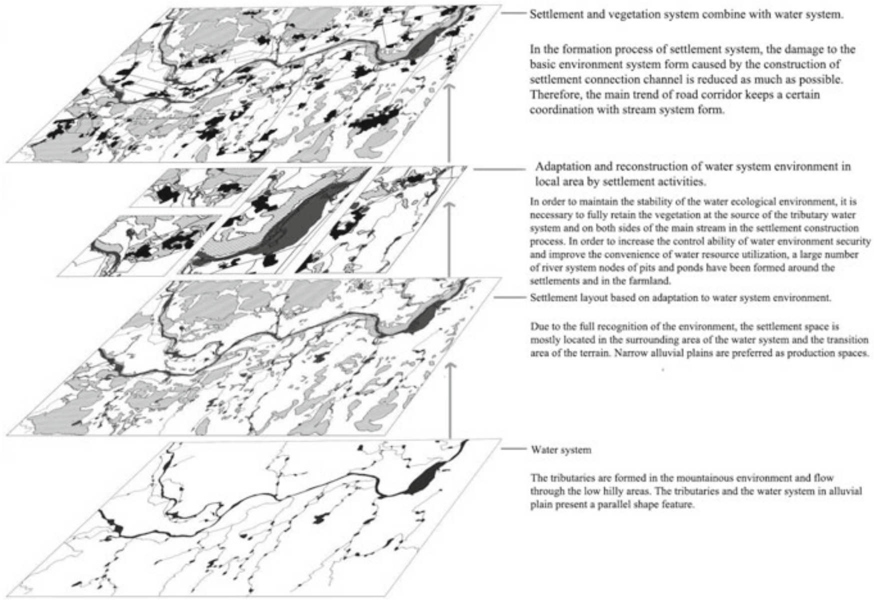


Fig. 8.3 Integration and organization of network pattern in valley environment

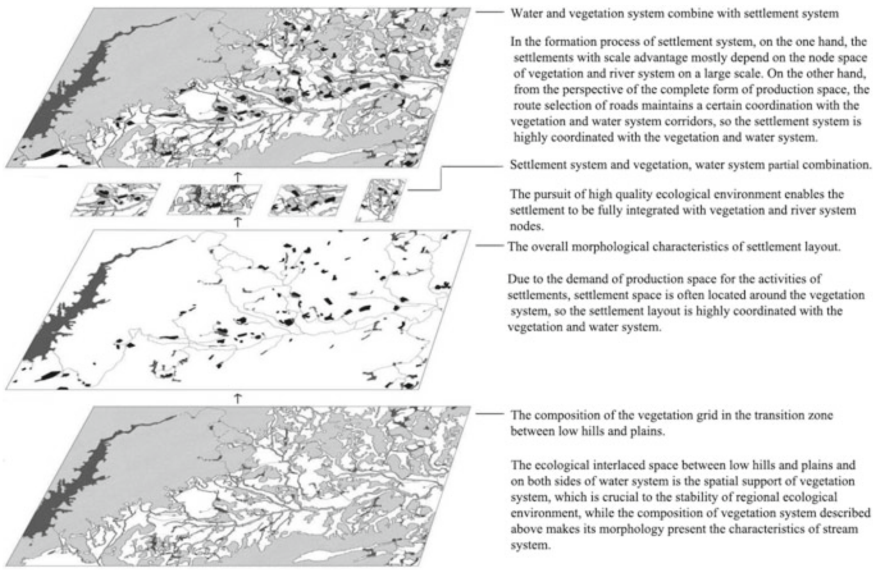


Fig. 8.4 Integration and organization of network pattern in hilly environment

essentially a network construction and organization process completely adapted to the specific geographical environment.

8.2.2 *Transferred-Epithet*

Transferred-epithet refers to the rhetoric method of replacing the words describing one landscape to describe another landscape with consciousness, which has the effects of making the sentence more concise and vivid, enhancing the expression, giving people the space of imagination, and having poetic emotion. The syntax of transferred-epithet in landscape spatial network refers that the overall network is endowed with richer human connotation by integrating a network with the function of maintaining socio-ecological process on the basis of preserving and continuing the existing network. The organizing process of overall network dominated by transferred-epithet is not only a process leading to the complexity of network structure, but also an active process of adaptation and transformation of network oriented by human needs (Figs. 8.5, 8.6 and 8.7).

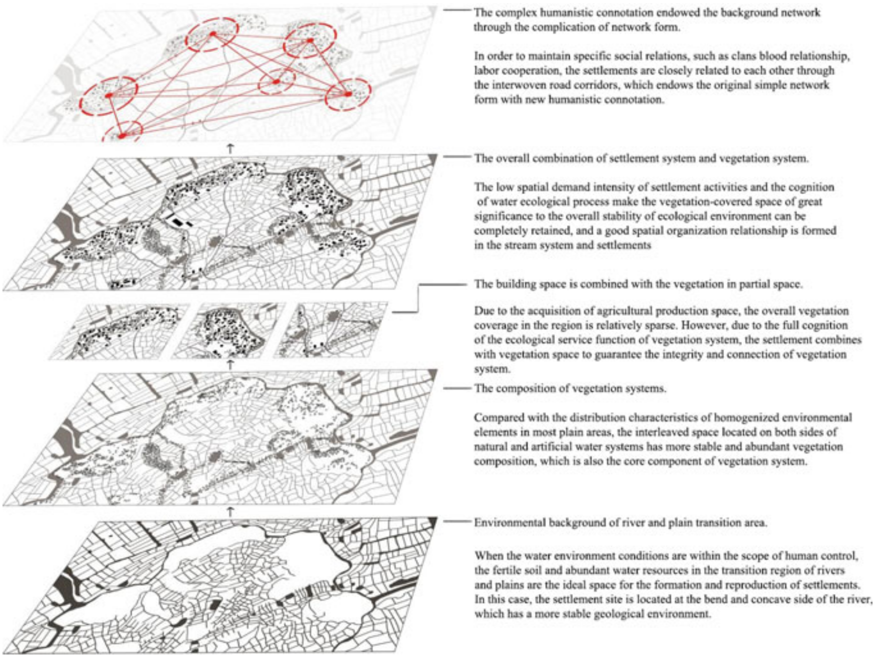


Fig. 8.5 Integration and organization of network pattern in alluvial plain

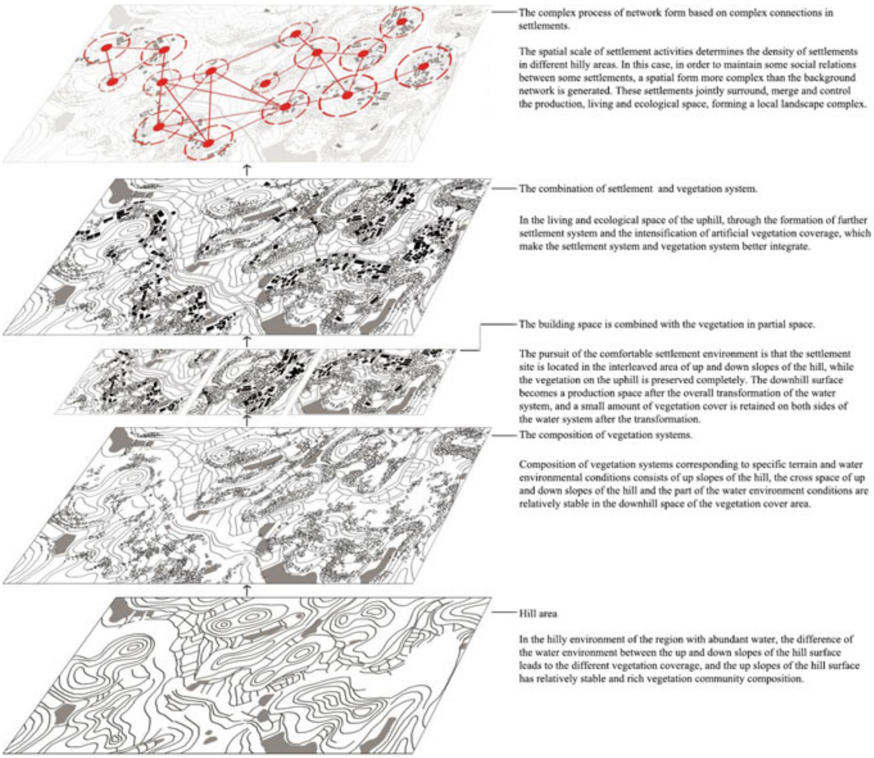


Fig. 8.6 Integration and organization of network pattern in hilly environment

8.2.3 Orderly Syntax

Networking process with the orderly syntax reflects a network integrating the characteristics of human ecosystem and regional landscape. Landscape spatial network presents the morphological characteristics which could be easily recognized by transforming the established environment comprehensively through the methods of similar environmental transformation with the orientation of satisfying the realistic needs of survival. It should be pointed out that residents in a specific region would not reach a systematic cognition of the overall network pattern, but the network organization dominated by the orderly syntax is based on the same environmental cognition and transformation mode in the subconscious of residents in the region, on which the residents would form a unified cognitive framework of space totally, which is crucial to the identity of regional culture, the maintenance of social relations, and even the construction of a new space order (Figs. 8.8 and 8.9).

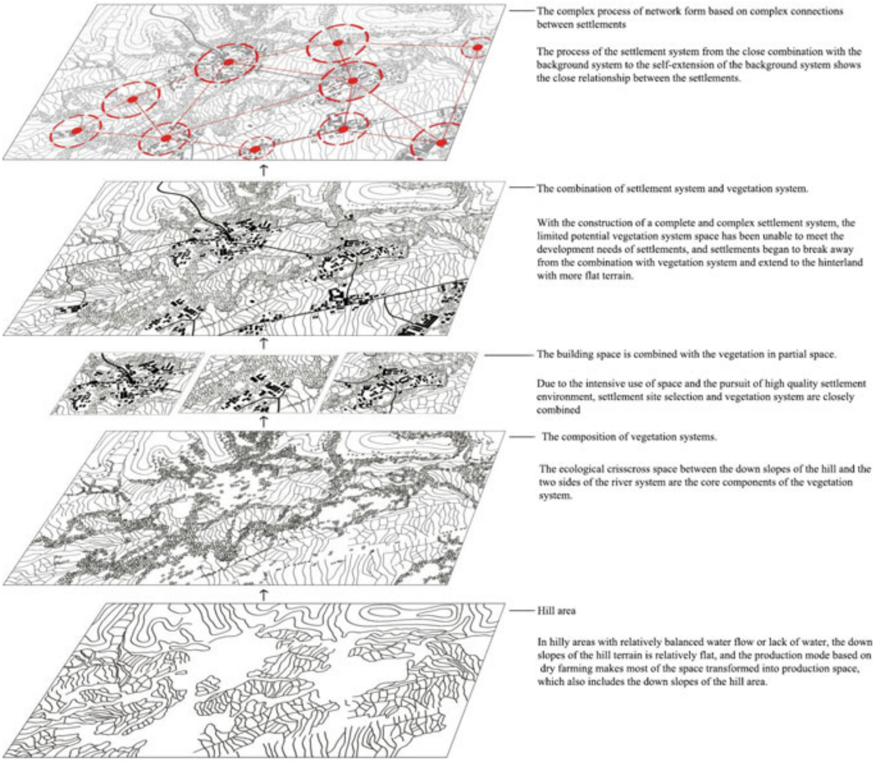


Fig. 8.7 Integration and organization of network pattern in transition region between low hills and plain

8.2.4 Modifying

Modifying is a kind of network construction method which keeps the environment network as a wholeness and adapts to meet the specific needs to survive through two ways of partial transformation, one of which is to enrich the organizations and compositions of overall network through the networking construction of local space, the other is to highlight the potential environment network through the process of shaping production and living spaces, but both ways could not affect the structure of environment network, the integrity of landscape pattern, and the continuity of ecological process (Schaich et al. 2010). In the process of organizing spatial networks with modifying syntax, on the one hand, it is the key to cognition of the overall network through reading the environment network; on the other hand, it still needs the correction model for extraction from specific environment to analyze the influences on form and texture of network spaces at small and moderate scales although the landscape modification process of local network would not cause substantial impacts

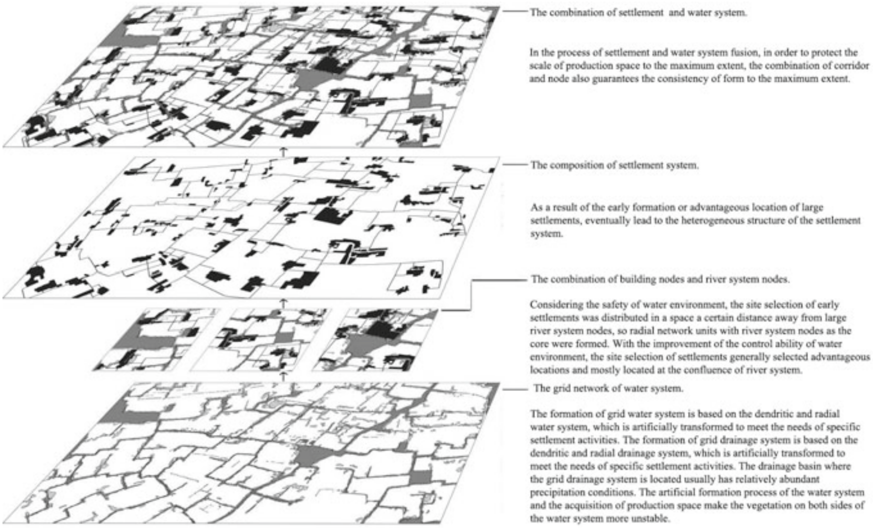


Fig. 8.8 Integration and organization of network pattern in water-town area

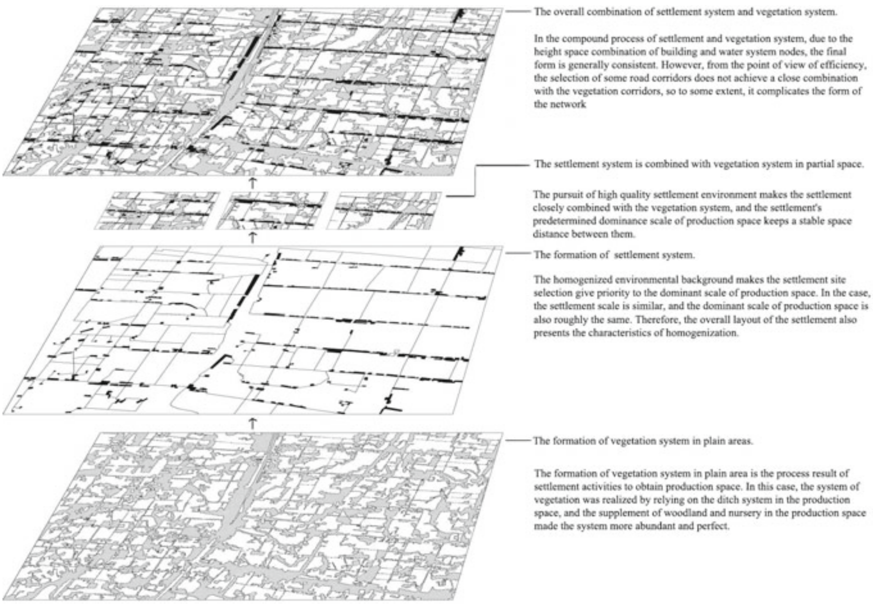


Fig. 8.9 Integration and organization of network pattern around the Taihu plain

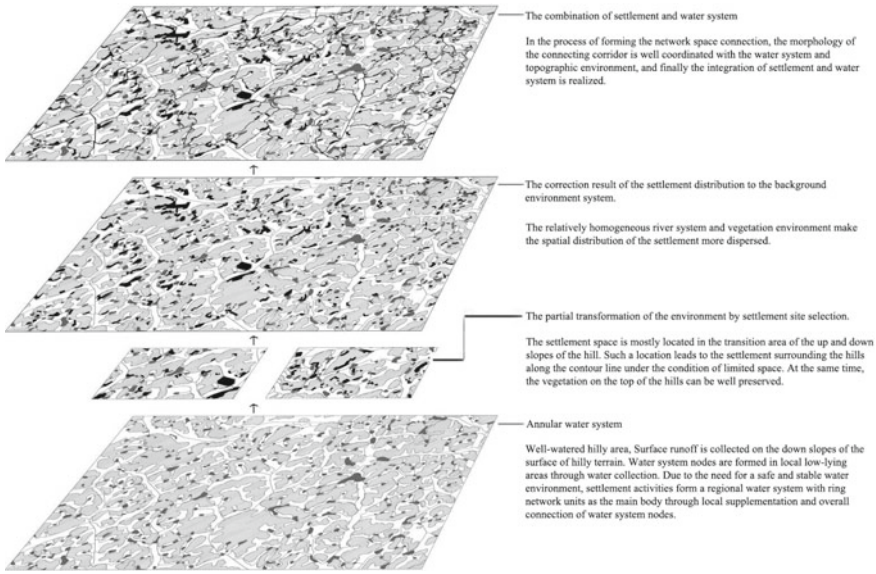


Fig. 8.10 Integration and organization of network pattern in hilly area by the modification

to network as a research approach to the cultural and socio-ecological processes (Figs. 8.10, 8.11 and 8.12).

8.3 Basic Principles of Scaling

From the structural scale of system, network contraction is considered as the basic process and based on which the state of network coupling could be realized at a high level through maintaining the fractal characteristics of network on the premise of following the principle of network structure and organization corresponding to network fractal (Dramstad et al. 1996).

The universality of fractal features of landscape spatial networks in the process of scaling is demonstrated through the construction of specific pattern of typical network, and the network organizing principles for the generation and maintenance of network fractal features are further expounded based on the summary of network pattern vocabularies, namely the degrees of network nodes and its corresponding level with single element participating in the formation of composite networks within the scale and the nodes with a smaller degree tend to connect nodes with a larger degree across the scale, among which the direct connections are deficient.

By comparing the fractal pattern of network and the coupling process corresponding to the spatial reasoning of network, as a result, it is important to maintain the fractal characteristics of network in the process of scaling for the stability of high

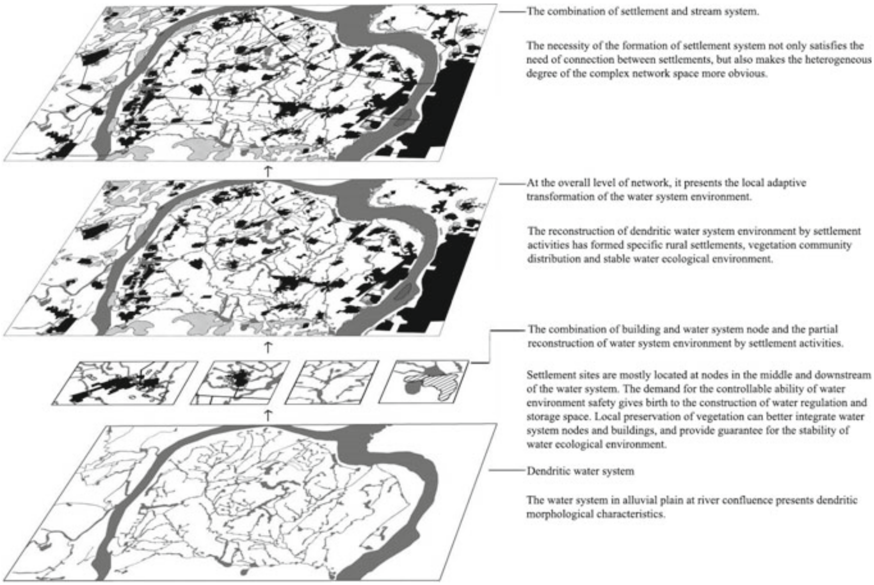


Fig. 8.11 Integration and organization of network pattern in sediment plain

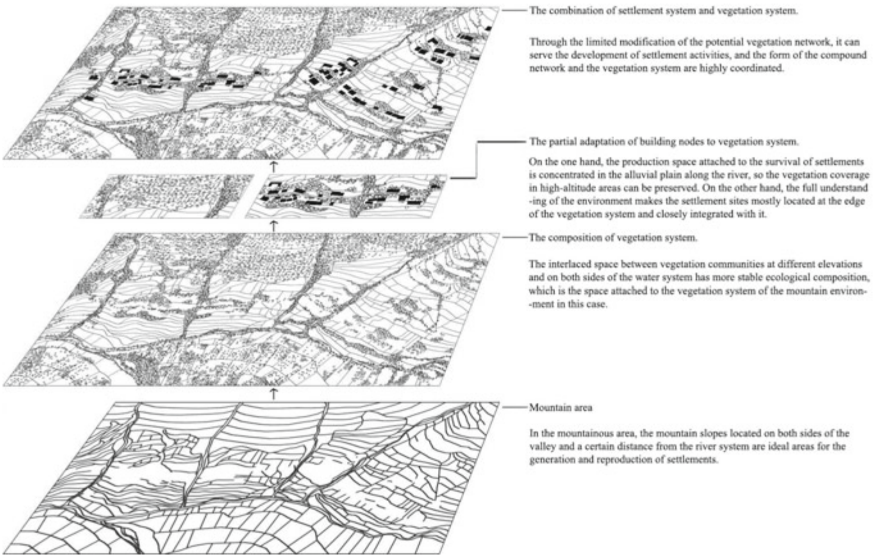


Fig. 8.12 Integration and organization of network pattern in the transition region between mountain and plain

coupling network. Here, two key indicators which affect the process of network fractal and the degree of landscape fragmentation and connectivity are selected according to the coupling degree of network. The scale research of network pattern could be constructed through the analysis of structural scale effects of indicators, which are composed of three numerical intervals of the structural scale *K* value 1–2, 3–4, 5–*N*, respectively.

8.3.1 Fractal Features of Network in Scaling

8.3.1.1 Possibility and Necessity

Through understanding the connotation of landscape network, it is qualitative description of the morphological characteristics through the degree of network connectivity which acts as a driver of landscape spatial network and morphological similarity which express directly the morphological characteristics of network at horizontal and vertical dimensions under the condition of multiple scales (An and Shen 2013). Fractal is a geometric description of the characteristics of self-similarity of graphs and the morphological characteristics of filling space with non-integer dimensions. Benoit B. Mandelbrot made a rigorous exposition of the extensive morphological similarities in nature from perspective of fractal geometry in the book of *Fractal Geometry of Nature*. Scholars have studied the fractal characteristics of landscape network including the network of rivers and network of forests and demonstrated its widespread objectivity (Cai 2016). It is believed that the morphological characteristics of landscape network could be summarized quantitatively by means of network fractal (Chen 2007). In addition, the structural description of complex networks could be carried out by means of complex network research considering the characteristics of complex networks involved in the research of network fractal.

It is difficult to grasp the laws of spatial organization through intuitive analysis because of the complexity of network organization. At the same time, the degree of connectivity and the morphological similarity crossing scales are exactly the state description based on intuitive analysis, the results would remain at the level just from intuitive interpretation to intuitive expression. The introduction of fractal is to demonstrate the two core morphological characteristics of network through quantitative analysis, on which the typical network pattern would be testified with the fractal characteristics of network, the research would discuss the theory and method of complex network with the help of graph theory.

It would provide a platform for the construction of landscape pattern language of network to analyze the balance between commonness and individuality in the process of networking (Gao and Wang 2016). Network fractal is a generalization and summary of the characteristics of landscape network configuration, and the rules of formation and maintenance are the common mechanism of landscape network. In general, the diversity of configuration is objectively to a specific network, but the influential factors and their mechanisms which lead to its occurrence are the individuality of landscape network, between which the differences could be distinguish through the introduction of network fractal research.

It provides a condition for constructing the scale system of network spatial relationship to introduce network fractal. The analysis of network fractal features includes the rules of network organization in horizontal and vertical patterns, and to which the corresponding supports of the coupling process at different levels. Both of them have close interactions and correlations at levels of network composition. In the case, it is inoperable to analyze the coupling degree of network through conventional quantitative, but the corresponding relationships between network fractal and coupling make it feasible to analyze the coupling degree through network fractal (Liu 2014). The research uses this method to select the indicators which are closely related to the reasoning and maintenance of network fractal and provide conditions for the construction of scale framework of network.

8.3.1.2 Spatial Network Model of Landscape

It is a basic approach to interpret the fractal features of network through the spatial model construction of landscape network, and the accordance of interpretation is the fractal dimension calculation of network model. The reason why the research does not directly use the digitalized results of typical network is that the network pattern with similar characteristics of configuration often has various concrete spatial forms. The research results would not be able to achieve the common mechanism to maintain the fractal characteristics of network due to the influences of individual factors if the research of network fractal characteristics is conducted on the basis of specific network space. Therefore, the research on configuration of network focuses on the structural form and so as to the corresponding scale involved is also the structural scale of network. The construction of landscape network model is based on 10 scale mechanisms of the typical network patterns selected in the previous study and is numbered with cases from 1 to 10. The steps of construction are as follows:

After, the single networks such as settlement, vegetation, water system, and production are extracted, respectively, and then, the adjacency matrix of single network of settlement, water system, and vegetation is constructed based on the results of pattern digitalization of network. The weight value of connection between nodes of network would not be considered, and the values were always given as 1 in the process of adjacency matrix construction.

The adjacency matrix is constructed for the composite network based on the digital results of network pattern, which is also constructed without the consideration of direction and weight between nodes. The research mainly examines the spatial proximity and dependency of landscape elements to judge the size of composite nodes.

The software Pajek is used to construct the models of 10 typical network patterns through building the single and composite network matrix (Fig. 8.13) and make statistics of indicators including the network diameter, number of nodes and corridors, cluster coefficient, average degree of network, and the shortest path in average of the complex network model.

The software Pajek is used to classify and procedure the composite networks which are classified into *K* subgraphs of network with different characteristics of structure and morphology through *K*-core classification. The value of *K* represents the degree of complexity and saturation of network and plays an important role in defining of scale structure, analyzing fractal characteristics, and integrating pattern language of network design through *K*-core network.

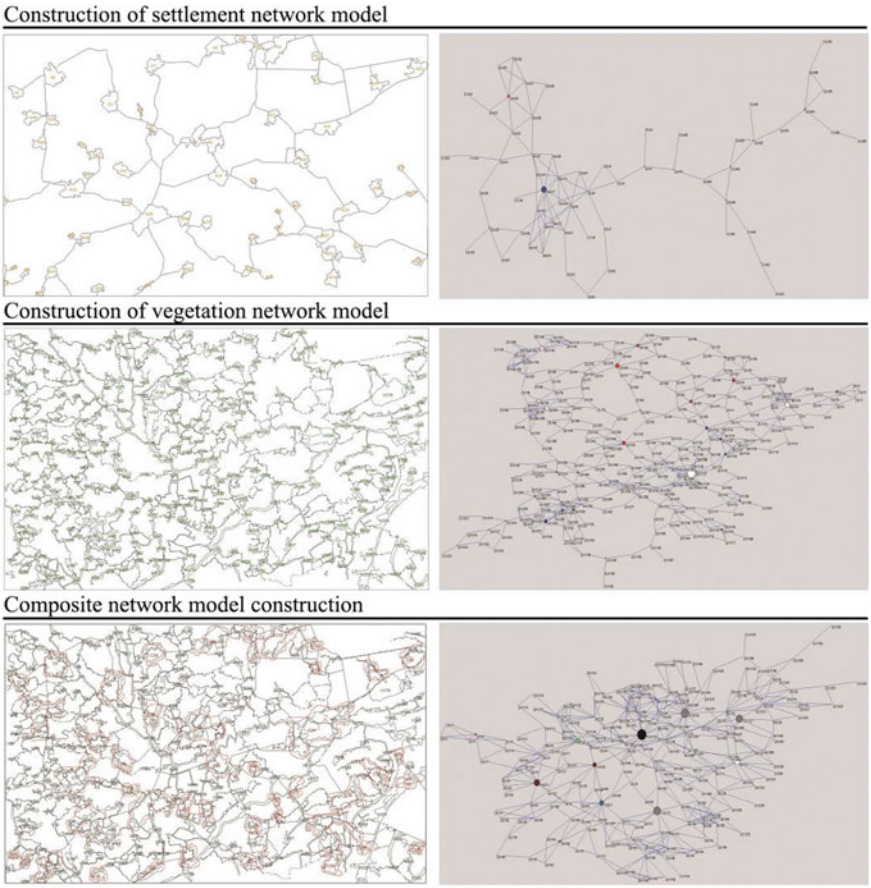


Fig. 8.13 Construction of landscape network models

8.3.1.3 Numerical Analysis of Network Indicators

The results mainly include 10 typical network patterns corresponding to the models of single element network and composite network which are measured by indicators of network diameter, the number of nodes and corridors, cluster coefficient, average degree of network, length of the shortest path in average (Table 8.1).

The nodes of building are usually less than the nodes of vegetation or waterbody in network with single element, but the number of composite nodes would fluctuate based on the node types with scale advantages, which indicates that there are different kinds of spatial combination models with various kind of single element nodes. In the composite process of single element network with the advantage of node number, the greater the fluctuation of node number, the higher the structural heterogeneity of composite network.

For a network with single element, the nodes of settlement usually have much more connections with corridor, such as water systems and vegetation, the actual number of corridors is less than that of the maximum possibility in theory, and this is due to the hierarchical characteristics of natural water system and vegetation network, which organize the nodes at different scales through the limited corridors to maintain the stability of system. Based on this, the changes of natural water system network and vegetation network driven by settlement activities adaptively are aiming to keep their original state as far as possible under considering of the stability of natural water system and vegetation networks.

Network diameter is an important indicator to measure the size of network. The diameter scale of a composite network is between the maximum and minimum of a single element network, which shows that the process from a single element network to the composite network is really the systematically process of network integrating the parts to the whole. It is the process that make the single element networks with smaller diameter embedded in the network with larger diameter, and the bigger diameter of a single element network could improve the heterogeneous and agglomeration degree of a composite network totally through integrating its own nodes in parts of network due to the integration process.

Settlement network has a higher networking degree in average through hierarchical differentiation, but networks of water system and vegetation have a lower average degree due to relatively smaller connection saturation of network. In the combining process of networks with single element, the difference of the configurative heterogeneity of different network leads to a process of homogenize the distribution of average degrees, so that the average degree of composite network reflects the process of mutual homogenizing of the average degree of network with single element.

The shortest path length in average of settlement network is relatively smaller, but of which the water system and vegetation networks are relatively bigger. This is due to the advantages of corridors and nodes number of the vegetation and water system networks when the scale and size are defined, as well as the lower degree of heterogeneity of vegetation and river network configuration, and in some cases,

Table 8.1 Index of 10 network models

Network name	Number of nodes	Number of corridors	The diameter	Average in networking	Average path length	Clustering coefficient
1—A	79.000	133.000	15.000	3.367	6.105	0.418
1—W	214.000	273.000	22.000	3.107	8.311	0.114
1—C	182.000	305.000	14.000	3.352	5.352	0.208
2—A	99.000	327.000	10.000	6.606	4.522	0.672
2—W	111.000	128.000	19.000	2.306	7.751	0.050
2—V	112.000	141.000	18.000	2.518	7.922	0.093
2—C	139.000	397.000	10.000	5.712	4.309	0.416
3—A	165.000	336.000	20.000	4.073	7.511	0.369
3—V	139.000	199.000	25.000	2.863	8.651	0.265
3—C	161.000	398.000	15.000	4.944	5.789	0.411
4—A	110.000	371.000	13.000	6.145	4.740	0.623
4—W	233.000	385.000	18.000	3.305	6.772	0.291
4—C	205.000	553.000	11.000	5.395	4.556	0.379
5—A	73.000	170.000	13.000	4.225	5.214	0.456
5—W	103.000	121.000	20.000	2.785	6.403	0.123
5—V	233.000	411.000	22.000	3.528	8.610	0.308
5—C	202.000	454.000	11.000	4.495	4.547	0.345
6—A	214.000	466.000	18.000	4.355	8.092	0.529
6—W	364.000	482.000	40.000	2.648	14.598	0.196
6—C	244.000	351.000	26.000	2.977	10.218	0.286
7—A	169.000	392.000	20.000	4.639	7.721	0.395
7—V	366.000	688.000	23.000	3.760	9.590	0.312
7—C	270.000	622.000	12.000	4.904	4.985	0.424
8—A	61.000	101.000	15.000	3.336	6.079	0.348
8—V	285.000	651.000	22.000	4.568	8.691	0.376
8—C	280.000	602.000	18.000	4.300	5.160	0.370
9—A	13.000	37.000	3.000	5.492	1.769	0.538
9—V	343.000	699.000	24.000	4.076	9.806	0.306
9—C	288.000	633.000	17.000	4.396	6.069	0.336
10—A	77.000	311.000	12.000	8.078	4.421	0.676
10—W	119.000	145.000	25.000	2.437	9.940	0.176
10—V	210.000	326.000	24.000	3.086	8.773	0.215
10—C	213.000	568.000	11.000	5.333	4.455	0.326

Note 1–10: number of case, A: settlement network, W: water system network, V: vegetation network, and C composite network the changes driven by settlement activities would further weak the degree of their heterogeneity.

Settlement network has higher clustering coefficient as a result of pursuit the efficiency driven by settlement activity. As far as other single element networks, the clustering coefficient corresponding to limited degree of heterogeneity is smaller. In the composite process of a single element network, the change of clustering coefficient could be reflected as two situations, one of which is the increase of local clustering degree of composite network caused by the integration of settlement network in water system or vegetation networks with advantages of the homogenizing process of clustering coefficient in a single element network, the other of which is the clustering coefficient of composite network is higher than that of any other single element network, which is due to the completely components integration of single element network through spatial combining. The connection of vegetation and water corridors in settlement network strengthens the connection of settlement nodes. The saturation of composite network connectivity would be higher than that of all single element networks, and its clustering coefficient would be larger numerically than that of any single element networks.

8.3.1.4 Complexity Analysis of Landscape Network

It could be known that the small-world effect, scaleless property, and network fractal are three essential characteristics of complex network. Based on the network model construction and relevant index selection, the research analyzes whether landscape network has the characteristic of small-world effect and scaleless property.

It is considered that landscape network has the obvious effects of small-world, of which the basic idea of analysis is that it could be reached with only a few limited connections between units although the number of unit is very large in some networks. The average shortest path lengths of 10 typical network patterns are mostly 1/2 to 1/3 of the network diameter, which indicate that the shortest path length between most nodes in network is much smaller than the network diameter. The analysis of clustering coefficient of composite network shows that it has obvious clustering characteristics. There are situations of nodes concentrating at some spaces of network, which not only shorten the length of connection path between nodes in clustering spaces, but also shorten the length of the shortest path between nodes out of clustering spaces, so as to make the connection between nodes in network more closely.

It is considered that landscape network has the characteristic of limited scaleless property, which refers to the fact that most nodes in network are connected just with few nodes, while few nodes are connected with most parts of nodes. Network with scaleless property has the characteristics of growth and preferential connection, which is an open system with the phenomenon of '*The Rich Getting Richer*', and would continue to expand, and the new nodes are more inclined to connect those nodes with high value of degree in the process of addition nodes integrating in network. Normally, the evaluation of scaleless property is based on whether the distribution of network degree conforms to the power-law distribution. However, due to the limited cases and inspired by the idea of scaleless property, it is found that there are indeed a few nodes with high degree playing a relatively important position in landscape composite network, while those nodes with a smaller degree tend to be in a dominant position at scale with high probability.

8.3.1.5 Analysis of Network Fractal Features

In this research, MATLAB is used to compile the calculation method of box dimension, and the classification results of K-core network of single and composite network model are considered as the upper limits of structure scale required for fractal dimension calculation. For example, the box dimensions of a composite network with K-core networks are calculated using boxes at different scales with diameters from 1 to K. To calculate the box dimensions of 10 composite networks representing typical network patterns and their single element networks, respectively, the fitting line could be obtained by putting these box sizes and the corresponding number of boxes into the log–log coordinates and using the least square method, of which the slope is the fractal dimension and would prove that the corresponding network model in the study has the fractal characteristics. By calculating the fractal dimensions of the fitting graphics obtained from fractal box dimension calculation and the fractal dimensions of the single element network and composite network contained in typical network pattern, the following conclusions are drawn:

The overall landscape network and the configuration of single element network have obvious features of network fractal. Although the calculation of fractal dimension indicates the existence of network fractal, the similarity in morphology is not obvious through the observation of the specific morphology of single and composite networks in these cases, it is because that the morphological similarity of network in fractal dimension calculation is just a statistical interpretation. To be specific, comparing the settlement networks with water systems and vegetation networks, the water systems and vegetation networks are relatively homogeneous networks because of lower structural levels and heterogeneous degrees, of which their morphological similarities could be intuitively identified. The configuration of settlement networks focused on the identification of network fractal in statistical significance because of the complexity of the structure and hierarchy. The formative process of landscape network is the homogenizing process of the fractal characteristics of network to integrate settlement into the environment and form a network with the significance of intuition and statistics. Whether the identification of composite network fractal is the perceptual intuition or statistical significance depends on the single element network which is the main body of composite network configuration.

The fractal characteristics of landscape network formation and rules of spatial organization maintaining at the horizontal patterns are corresponding to the nodes degree of single element networks which participate in the construction of composite networks. From the perspective of statistical analysis, it is considered that the fractal features of landscape networks on the level of horizontal pattern originate from the

Table 8.2 Fractal dimensions of single and composite networks for each case

	Case one	Case two	Case three	Case four	Case five
Live network	1.596	1.309	1.692	1.409	1.409
Drainage network	1.602	1.651	–	1.607	1.686
Vegetation network	–	1.606	1.695	–	1.696
Complex network	1.592	1.307	1.689	1.693	1.491
	Case six	Case seven	Case eight	Case nine	Case ten
Live network	1.604	1.699	1.479	1.044	1.693
Drainage network	1.683	–	–	–	1.699
Vegetation network	–	1.625	1.613	1.671	1.696
Complex network	1.735	1.684	1.694	1.545	1.691

fractal features maintenance of single element network in the composite process. The rule of spatial organization is that the nodes with larger degree are combined with the nodes also with larger degree in other single element networks, while the nodes with smaller degree are combined with the nodes with smaller degree in other single element networks in the composite process of single element networks. Only by spatial organization rules could the harmonious coexistence be ensured the heterogeneity of single element networks in a composite network (Table 8.2).

The fractal characteristics formation of landscape network and rules of spatial organization maintaining at the vertical pattern are that nodes with smaller degree tend to connect with nodes with larger degree, while it is lacking to connect directly among the nodes with larger degree, which have been proved by a large number of empirical analyzes that complex networks with fractal features have this kind of structural mismatch. The settlement nodes are usually located at the space with large degree of heterogeneity in vegetation and water system network and are closely combined with nodes of water body and vegetation with high structural importance. Then, the induced new settlement nodes combined directly through corridors with the existing nodes of large settlement, which are driven by the same location requirements and combined with surrounding vegetation and water environment. As a result, the space of vegetation and water system is compressed by the continuous process of inducing new settlement. The location of new settlement begins turning to homogenizing space or isolates from network of water system and vegetation network as long as the growth of settlements adapting to the water system and vegetation networks exceeds the capacity of natural environment.

The new settlements are preferentially connected with relatively large-scale composite nodes at the initial stage of settlement network adaptation to water systems and vegetation networks. With the complicate process of scale advantage and hierarchy of settlement network, the configuration of composite network presents the characteristics of settlement network, which tend to connect inevitably the nodes with large degree of connectivity from the formation and evolution process of settlement network.

8.3.2 Hierarchy of Network Structure Based on Scale Effects

8.3.2.1 Horizontal Coupling Process and Effect

It contains two paths of horizontal and vertical pattern in the composition and organization of landscape network from a comprehensive perspective. The research analyzes separately the coupling process and effect of network through the research of main function and compound function. The main function refers to the function maintained by network elements participating in the coupling process without relying on other coupling components. The compound function is the function could not exist independently without any network components participating in the coupling process, which is the base of coupling effect analysis.

It is mainly reflected in two aspects for the coupling effects of landscape space network generated by the combination of single type of corridors or nodes. On the one hand, the function of network and its composition is strengthened through the coupling process, which are manifested as the improvement of spatial quality of building nodes, water systems, and vegetation nodes. On the other hand, the compound functions are realized depending on the coupling effects. Because the compound process of space gives the vegetation and water system nodes with cultural and spiritual connotations which are influenced by cognition and ecological ethics of residents. The process strengthens the recognizability of composite space, influences the way of settlement environment construction, and also provides a basis to form the characteristics of regional landscape, so the coupling effect of network mainly relies on the basic spaces of compound nodes and compound corridors.

The coupling process of landscape network at the level of horizontal pattern is reflected in spatial combining of nodes and corridors of single element network, which finally realizes the systematic integration of local coupling effect at the overall level of network. In this process, the main function of vegetation network is to provide spaces for the survival of other species and maintain its own diversity and stability through the succession and expansion process of vegetation community, as well as the function of water and soil conservation and microclimate regulation. The main function of water system network is to provide carrier for water circulation, act on the traffic connection of building spaces, meet the water demand of life and production, and shape habitat for species. The main function of settlement network is to form a system with social communication, material, and information flow.

The effect of network integrating single element networks through coupling process and spatial organization of networking is not just the accumulation of local effects but the enhancement of systematic function with the support of obvious processes and spatial patterns, which includes the stability improvement of the overall ecological processes and spatial patterns of vegetation and water system network and the systematic improvement of the overall environmental quality of settlement network.

The spatial organization mode of networking also improves systematically the compound functions driven by local coupling process in network and builds the more close relationship of dependency among networks with single element. On the one hand, the recognizability of settlement network from local form to total structure could be improved through the coupling with vegetation and water networks. On the other hand, the culture and the spiritual connotation fostered in the process of local spaces integrating the network of vegetation and water system with settlement networks could be harmonized and become the regional culture context, which provide a support for regional landscape feature, character, and personality as the feedback of network construction.

8.3.2.2 Vertical Coupling Process and Effect

The network coupling at vertical level is showed as the interconnections between network units of composite nodes and the coupling effect of parts of compound network could be reorganized and manifested at overall level of network in the formative process of compound network. The coupling effects at overall level of compound network include the following three aspects.

When settlement network is combined with ecological nodes and corridors in the process of building a specific settlement, it endures cultural and spiritual connotations in local space on the basis of maintaining the integrity and continuity of overall composition of ecological network spaces, which is firstly reflected in site selection and construction of settlement environment, then acts on the overall maintenance, protection, and reinforcement of ecological spaces, and finally forms the dependency relationship of fusion among three networks with single element. The overall ecological efficiency of compound network is greater than that of simple accumulation of local network.

The difference of landscape context leads to the unique cognitive framework of regional peoples, which is inherited through the social memory. It is the environmental cognition mode that peoples in a certain region would form common identity of culture and spirit, keep coordination, and tacit understanding of the process from settlement construction to ecological environment reconstruction in a long process of settlement environment construction and avoid the social and cultural conflicts in the process of space growth. It is the common cognitive framework that the overall layout could be constructed in site selection and construction of buildings in settlement network exactly in specific region. Therefore, as a common cognitive framework, the internal connections of this kind have already existed before settlement spaces are integrated to form a network pattern with roads and water systems as the connecting channels. The cognitive framework continues to act on the combination process of local architectural spaces with vegetation and water system, clear explicitly the spatial identifiability dependent on network of water system and vegetation, and finally establish a cognitive map to regional environment pattern based on the existing cognitive framework by local peoples.

The formation and maintenance process of landscape space are the gradual adaptation process of settlement construction to natural environment under a certain cultural context. First of all, the direct driving force of settlement network formation comes from the demand for connection among settlements, which involves social interaction, information exchange, and goods trading. The inevitable connections among settlements promote the integration and harmony of social culture within the region, which are the driving forces of regional characteristics of cultural landscape. The local and overall spiritual and cultural connotations of complex network could be interchanged and reconciled through settlement network and be melted into regional culture based on the spatial cognitive framework of communities. Specifically, local construction of landscape network is guided by the cognitive framework of residents to regional environment, which gives spiritual and cultural connotations to network spaces in parts. With the prominence of spatial cognitive framework and systematization of internal connections of settlement network, local spiritual and cultural connotations are gradually integrated into regional culture with social consensus which cooperate with the spatial cognitive framework.

It is found that the coupling processes and effects are both based on spatial combining of corridors and nodes with single type, by which the coupling effects of local space depend on various network organization to realize the common integration systematically at the level of horizontal and vertical network pattern. The coupling effects of compound network are centered on the improvement of overall ecological efficiency, highlighting of spatial cognitive framework, and strengthening of regional cultural identity. At the level of horizontal and vertical pattern, basic conditions of network coupling and effects of network spatial organization are the counterpoint combination between basic components of network with single element and spatial connections between basic components of compound network. Through the analysis of coupling processes and effects at the level of network pattern, the network coupling principles of spatial organization with single element are the counterpoints combination between components belonging to different networks with single element, which mean that nodes are combined with nodes, and corridors are combined with corridors. Through the analysis of coupling processes and effects of the vertical network pattern, the network organization principles of coupling processes and effects are the connecting processes among nodes within the main compound network, by which the coupling effects of local network could be integrated systematically.

8.3.2.3 Relation Between Fractal Feature and Coupling Process

Network coupling is a prerequisite for the fractal feature of network. The spatial principles of network coupling on the horizontal and vertical pattern are the counterpoint combination between basic components of network with single element and the spatial connections among basic components of composite network. The spatial principles to maintain the corresponding characteristics of network fractal on the horizontal and vertical pattern are the corresponding degree of nodes between single element networks in the combination of composite network, and the tendency of network nodes with lower degree connecting to nodes with higher degree to reduce the direct connections between nodes with higher degree in the process of connections between composite nodes. It is found that spatial principles formed by network coupling are consistent with the spatial principles required by network fractal when they are satisfied. However, it is necessary to further define the principles to meet the requirements of spatial organization with network fractal characteristics when spatial principles required by network coupling have been established. So it is considered that network coupling is a necessary prerequisite for network fractal characteristics, but not the sufficient condition.

Network fractal is the basis of network with high degree of coupling. On the one hand, network coupling is the necessary condition for network fractal features which corresponds to more specific state of network coupling described by the coupling degree. On the other hand, network coupling refers to the phenomenon which two or more systems or motions influenced each other through various interactions. Based on the corresponding relationship of network components and organization of the fractal and coupling processes and the common relationship between spatial organization principles on horizontal and vertical patterns, the feasible supports were provided to calculate the coupling degree of landscape network by fractal morphological indicators.

The overall coupling degrees of 10 typical networks were calculated, which showed that the value of coupling degree (C) is between 0 and 1, and landscape networks with fractal characteristics almost have high degree of coupling. The coupling degree reaches the maximum state of resonance coupling, and the system would tend to be a new structure with order when $C = 1$, and on the country, the coupling degree is minimal, and the system would turn to be disorder when $C = 0$. The system is at a lower level of coupling when $0 < C \leq 0.3$, the antagonistic stage when $0.3 < C \leq 0.5$, the running-in stage when $0.5 < C \leq 0.8$, and high-level coupling stage when $0.8 < C < 1$. The coupling degrees of 10 typical networks are all higher than 0.8, which are inevitable because network spaces could be regarded as space types between block with two dimensions and line with one dimension (Table 8.3), so the network dimension of fractal space is between 1 and 2. The probability which the coupling degree is higher than 0.8 is about 70% based on calculation of fractal coupling degree and on the premise of defining domain of fractal dimension (Fig. 8.14).

It is considered that network fractal and coupling are the core components of landscape network pattern and process. The analysis of spatial relationship should always focus on how to maintain the fractal feature of network on the level of horizontal and vertical pattern so as to maintain the overall state of high coupling degree of network. On the one hand, network fractal is a quantitative description of morphological characteristics of network pattern, and it is necessary to maintain network fractal features for the construction of landscape pattern language and ecological design practice. On the other hand, the coupling relationship of landscape network supports the process

Table 8.3 Coupling degree of network in each case based on fractal dimension

Case1	Case2	Case3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10
0.904	0.918	0.943	0.845	0.908	0.902	0.804	0.892	0.801	0.866

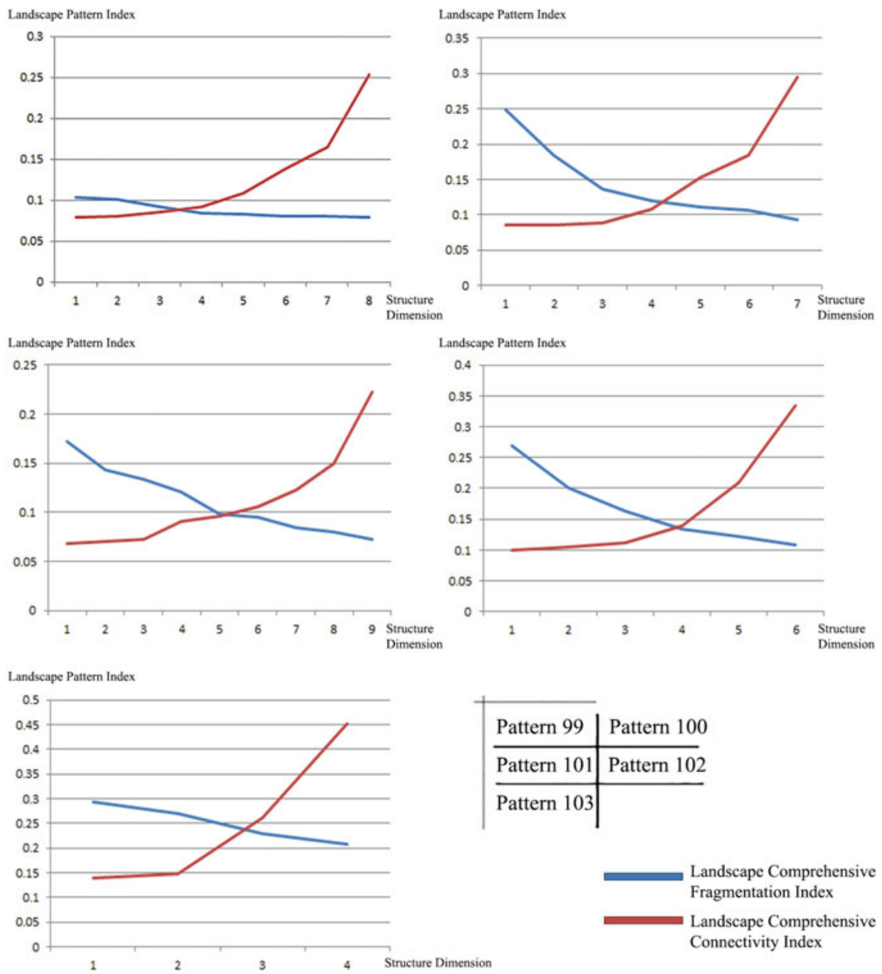


Fig. 8.14 Structural scale effect of fragmentation and connectedness of landscape

from the part to the whole system for the morphological characteristics of network. The fractal feature could make the coupling relationship between components closer and reach a high coupling degree of spatial patterns of network, of which the internal process is closely corresponding to the fractal morphological features of network.

8.3.2.4 Indexes Based on Scale Effect of Network

Three indexes of clustering coefficient (CC), average degree (AD), and proportion (PN) of nodes participating in the construction of composite network were selected to analyze the relationships between network fractal characteristics and network coupling processes, which could reflect partly the morphological structure and organizational characteristics of network and avoid the repetition or conflict (Table 8.4).

Clustering coefficient (CC) could not only describe the network structure and organizational characteristics but also be regarded as the evaluation index of the saturation degree of network connections. The larger the clustering coefficient, the higher overall heterogeneity of network, and the more obvious clusters in network, which indicates that some nodes in network occupy an important structural position and have a large degree for the network connectivity.

Average degree (AD) is the average value counting the degrees of nodes in network. The smaller average degree means that the probability of nodes with a smaller degree have an advantage dominantly, but a few nodes with a larger degree still has an advantage in network. The larger average degree indicates the lower heterogeneity of overall network. Compared with clustering coefficient, the difference is that the clustering coefficient could be combined with specific graphics to explain the structural features of space, while the average degree is the overall attributes of nodes in network.

Proportion of node (PN) participating in the construction of composite network considers that the fractal feature of network and coupling state is based on spatial combinations of single element network. It is to calculate the proportion of composite nodes in a single element network based on the number of composite nodes and then calculate the proportion of nodes but participating in the construction of composite network in the single element network. And the ratio of the total number of nodes in composite network is the result of coordination from a single element network to a composite network, which could indicate the degree of fusion between single element networks.

8.3.2.5 Index of Scale Effect Based on Correlation

Clustering coefficient (CC), average degree (AD), and proportion of node (PN) participating in the construction of composite network have different degrees of influence on network fractal, and the degree of close connection with network coupling is also not consistent.

In addition, according to the analysis of the relationship between network fractal and network coupling, if specific indicators have a greater impact on the network fractal, then their impacts on the overall network coupling degree are also greater. Therefore, this research calculated the coupling degrees based on CC, AD, and PN in a single and composite network and analyzed the correlations between the coupling degree values of three factors mentioned above and the coupling degree values calculated based on the fractal dimension of network, which are the basis for selection of final impact factors (Table 8.5).

The correlation analysis shows that the R^2 of correlation comparison among three groups is 0.417, 0.001, and 0.717, respectively, which indicate that the clustering coefficient and the proportion of nodes participating in the construction of composite

Table 8.4 Clustering coefficient, average degree, and proportion of nodes participating in the construction of composite network in each case

Case number	Network type	Clustering coefficient (CC)	Average degree (AD)	Proportion of node (PN)
Case 1	Settlement system	0.418	3.367	0.747
	Water system	0.114	3.107	0.472
	Composite network	0.208	3.352	0.240
Case 2	Settlement system	0.672	6.606	0.756
	Water system	0.050	2.306	0.738
	Vegetation system	0.093	2.518	0.883
	Composite network	0.416	5.712	0.518
Case 3	Settlement system	0.369	4.073	0.812
	Vegetation system	0.265	2.863	0.836
	Composite network	0.411	4.944	0.647
Case 4	Settlement system	0.623	6.145	0.864
	Water system	0.291	3.305	0.455
	Composite network	0.379	5.395	0.307
Case 5	Settlement system	0.456	4.225	0.904
	Water system	0.123	2.785	0.748
	Vegetation system	0.308	3.528	0.704
	Composite network	0.345	4.495	0.441
Case 6	Settlement system	0.529	4.355	0.832
	Water system	0.196	2.648	0.723
	Composite network	0.286	2.977	0.385
Case 7	Settlement system	0.395	4.639	0.970
	Vegetation system	0.312	3.760	0.519

(continued)

Table 8.4 (continued)

Case number	Network type	Clustering coefficient (CC)	Average degree (AD)	Proportion of node (PN)
	Composite network	0.424	4.904	0.322
Case 8	Settlement system	0.348	3.336	0.902
	Vegetation system	0.376	4.568	0.386
	Composite network	0.370	4.300	0.164
Case 9	Settlement system	0.538	5.492	0.923
	Vegetation system	0.306	4.076	0.195
	Composite network	0.336	4.396	0.042
Case 10	Settlement system	0.676	8.078	0.974
	Water system	0.176	2.437	0.899
	Vegetation system	0.215	3.086	0.567
	Composite network	0.326	5.333	0.432

Table 8.5 Coupling degree of network fractal dimension

Name	Clustering coefficient (CC)	Average degree (AD)	Proportion of node (PN)	Coupling degree (C)
Casa 1	0.924	0.847	0.928	0.924
Casa 2	0.989	0.819	1.000	0.991
Casa 3	0.833	0.912	0.998	0.926
Casa 4	0.883	0.882	0.815	0.845
Casa 5	0.997	0.746	0.971	0.977
Casa 6	0.888	0.789	0.990	0.942
Casa 7	0.808	0.782	0.846	0.828
Casa 8	0.821	0.825	0.843	0.833
Casa 9	0.671	0.836	0.710	0.697
Case 10	0.889	0.999	0.803	0.844

network are highly correlated with the fractal dimension of network, while the *P*-values indicating the possibility of $R = 0$ are 0.001, 0.926, and 0.002. Therefore, the clustering coefficient (CC) and the proportion of nodes participating in the construction of composite network (PN) have a significant correlation with fractal dimension of network. In conclusion, these two factors are closely related to the formative process of network fractal features on the basis of ensuring network fractal and network coupling as the core components of pattern and process in landscape network. The study of correlation also shows that two indexes have similar influences on the fractal feature of network.

8.3.2.6 Indicators Translation of Scale Effects

From the perspective of landscape architecture, the clustering coefficient contains a description of landscape connectivity (SC) and contains more abundant information of the connected pattern, especially the structure information, so the complete translation needs to be supplemented and improved by other indexes. The research selected landscape contagion index (CONTAG) as the supplement to describe the clustering degree or extension trend of patch types in landscape making up the deficiency of landscape connectivity in structure description and Shannon–Wiener index (SHEI) which takes into account the changes of special network structure in vertical pattern supplementing the description defects of landscape connectivity index. Landscape connectivity index (SC), landscape contagion index (CONTAG), and Shannon–Wiener index (SHEI) of landscape scale are integrated into the index system of clustering coefficient translation, which collectively referred as the system of integrated landscape connectivity index.

From a network with single element to a composite network, a higher proportion of nodes participating in the process indicates that the bigger number of nodes of single element network participating in and the more composite space would eventually be formed. On the contrary, if the proportion of nodes participating in the composition is low, the number of nodes in a composite network would eventually be more. There are two ways to reduce the number of patches through controlling the composite networks, one of which is realized by network combining of single elements at the structural scale of horizontal pattern, and the other is realized by network contraction process in the process of scale transformation. In this research, the mean Euclidean nearest neighbor distance distribution (ENN) and Shannon diversity index (SHDI) are introduced to improve the translation of the proportion of nodes participating in the composition based on the number of patch (NP) taken as basic index of fragmentation evaluation. The ENN of landscape reflects the distance between blocks of the same type, and its larger value indicates that the connections within network are weak, and the degree of homogenization is high. The SHDI could reflect the degree of heterogeneity of landscape, especially sensitivity to the unbalanced distribution of various patches in landscape (Table 8.6).

Table 8.6 Indexes of scale effects in landscape space network

Network clustering coefficient (CC)			Proportion of nodes participating in recombination (PN)		
Landscape comprehensive connectivity index			Landscape comprehensive fragmentation index		
Landscape connectivity index (SC)	Landscape contagion index (CONTAG)	Shannon–Wiener index of landscape (SHEI)	Number of patch (NP)	Mean Euclidean nearest neighbor distance distribution of landscape (ENN)	Shannon diversity index of landscape (SHDI)

8.3.3 Scale Effect and Structure of Network

8.3.3.1 Landscape Pattern Index at Multiple Structural Scales

In this research, the structural scale was defined by the K-core division of network models, which could be measured using the index of landscape comprehensive connectivity and fragmentation of landscape corresponding to multiple structure scales. It should be emphasized that, on the one hand, the numerical fluctuation between the indexes representing the degree of connection and fragmentation is relatively small, and the connotation expression and contribution degree of each index to the comprehensive index are similar through the calculation and normalization of six independent indexes, therefore, the research assigns the same weight value to each index; on the other hand, five patterns numbered 99, 100, 101, 102, and 103 were selected from the typical network patterns, which were based on the differences and typicality in structure and morphology as far as possible between the cases.

The calculation process of landscape pattern index at multiple structural scales is as follows: According to the order of structural scale from small to large, starting from the structural scale $K = 1$, patterns of network space are processed according to the model of K-core network and given the corresponding color according to the degree of nodes. In the process from a smaller structural scale K to an adjacent larger structural scale $K + 1$, and according to the principle of spatial organization maintained by network fractal at the level of vertical pattern, nodes with a smaller degree tend to connect nodes with a larger degree, while the direct connection between nodes with a larger degree is reduced, and the nodes with a degree of no more than K are integrated into the larger nodes around them. The process would be repeated until the value of K reaches the maximum of network, and finally, landscape patterns at multiple structure scales corresponding to five typical network patterns could be mapped. The landscape comprehensive connectivity and fragmentation index could be calculated using the software *Fragstats* by the way of importing structure diagrams of landscape pattern at multiple structural scales of typical network patterns into *Arcgis10.0* (Table 8.7).

8.3.3.2 Scale Effect of Landscape Pattern Index

Landscape pattern would be in the stable state with low comprehensive connectivity of landscape and the value of structural scale $1 < K < 2$. It means that landscape spatial network model is a graph of connections, and this kind of detailed classifications of network corridor and node composition leads to the relatively homogenization and lack of structural characteristics of network. According to the spatial organization principles of network fractal at the level of vertical pattern, the clustering degree of regions with relatively important nodes in the homogenized network would be improved in the process of connecting nodes with lower degree to nodes with higher degree, and correspondingly, the homogenization characteristics of network would be gradually weakened. When the structural scale is at $3 < K < 4$, the network contraction improves the network connectivity and strengthens the small-word network totally.

With the continuous contraction of network, the integration of total network is finally realized at the level of higher structural scale, in which there are a few nodes with large degree integrating network as their inner components during the contraction process, so that the total network has a very high degree of connectivity.

When the value of structural scale is at $1 < K < 2$, there are a large number of nodes with small degree in network. With the network contraction, the quantity of patches decreases sharply by connecting the nodes with larger degree, and correspondingly, the degree of landscape comprehensive fragmentation also shows a trend of sharp decline. When the value of structural scale is at $3 < K < 4$, the degree of nodes is relatively large because of absorbing some nodes with small degree in the process of network contraction, and the number of nodes is relatively small compared with the node number when the structural scale is at $1 < K < 2$, thus the change in the number of patches caused by further network contraction is relatively gentle. With the continuous increase of structure scale, the network contraction process finally leads to the network being merged into a few key patches with high degree, so a higher degree of integration eventually leads to a very low degree of comprehensive fragmentation of landscape.

8.3.3.3 Hierarchy of Structural Scale

For landscape network with fractal characteristics, the organization model of network spaces at the level of horizontal pattern maintains a relatively stable situation within three structural scales. Specifically, when the value of structural scale is at $1 < K < 2$, the network model is mainly composed of independent nodes and nodes playing the role of articulation, in which a large number of nodes and their characteristics of homogeneous distribution have little influence on the overall heterogeneity of network. When the value of structural scale is at $3 < K < 4$, the network units with

Table 8.7 Index of landscape network pattern with different structure and scale

Number	Scale	NP	ENN	SHDI	Integrated fragmentation	SC	CONTAG	SHEI	Integrated connectivity
99	K_1	0.164	0.015	0.103	0.019	0.110	0.108	0.079	0.183
	K_2	0.156	0.015	0.100	0.022	0.111	0.109	0.081	0.181
	K_3	0.131	0.014	0.091	0.033	0.112	0.110	0.085	0.176
	K_4	0.111	0.013	0.084	0.051	0.113	0.112	0.092	0.176
	K_5	0.110	0.013	0.082	0.087	0.119	0.120	0.109	0.191
	K_6	0.106	0.011	0.080	0.154	0.128	0.131	0.138	0.218
	K_7	0.111	0.010	0.080	0.213	0.137	0.143	0.164	0.245
	K_8	0.111	0.008	0.079	0.421	0.171	0.166	0.253	0.332
100	K_1	0.395	0.163	0.249	0.015	0.123	0.118	0.0 86	0.335
	K_2	0.209	0.163	0.185	0.017	0.123	0.118	0.086	0.271
	K_3	0.093	0.151	0.136	0.023	0.124	0.119	0.089	0.225
	K_4	0.076	0.153	0.119	0.057	0.132	0.134	0.108	0.227
	K_5	0.076	0.144	0.111	0.171	0.140	0.147	0.153	0.264
	K_6	0.076	0.129	0.106	0.231	0.157	0.166	0.185	0.290
	K_7	0.076	0.097	0.093	0.486	0.201	0.198	0.295	0.388
101	K_1	0.238	0.139	0.172	0.010	0.098	0.098	0.069	0.240
	K_2	0.161	0.135	0.143	0.011	0.099	0.100	0.070	0.214
	K_3	0.153	0.127	0.134	0.020	0.099	0.099	0.073	0.206
	K_4	0.137	0.122	0.121	0.068	0.101	0.102	0.090	0.212
	K_5	0.086	0.107	0.099	0.093	0.100	0.098	0.097	0.195
	K_6	0.075	0.107	0.095	0.104	0.107	0.108	0.106	0.201

(continued)

Table 8.7 (continued)

Number	Scale	NP	ENN	SHDI	Integrated fragmentation	SC	CONTAG	SHEI	Integrated connectivity
	K_7	0.054	0.099	0.085	0.140	0.113	0.116	0.123	0.208
	K_8	0.054	0.086	0.080	0.194	0.127	0.128	0.150	0.229
	K_9	0.042	0.078	0.072	0.362	0.156	0.150	0.222	0.295
102	K_1	0.411	0.195	0.270	0.026	0.140	0.134	0.100	0.370
	K_2	0.210	0.191	0.201	0.029	0.145	0.143	0.105	0.306
	K_3	0.131	0.177	0.163	0.041	0.148	0.147	0.112	0.275
	K_4	0.088	0.166	0.135	0.100	0.156	0.160	0.139	0.273
	K_5	0.081	0.154	0.123	0.260	0.178	0.188	0.209	0.332
	K_6	0.080	0.118	0.108	0.544	0.234	0.227	0.335	0.444
103	K_1	0.259	0.278	0.293	0.018	0.205	0.194	0.139	0.432
	K_2	0.251	0.252	0.269	0.027	0.212	0.204	0.148	0.417
	K_3	0.245	0.263	0.229	0.268	0.251	0.268	0.262	0.492
	K_4	0.245	0.207	0.209	0.687	0.331	0.335	0.451	0.660

configuration begin to appear, and its stable structural composition and the increase of units lead to further network contraction and a significant increase in the saturation of network heterogeneity and internal connections. When the value of structural scale is at $5 < K < \mathrm{N}$, the clusters composed of a few nodes with high connection saturation appeared as the result of network contraction. Therefore, the structural scale would remain relatively stable when the internal connections of network reach the state of saturation with the continuous increase of structural scale.

For the spatial organization at the level of vertical pattern, network patterns with the value of structural scale $1 < K < 2$ are reflected in spaces with relatively high identifiable characteristics of network texture. However, network patterns with the value of $3 < K < 4$ show preliminary features of structure. Network patterns with $5 < K < N$ have obviously individual features of network, which are consistent with the structural features of natural landscape pattern. It is the relatively stable relationship of spatial organization within the scope of structural scale that constitutes the totality of landscape network through the systematical integration at the level of vertical pattern.

8.4 Network Types with Shrinking and Nesting

Through the graphical description of contraction process of typical network patterns at multiple structural scales, the internal organization of the typical network patterns in landscape could be summarized as the spatial nested structure supported by network contraction, which is based on stratification of the network structural scale, the network contraction process under the transformation of structural scale, the coordination among the spatial relationships in horizontal pattern, and the adherence to spatial organization principles of the vertical pattern of network. It is the contraction process and nested structure that integrate network components at multiple structural scales and maintain the spatial organization model with fractal features of network in vertical pattern.

The analysis of typical network patterns showed that the network contraction process and nested organization relationship consisted of two basic types of the progressive nested and the leapfrog nested. The progressive nested relations could also be divided into the progressive nested between isomorphic networks and that between the heterogeneous networks. The leapfrog nested could be divided into the leapfrog nested with structural reinforcement and that with structural remolding.

8.4.1 Progressive Nested

The progressive nested means that network compositions within the interval of small structural scale in the structural scale transformation are the main objects fused in the contraction process with the compositions of adjacent network within the interval of higher scale. Therefore, the nested relationships between networks with structural scales are progressive layer by layer, and on which usually network patterns are relatively complete and clear.

8.4.1.1 Organizational Relations with Structural Scales

Here, the study selected the typical network pattern numbered 99 as a case to analyze the type of progressive nested (Fig. 8.15). The selected area of network is located in Tushan Village, Nanxun District, Huzhou, Zhejiang Province, which has the characteristics of Jiangnan water-town landscape. Through the construction of network model and analysis of K-core network, network compositions with value of structural scale $1 < K < 2$, $3 < K < 4$, and $5 < K < N$ were extracted and numbered, respectively, with the letters of a, b, and c (Fig. 8.16).

When the value of structural scale is at $1 < K < 2$, the structure features of network are not obvious, which present the evolutionary characteristics of network nodes in local space and the basic laws of the micromechanism of network organization (Fig. 8.17).

The following two aspects could be read from patterns of regional network about the villages in the South of Yangtze River selected in the research. One is a close spatial connection between settlement construction and the nodes of water system, which is mostly mediated by vegetation space. The other is nodes of water system mostly enhancing their heterogeneity and stability through the combination of vegetation.

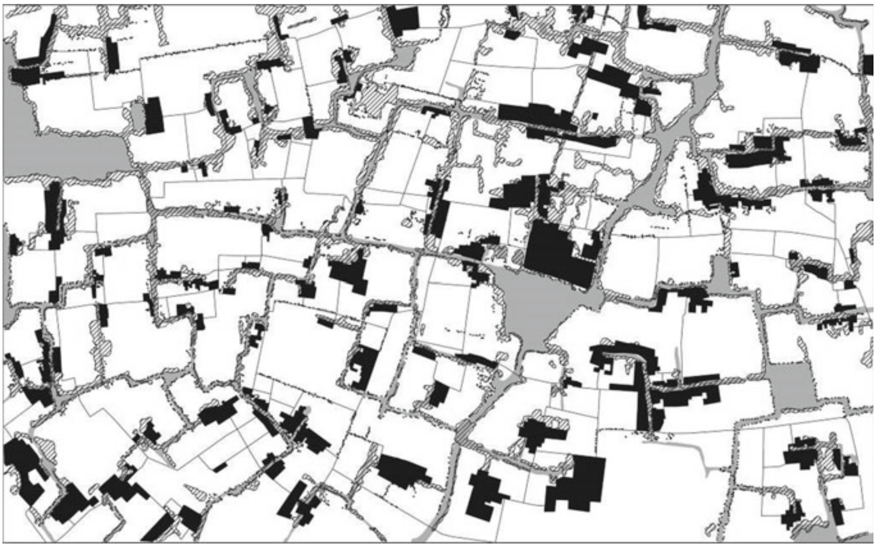


Fig. 8.15 Vectorization of typical network pattern No. 99

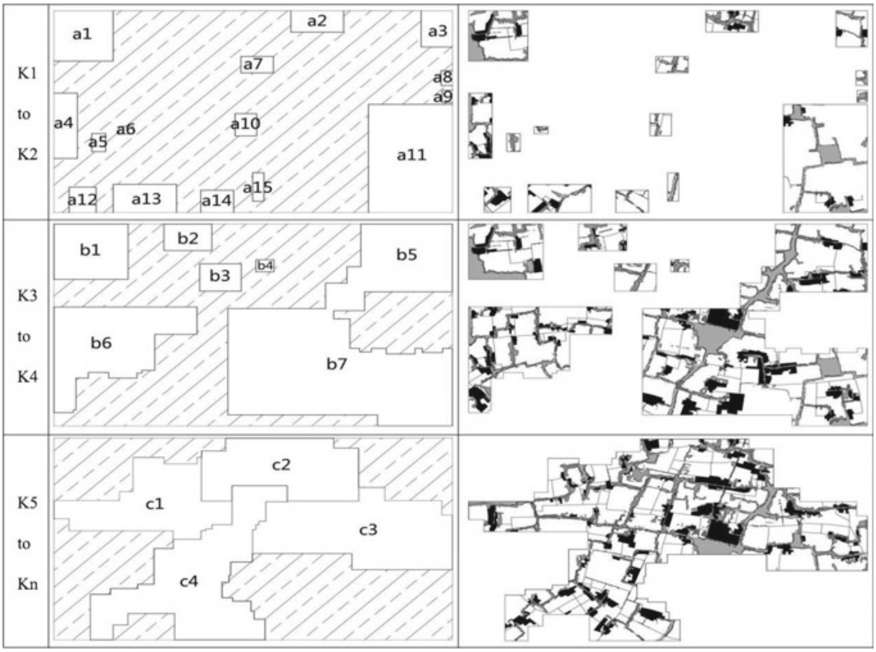


Fig. 8.16 Space composition and number of core networks under structural scales

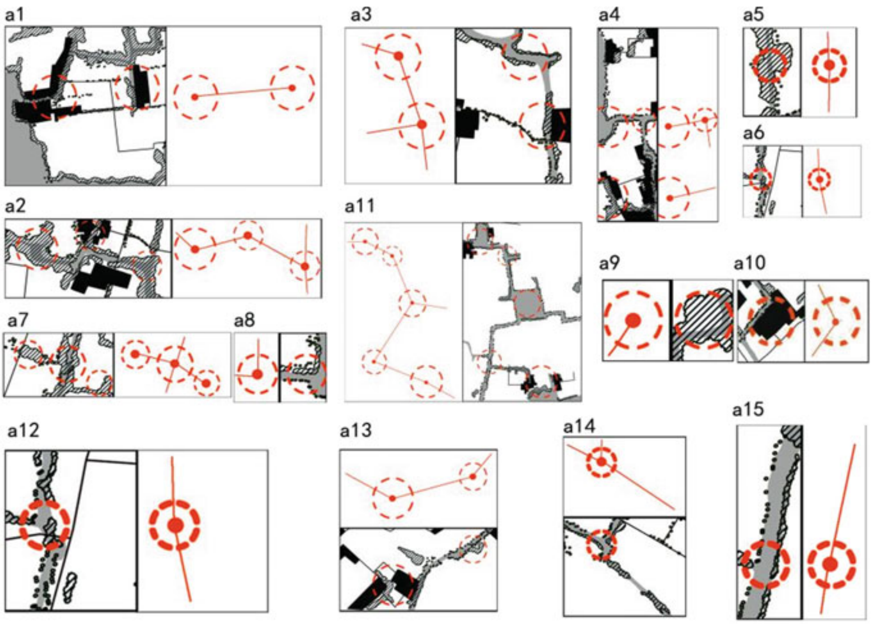


Fig. 8.17 Space composition pattern of core network with structural scale $1 < K < 2$

When the value of structural scale is at $3 < K < 4$, landscape pattern preliminarily forms features of networking, which mainly depends on the adaptive transformation mode of local settlements to the environment and water systems or vegetation spaces. The difference in form and structure of network space is reflected in the number of nodes involved in the formation of annular network units and the ring connected vegetation and water systems in different regional environments. For the villages in the South of Yangtze River selected for the study, the scale of annular units is influenced by the grading water system with ring connection and morphological changes of water system in part (Fig. 8.18). The research considers the network at this structural scale as the type of homogeneous structure, on which more complex core networks are formed and evolved with the complexity of node connection and corridor saturation, which lead to further differentiation of network structure.

When the value of structural scale is at $5 < K < N$, the annular network units of network with structural scale of $3 < K < 4$ would be complicated by strengthening the direct connections among nodes, which is specifically manifested as the enhancement

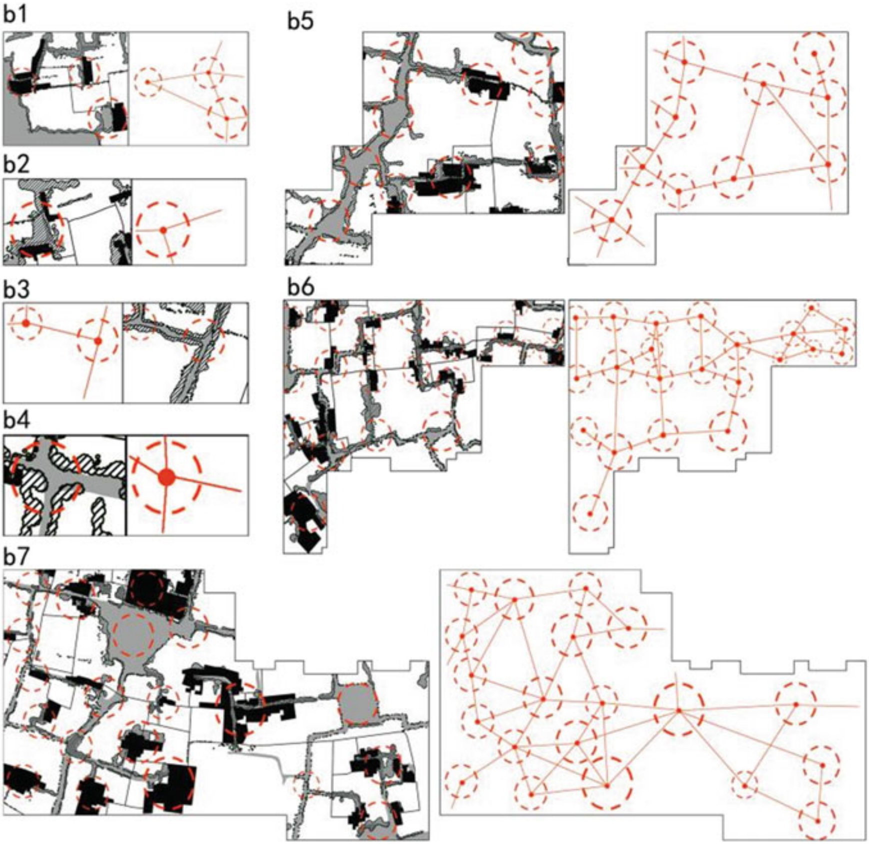


Fig. 8.18 Space composition pattern of core network with structural scale $3 < K < 4$

of connection saturation inside the annular network units and the node clusters of network with the obviously structural heterogeneity. Spatial relations of the annular network units under the structural scale are mainly interwoven (Fig. 8.19).

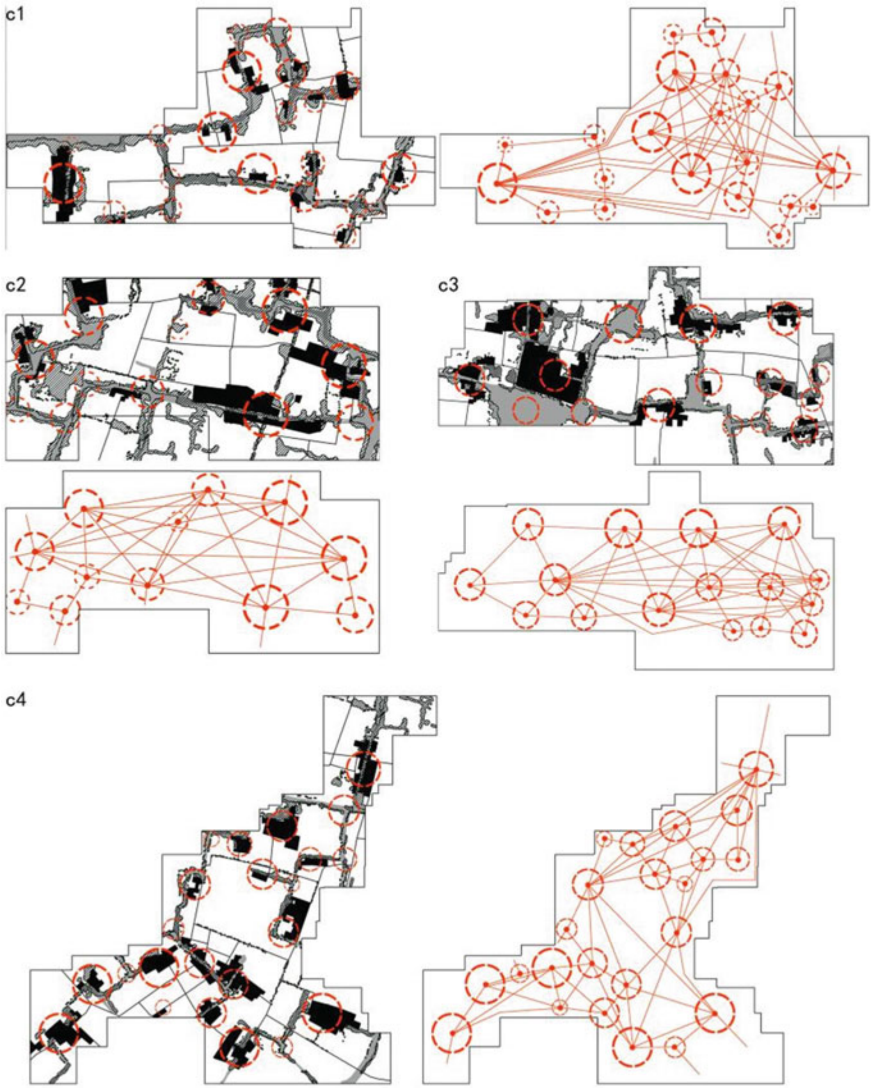


Fig. 8.19 Space composition pattern of core network with structural scale $5 < K < N$

8.4.1.2 Shrinking and Nested Relationship in Structural Scaling

The compositions of landscape network would not disappear in vision in the process of structural scaling, but the same typical network patterns reflect the spatial relationships and organizational characteristics corresponding to the specific structural scales due to their constraints. It is summarized as the organizational and evolutionary characteristics of network in part at the structural scale $1 < K < 2$, the structural characteristics of network space at the structural scale $3 < K < 4$, and the overall landscape pattern characteristics of composite network at the structural scale $5 < K < N$. In the process of scaling, the regions with feature of network unreflecting the obvious characteristics of structural scale are fused with some key nodes through network contraction to meet the requirements of being identified with the conditions of specific structural scale.

The fusion between nodes in the case No. 99 (Fig. 8.20) and the adjacent large nodes with close spatial connection would satisfy the requirement of being recognized under the condition of structural scale $3 < K < 4$ in the process of structural scaling from $1 < K < 2$ to $3 < K < 4$. As a background, the network region with $3 < K < 4$ is decomposed and further connected with the nodes with high connectivity of network with higher structural scale, which are fused totally to meet the requirements of being identified under the condition of higher structural scale in the process of structural scaling up from $3 < K < 4$ to $5 < K < N$.

In the process of network contraction, when the structural scale is at $5 < K < N$, due to the fusion of background network patterns with relatively homogenization structure and enhancement of internal connection complexity in annular network units, it eventually formed several regions with K-core networks and the relatively saturated connections, which embodied in case No. 99 with K equaling 5, 6, 7, 8 separately with the main difference of nodes number. The difference between the K-core networks and the absorbed K-core networks at low level is mostly represented by the overall landscape framework of the region where landscape network locates in. It is a few nodes of the framework of network pattern that K-core networks are integrated each other (Fig. 8.21).

When the structural scale is at $3 < K < 4$, networks of $1 < K < 2$ would be fused into the network of $3 < K < 4$. This process would not have an essential impacts on the structure of the core network with $3 < K < 4$. Networks with high connection saturation could only be distinguished and unreflect the particularity of their structures and connections due to the limitation of structural scale, therefore, it is necessary to subdivide the K-core networks with $5 < K < N$ (Fig. 8.22). Since networks with $3 < K < 4$ are incorporated into the K-core network at large scale through contraction and fusion, there are less direct connections between them and the framework of overall network pattern, but the main ways of their connection with external spaces are established through connecting the nodes near the boundary of network with structure scale $5 < K < N$. The process based on network contraction and fusion gives rise to the nested relationship of landscape spaces in the process of structural scaling.

Fig. 8.20 Contraction and nested relationships with the change of structural scale

8.4.1.3 Progressive Nested Among Isomorphic Networks

The progressive nested among isomorphic networks refers to the relations of similar space organization and morphological structures among networks with different structural scales participating in nesting process, which is based on the conditions of homogeneous ecological context, settlement systems with clear hierarchy or relative dissociation, the complete same land uses, and their transformation models.

The study selected network pattern No. 106 as a typical case to discuss the nested type of landscape further, which cultivates the nested structure of network under the condition of the moderate and small structural scale through the contraction process of network, but the nested structure of network has almost the similar spatial

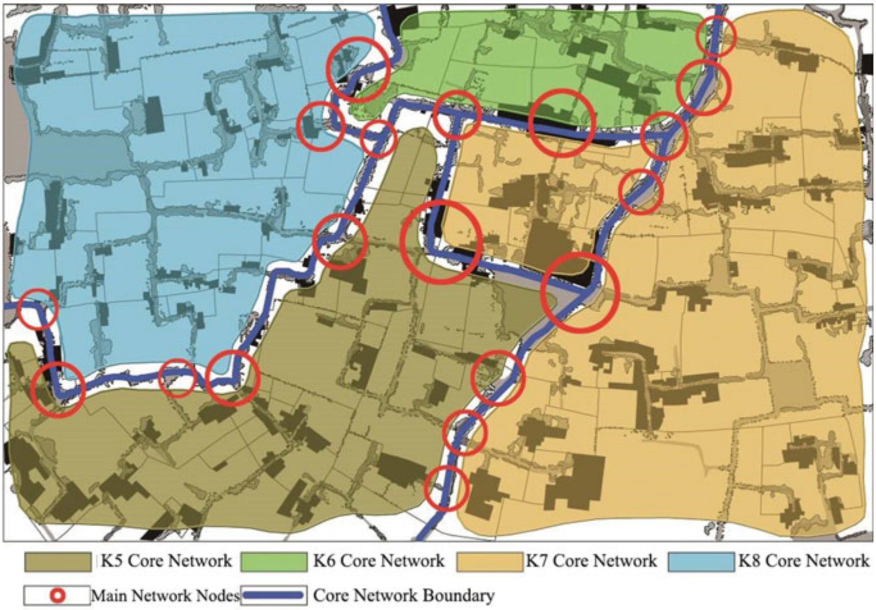


Fig. 8.21 Overall landscape pattern of network with structural scale $5 < K < N$

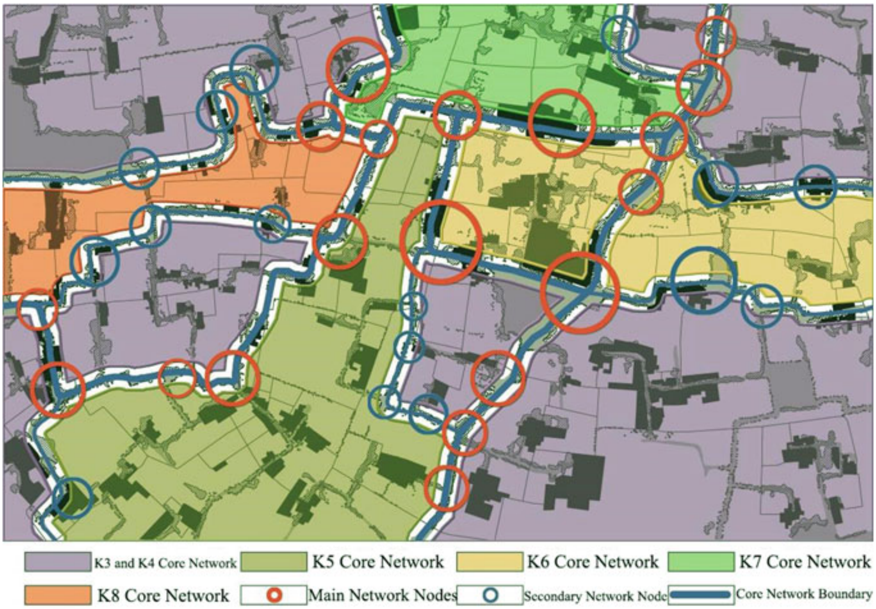


Fig. 8.22 Overall landscape pattern of network with structural scale $3 < K < 4$

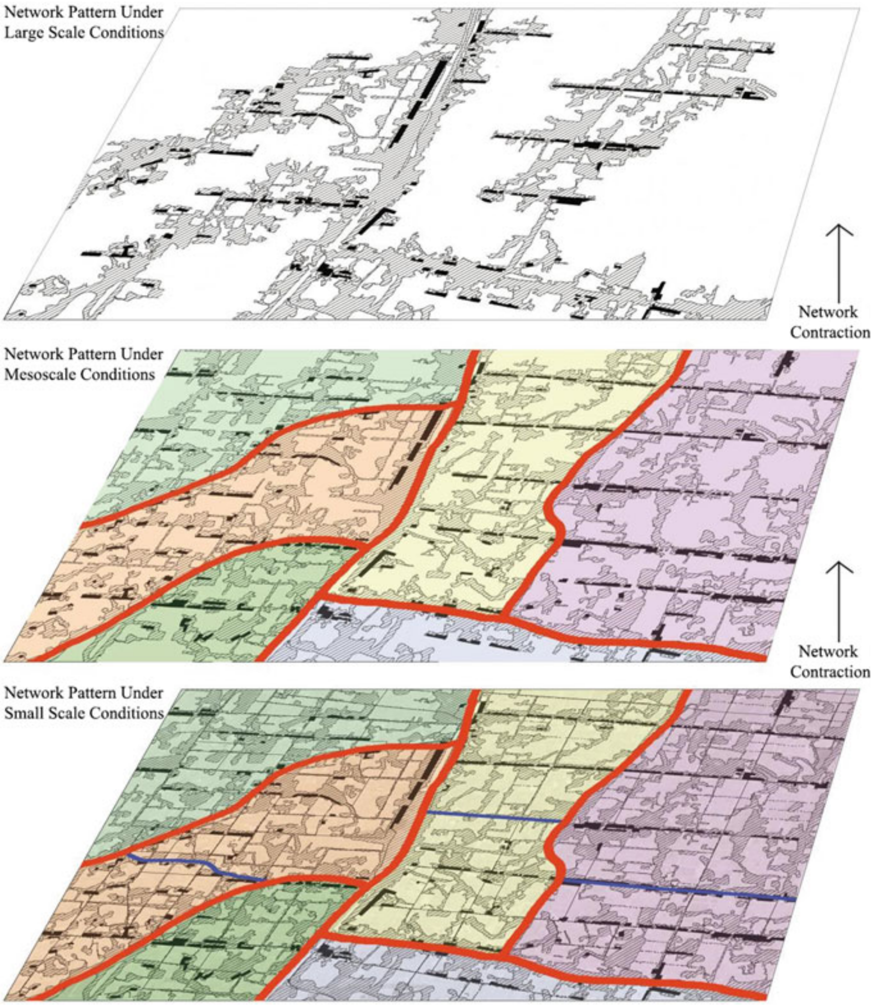


Fig. 8.23 Contraction process of typical network pattern No. 106

organizations and morphological characteristics of structure (Figs. 8.23, 8.24 and 8.25).

8.4.1.4 Progressive Nested Among Heterogeneous Networks

Under the conditions of different structural scales, the progressive nested network could be realized among networks with different relations of spatial organizations and characteristics of morphological structure through network contraction. The nested relationship requires strong hierarchical correspondence among landscape

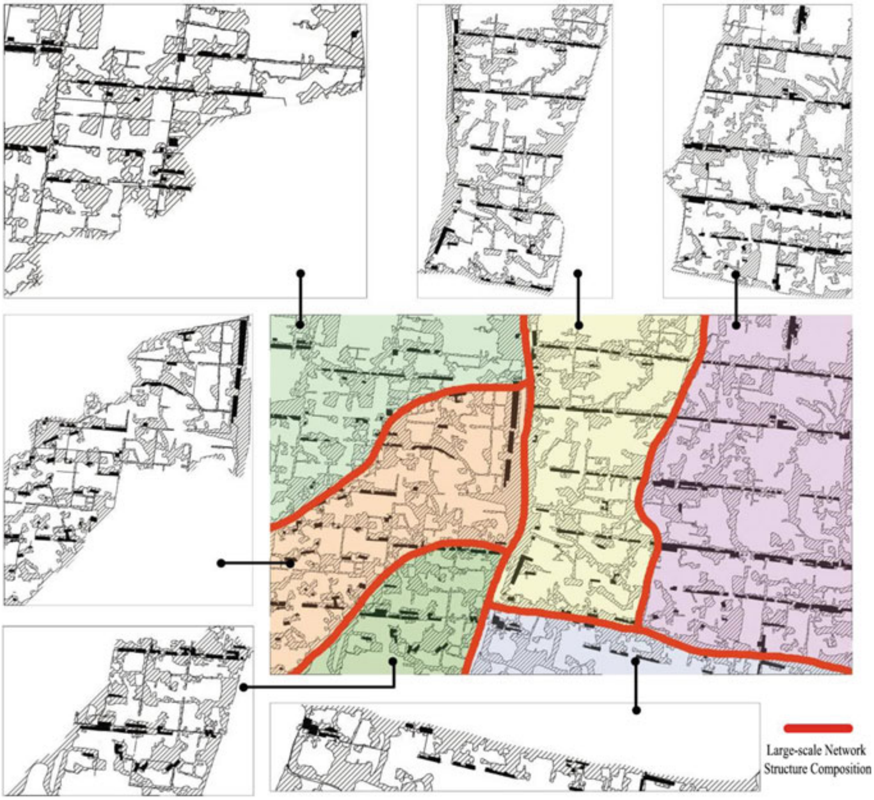


Fig. 8.24 Nested structure of typical network pattern No. 106 at mesoscale

elements of single network of water system, vegetation, and settlements, of which the limitation keeps the coordination between network components in the process of network contraction.

Network pattern No. 105 is selected as a typical case to further discuss this nested type. The corresponding level and spatial coordination among nodes and corridors of network combining settlement, vegetation, and water system are existed in local space. Although there are obvious differences in the morphological structure and organizational relations among networks with nested structure, networks with single element maintain the high degree of coordination which integrates them into the compositions of network at higher level of scale in the process of network contraction (Figs. 8.26, 8.27 and 8.28).

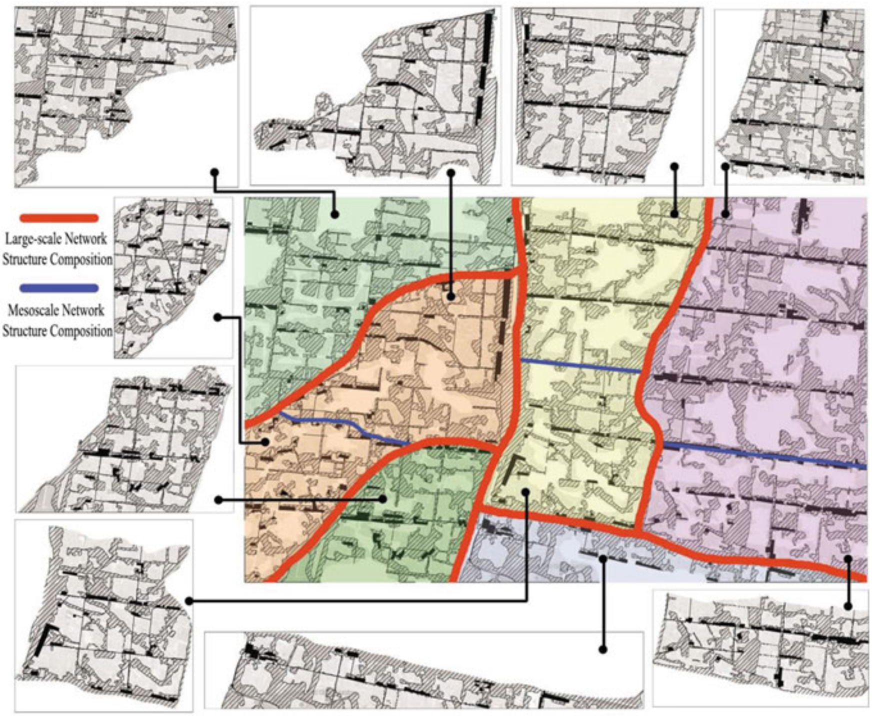


Fig. 8.25 Nested structure of typical network pattern No. 106 at microscale

8.4.2 Leapfrog Nested

The leapfrog nested refers to the situation in which network compositions at smaller structural scale are fused directly with networks at other structural scales crossing the adjacent higher structural scale interval in the process of network contraction.

8.4.2.1 Organizational Relations at Multiple Structural Scales

The leapfrog nested in vertical pattern of network was analyzed through the network pattern No. 101 (Fig. 8.29). The selected area of network is located in Chenhe Village, Dayi County, Chengdu, Sichuan Province, which has typical landscape pattern of *Linpan* in western Sichuan. Through the network model construction and K-core network analysis, the compositions of K-core network at multiple structural scales are extracted according to value of structural scale $1 < K < 2$, $3 < K < 4$, and $5 < K < N$, respectively, and are numbered with letters of a, b, and c, respectively (Fig. 8.30).

The structural characteristics of network at structural scale$1 < K < 2$ are not obvious, but they are similar to the pattern No. 99 in the evolutionary characteristics

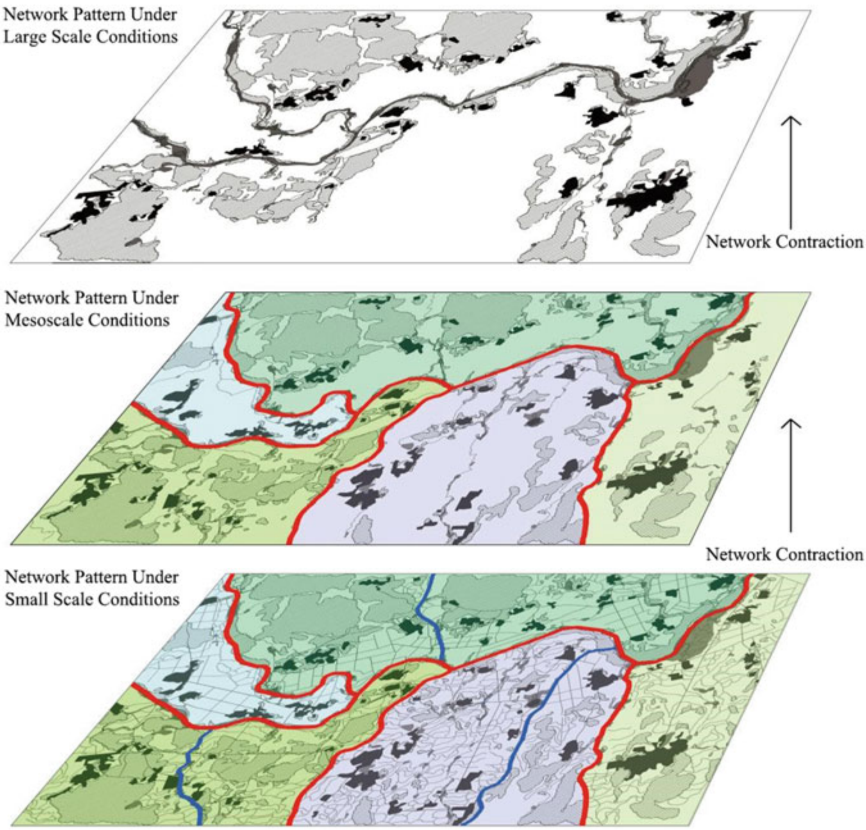


Fig. 8.26 Contraction process of typical network pattern No. 105

of nodes in part of network compositions at specific value of K, which is the basic law of networking mechanism at microlevel. To be specific, the following two aspects could be read in regional network pattern of *The Linpan*, one of which is the close connections between settlement construction and vegetation nodes, which highlights the homogenization of vegetation distribution in the area, and the other is to enhance its stability of vegetation nodes through combination with settlement spaces. It is obviously observed that the forms of vegetation and settlement network fit each other completely at structural scale $1 < K < 2$ (Fig. 8.31).

The characteristics of networking structure were formed initially in landscape pattern at structural scale $3 < K < 4$. For the case of *Linpan*, the morphological characteristics of vegetation network are presented at the early stage of networking in the process of combining between architectures and vegetation nodes, which were affected by surface runoff and distributed with independent characteristics of paralleled relation between water-green corridors connected weakly. With the ability decrease of vegetation space to meet the complex demands of settlement activities,

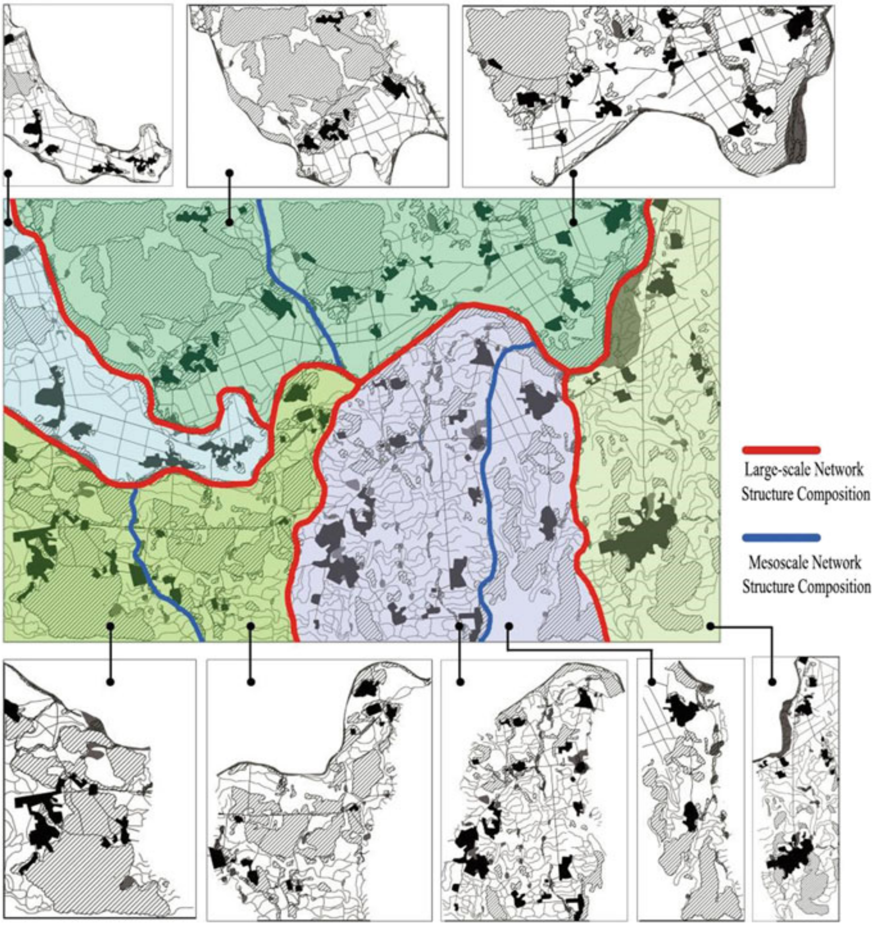


Fig. 8.27 Nested structure of typical network pattern No. 105 at microscale

new settlements began to be built in the area with sparse vegetation breaking away from the rules of traditional settlement selection, which act on as an intermediate node connecting the composite nodes in the system of parallel water-green corridors and forming a large number of annular network units (Fig. 8.32). The *K*-core network at this scale is regarded as a kind of homogeneous network structure which means all the complex *K*-core networks would evolve on this basis and the complexity of connections between nodes within the annular network unit, and the increase of saturation would lead to further differentiation of network structure.

When structural scale is at $5 < K < N$, with the stratification of settlement networks in units of annular network at structural scale $3 < K < 4$, settlements with scale superiority, which represented as networking area with advantages of traffic locations or large vegetation spaces in the case, would form the clusters of network node

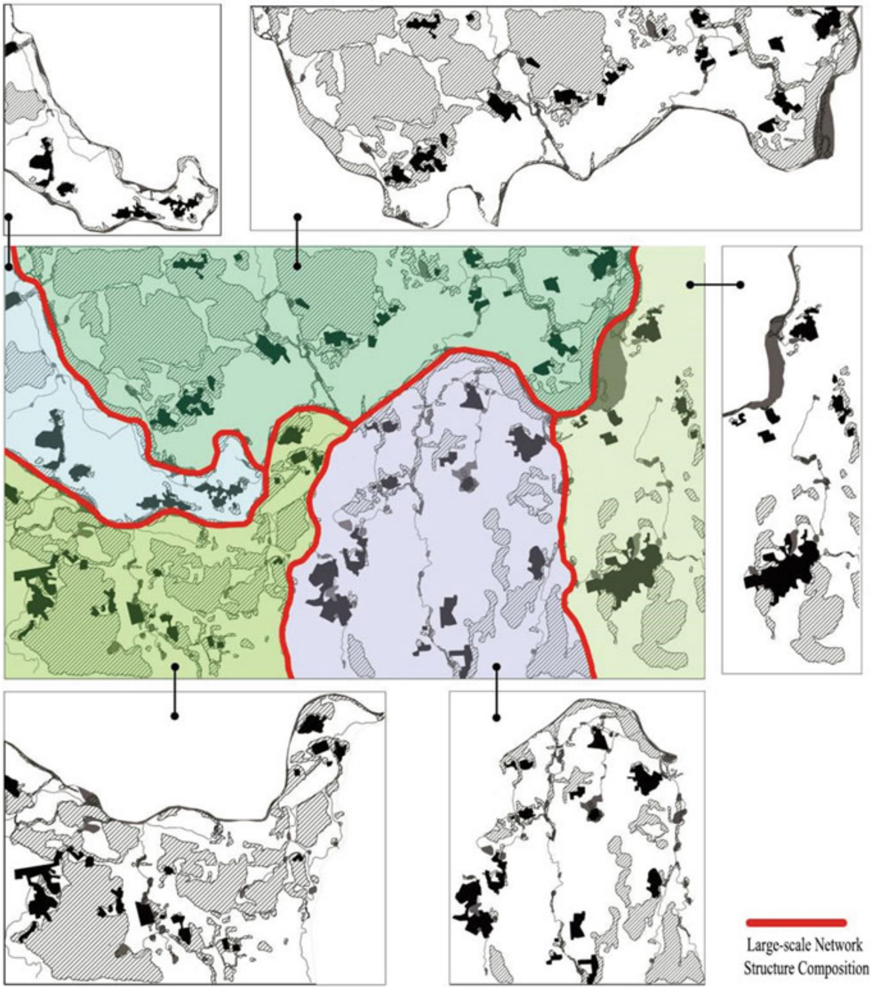


Fig. 8.28 Nested structure of typical network pattern No. 105 at mesoscale

with obvious structural heterogeneity through improving the degree of connection saturation among inner nodes of annular network units through adding vegetation or road corridor connections (Fig. 8.33).

8.4.2.2 Shrinking and Nested Relationships with Scaling

In the process of structural scaling from $1 < K < 2$ to $3 < K < 4$ of typical network pattern No. 101 (Fig. 8.34), the nodes in the case and adjacent nodes with close spatial connection are fused to meet the requirements of being recognized of network with

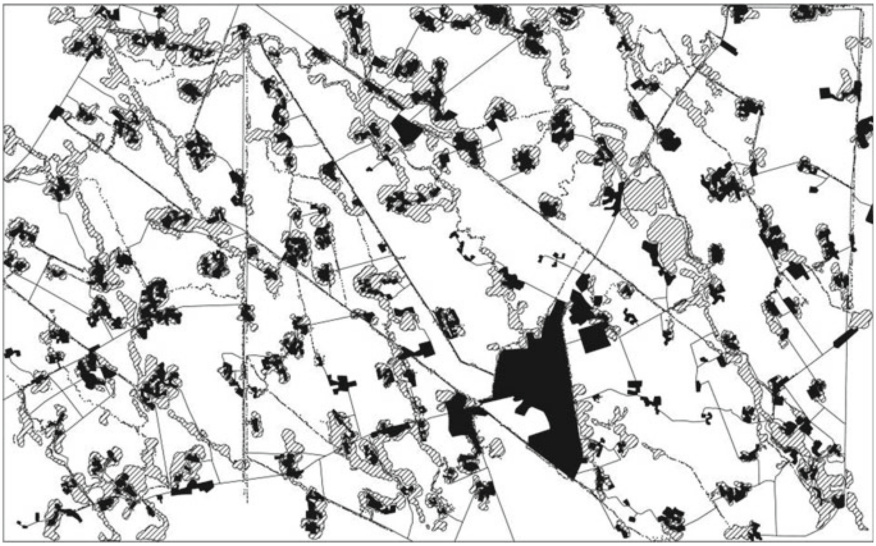


Fig. 8.29 Vectorization of typical network pattern No. 101

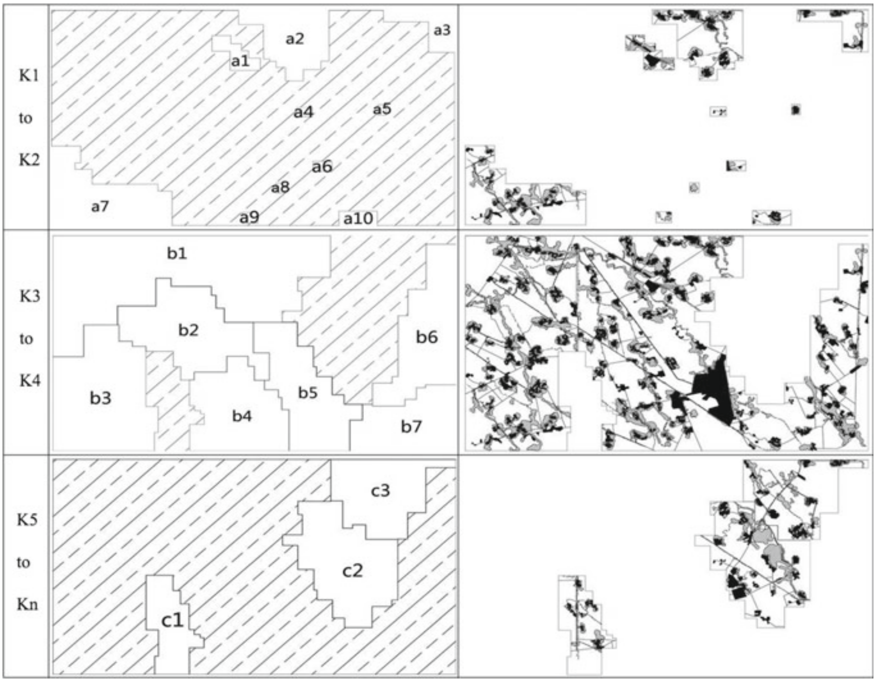


Fig. 8.30 Space composition and number of *K*-core network at structure scales

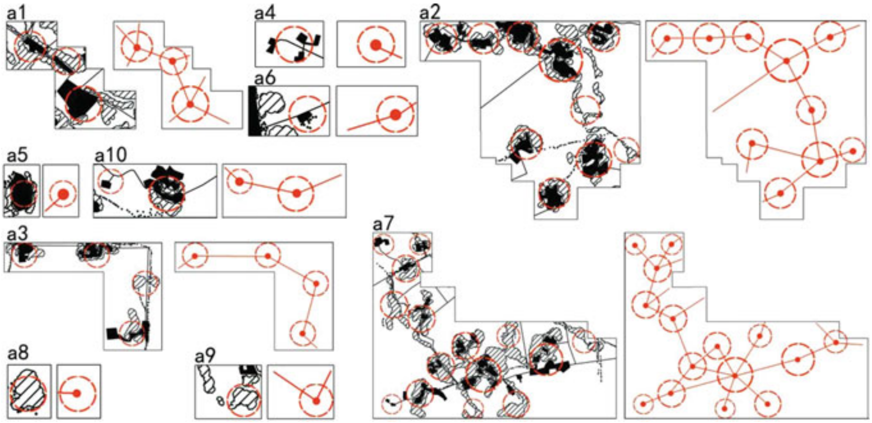


Fig. 8.31 Pattern of K-core network with structure scale $1 < K < 2$

structural scale $5 < K < N$. In the process from structural scale $3 < K < 4$ to $5 < K < N$, the K-core networks at $3 < K < 4$ acting as the background of structural network are decomposed and integrated into nodes with high degree of connectivity in network with large K value, which are absorbed totally and meet the requirements of being identified under the conditions of large structure scale.

In the process of network contraction, when networks at structure scale $5 < K < N$ were analyzed, the main difference between K-core networks at high structural scale and K-core networks absorbed at low structural scale is shown as the overall framework of landscape network pattern, by which K-core networks are integrated through a few nodes connection with the contraction and integrating of network pattern as context at low structure scale and the improvement of internal connection complexity of annular network units (Fig. 8.35). However, different from the progressive nested relationship, when networks at structural scale $3 < K < 4$ are analyzed and K-core networks at structural scale $5 < K < N$ are subdivided (Fig. 8.36), it is found that networks at structural scale $5 < K < N$ are in dominance, although K-core networks at structural scale $3 < K < 4$ are incorporated into K-core networks at large scale by means of contraction.

The compositions of network at structural scale $3 < K < 4$ would weaken the structure compositions of network at large scales, which are showed that K-core networks at structural scale $3 < K < 4$ are simultaneously merged into network area with $5 < K < N$ in pattern No. 101. Therefore, the leapfrog nested is also an incomplete type of nested structure, and network pattern shows the discontinuity and instability sometimes in the process of structural scaling compared with the progressive nested.

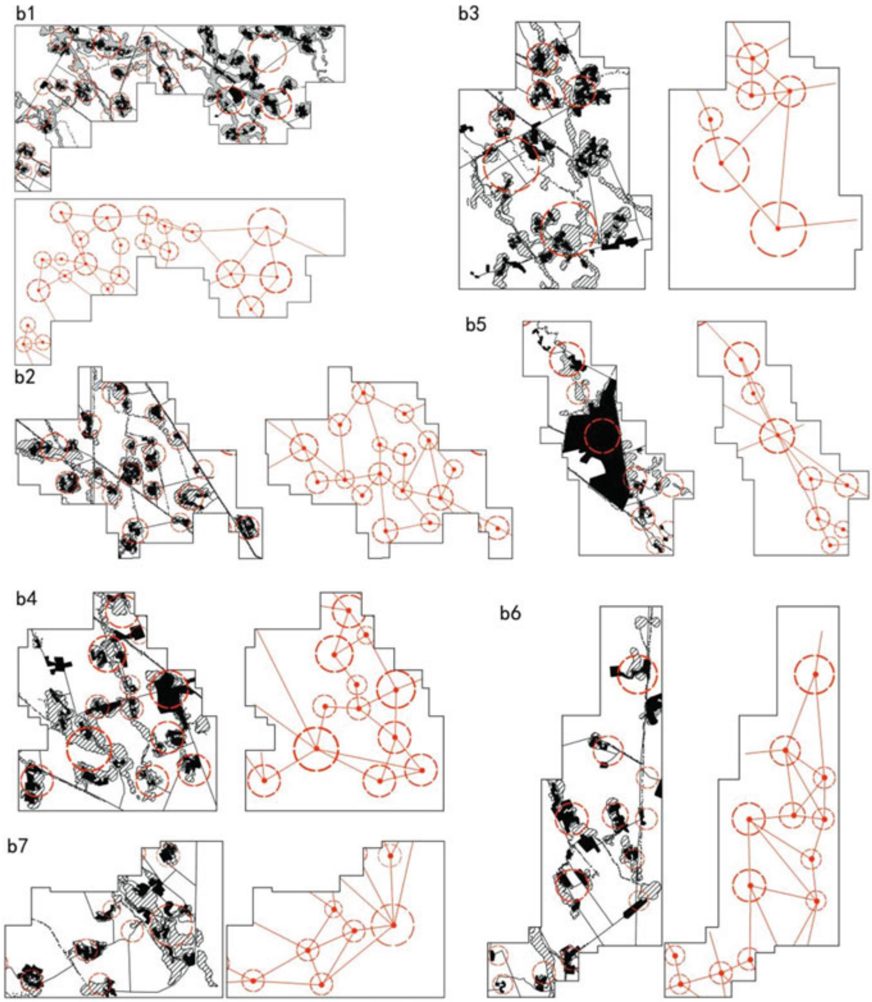


Fig. 8.32 Composition pattern of core network at structure scale $3 < K < 4$

8.4.2.3 Leapfrog Nested with Structural Reinforcement

The leapfrog nested with structural reinforcement refers to the hierarchical improvement of network elements at low structural scale and the composition increase of structural elements in network at high structural scale under the conditions of network structure consistence in the process of network contraction.

With the improvement of structural scale and the process of network contraction, networks in part at low structure scale are merged into compositions of network at high structural scale. The results of contraction and mergence could not be recognized

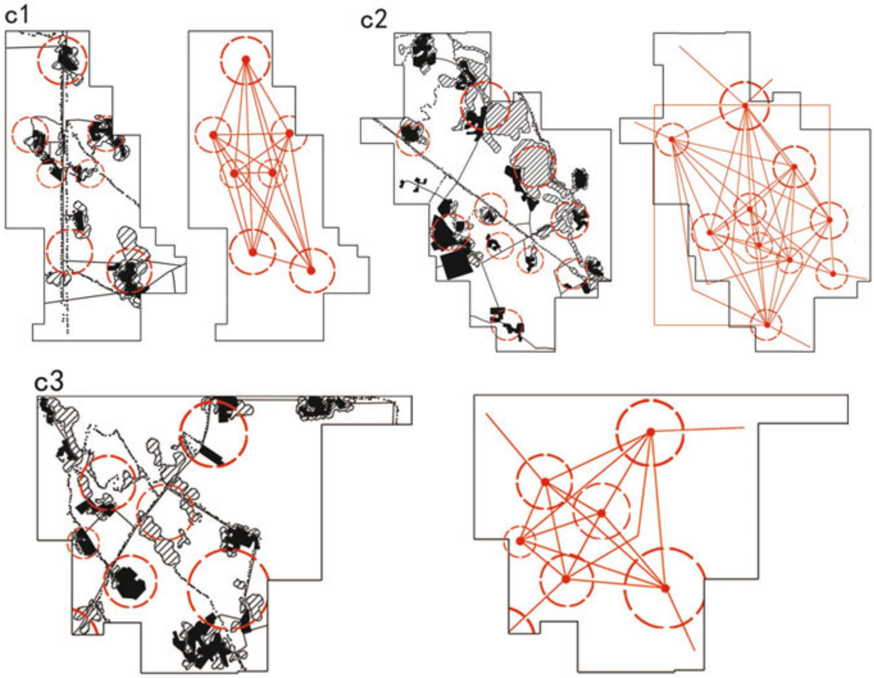


Fig. 8.33 Composition pattern of core network at structure scale $5 < K < N$

completely but partly at mesoscale and obviously at large scale, which could be showed definitely through the case of typical network pattern No. 102.

On the basis of network contraction, water system in the southeast of network pattern is recognized as a whole through integration of surrounding nodes at small and moderate structural scale, where is regarded as homogeneous space under the conditions of moderate and small scale. However, water system works as the components of network structure at large scale through integration with settlements under the conditions of large scale. Therefore, nested structure is a result of strengthening the network structure by leapfrog instead of step by step (Figs. 8.37, 8.38 and 8.39).

8.4.2.4 Leapfrog Nested with Structural Remodeling

The leapfrog nested with structural remodeling refers to the huge difference of network structure at local or overall level caused by network contraction, which could be regarded as the remodeling of network structure as the result of some special nodes with strong spatial attraction acting as the preferred fusion objects of small and moderate nodes in the process of network contraction. The influence of such attraction on network structure becomes more and more obvious with the improvement of structure scale, which finally leads to the remolding of network structure under the

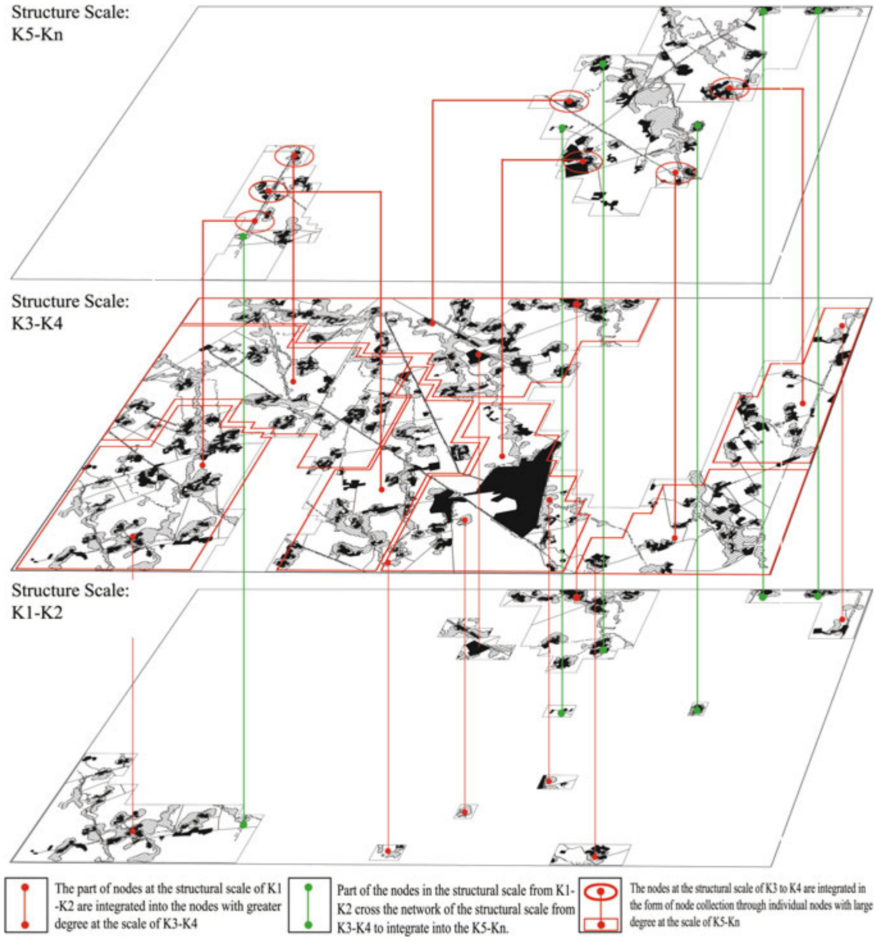


Fig. 8.34 Contraction and merging process of landscape space network

condition of large structure scale, which is demonstrated in typical network pattern No. 100. There are obvious differences between network structure at mesoscale and network structure at large scale in this case. The influences of two settlement nodes with large area in east of the case on network structure are gradually enhanced with the improvement of structure scale, which have led to the huge difference of network structure between two nodes at large and mesoscale conditions (Figs. 8.40, 8.41 and 8.42).

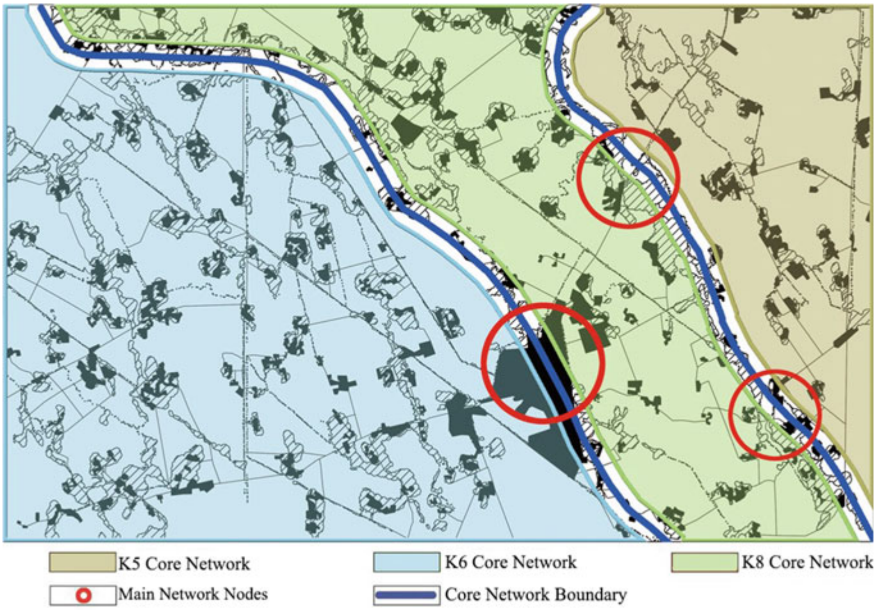


Fig. 8.35 Landscape pattern of network at structural scale $5 < K < N$

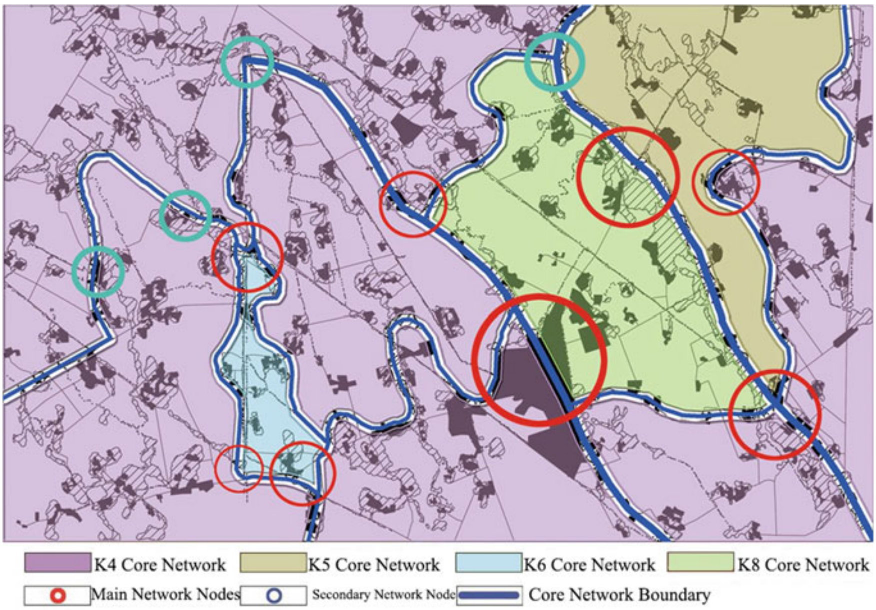


Fig. 8.36 Overall landscape pattern of network at structural scale $3 < K < 4$

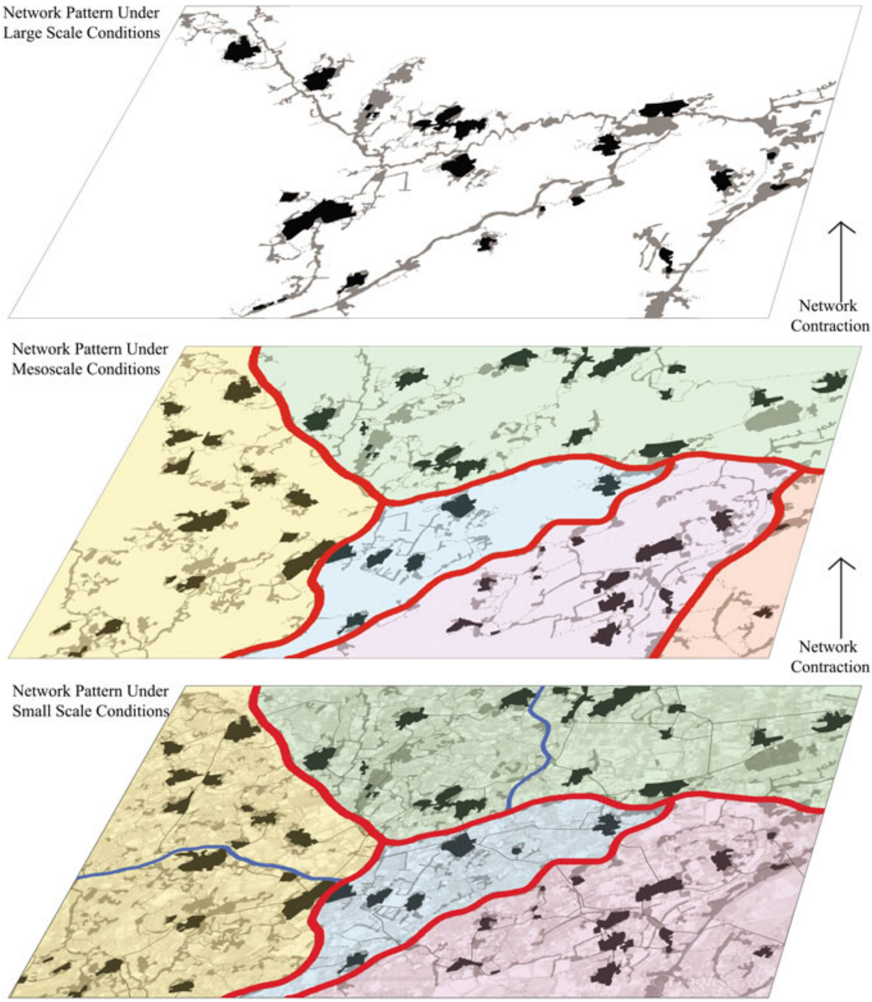


Fig. 8.37 Contraction process of typical network pattern No. 102

8.5 Network Patterns of Shrinking and Nesting

It is found that the progressive type has more continuous spatial relations and stable space structures compared with the leapfrog nested which could be regarded as a special nested type as a result of local organizational mutation in network in part on the basis of the progressive nested mechanism (Lv 2017). Therefore, the expression of network contraction and nested mechanism by means of pattern extraction could adopt the approach to seeking common ground while reserving differences, that is, network compositions of the progressive nested could be extracted on the premise of clarifying the special mechanisms of the leapfrog nested. Here, six typical network

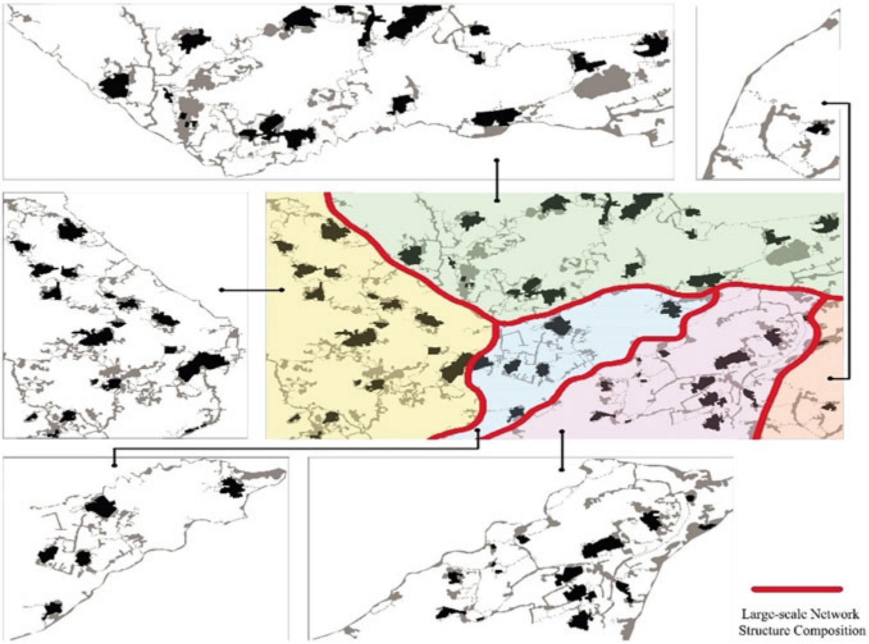


Fig. 8.38 Nested structure of typical network pattern No. 102 at mesoscale

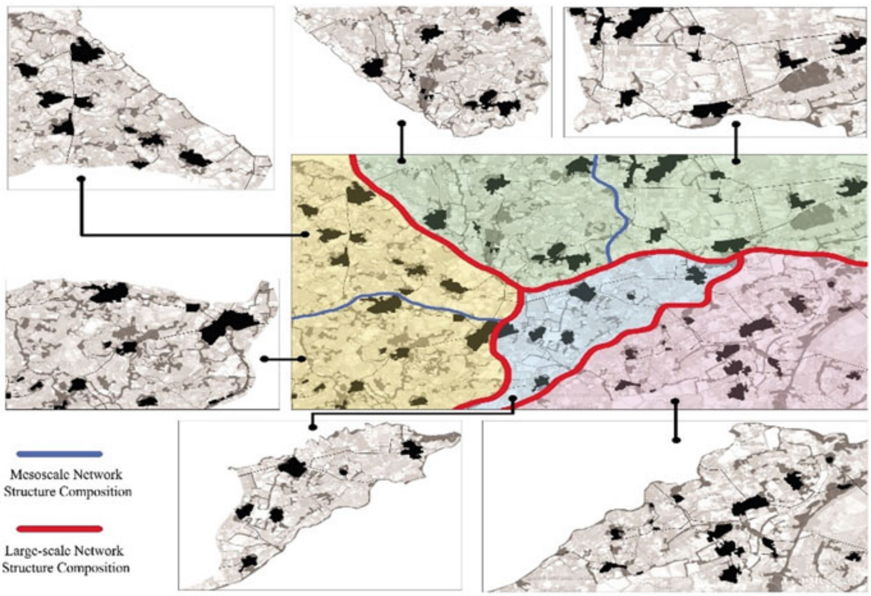


Fig. 8.39 Nested structure of typical network pattern No. 102 at microscale

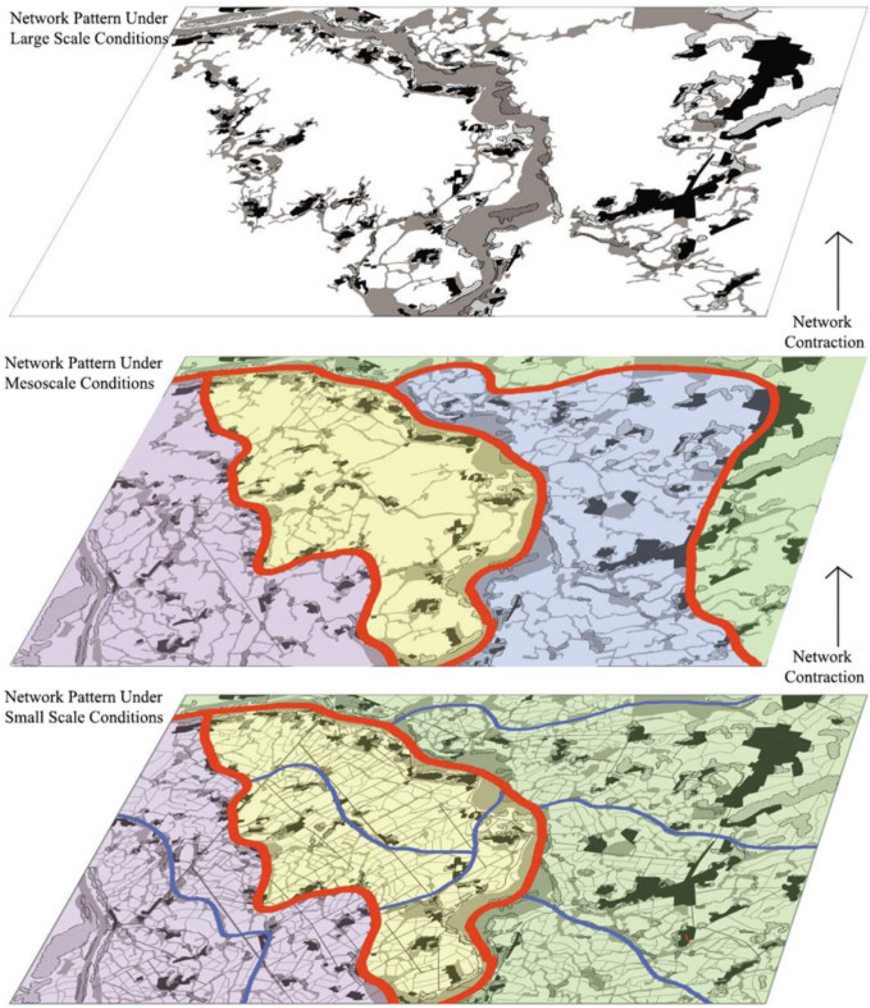


Fig. 8.40 Contraction process of typical network pattern No. 100

models with contraction and nested structure are selected, which are the patterns of grid landscape in Ningshao plain, water network in Taihu plain, Linpan landscape in western Sichuan, hilly area of eastern Zhejiang, polder landscape in Southern Anhui, and river valley in Southern Jiangxi.

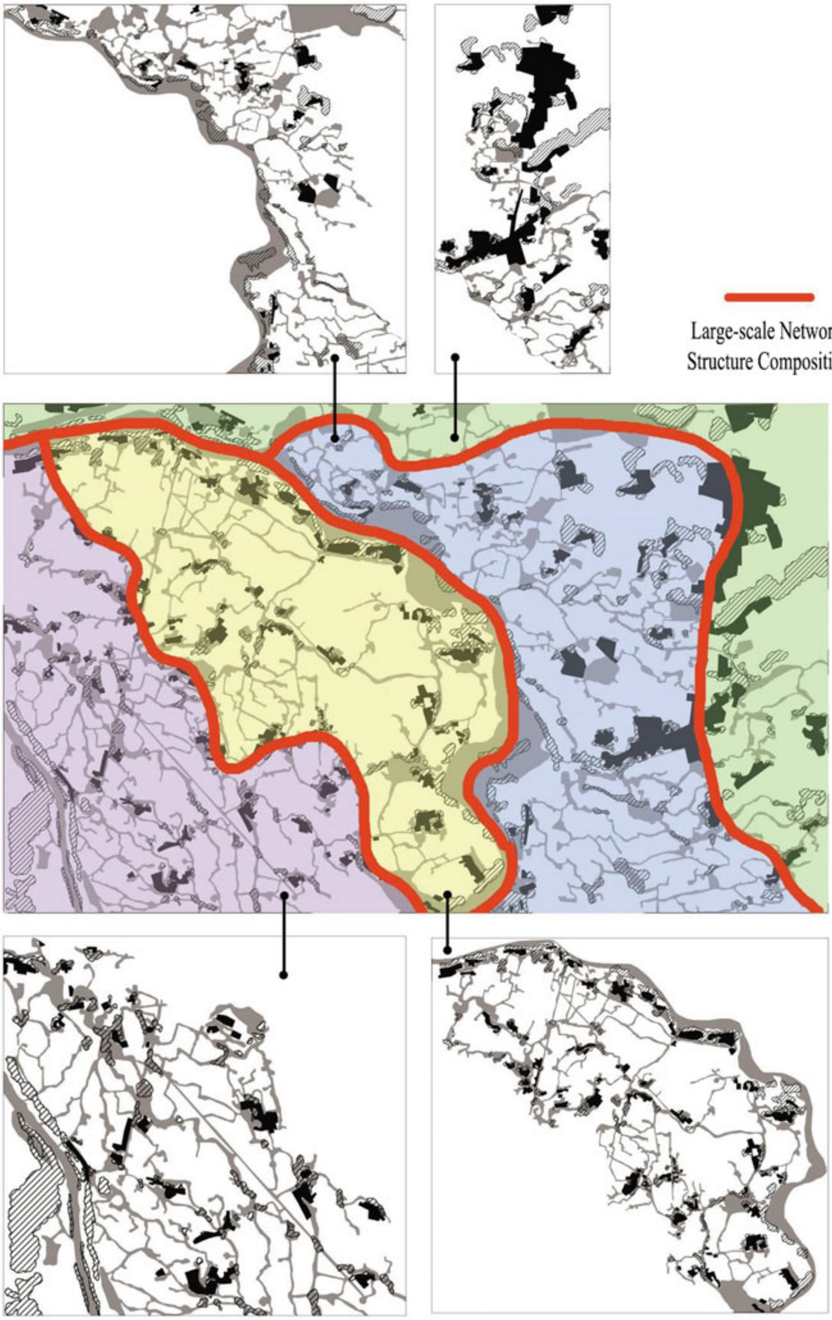


Fig. 8.41 Nested structure of typical network pattern No. 100 at large scale

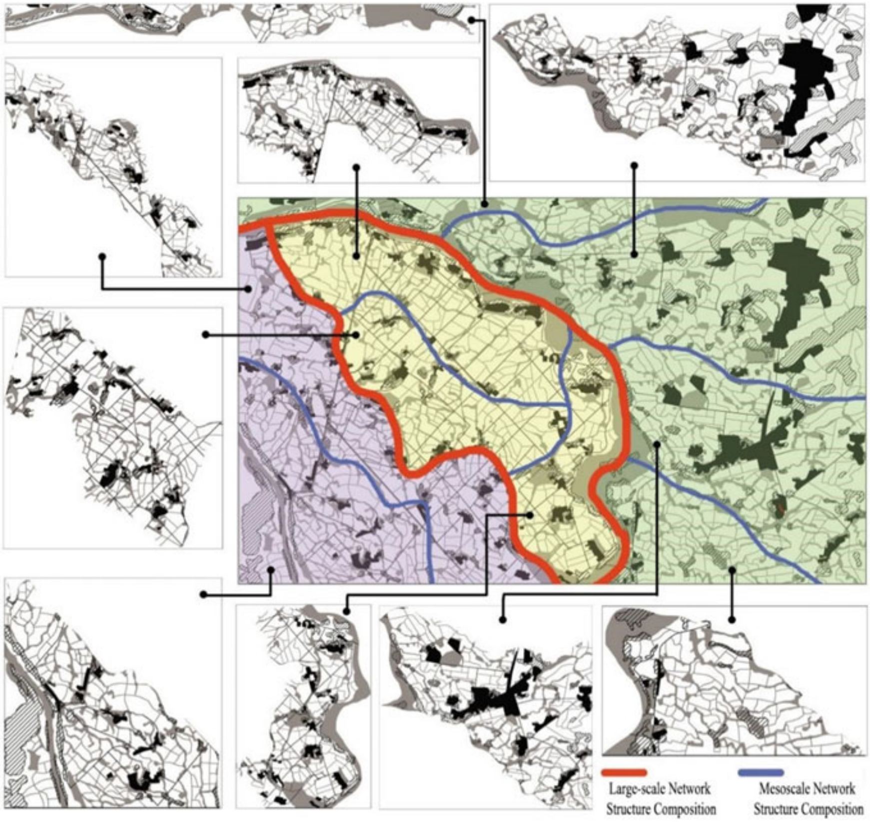


Fig. 8.42 Nested structure of typical network pattern No. 100 at mesoscale

8.5.1 Landscape Pattern of Shaoning Plain

In terms of nested relationship and contraction process mode, landscape structure of Shaoning plain with the typical characteristics of water-towns network cultivated the progressive nested pattern of isomorphism network with the similar grid organizational relationships and forms at multiple scales. Correspondingly, network structure at large scale is embodied as the units of network enclosed by high-grade water systems and settlement nodes attached to the water systems. Networks at mesoscale are embodied as using low-grade water network to divide the units of network at large scale and thereby foster settlement nodes based on the units of network at large scale. Networks at small scale are reflected in network forms generated from the improvement of road network and the construction of settlement system (Fig. 8.43).

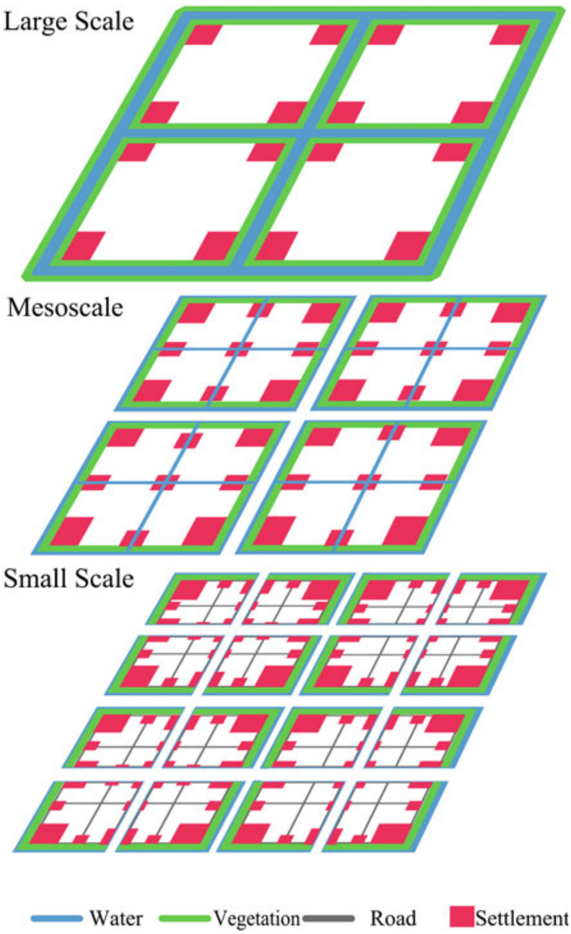
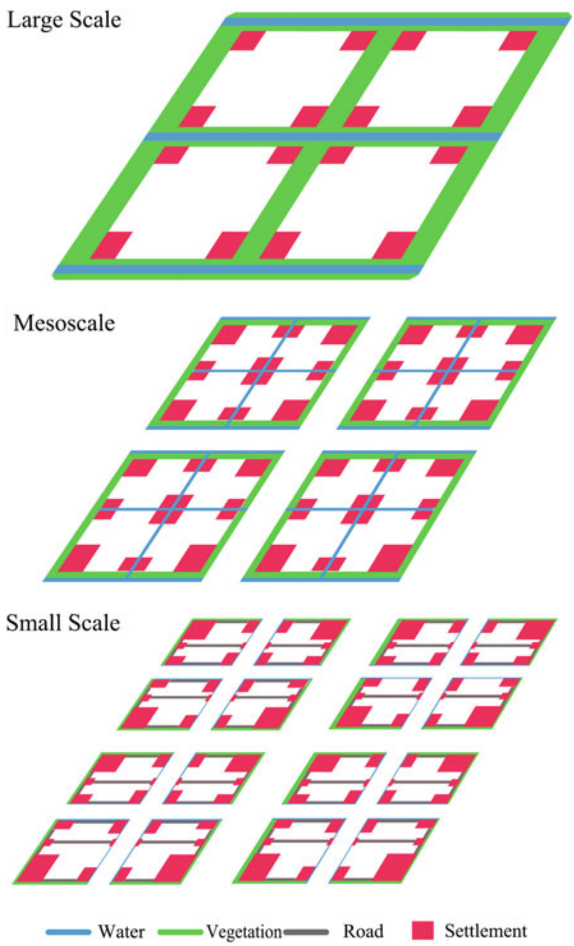


Fig. 8.43 Nested pattern of landscape network in Shaoning plain area

8.5.2 Landscape Pattern of Taihu Plain

As an important area of water-towns in South of Yangtze River, landscape structure in the Plain of Taihu Lake has been evolving a long history under the interaction between man and nature and has established a mature network, but it is different from landscape patterns of Ningshao Plain. Due to the topography of disk-shaped plain, the main water systems flow out from Taihu Lake which acts as the source, and the settlements with large area are distributed along the main river system in the paralleled pattern (Shen 2017). Meanwhile, in order to reduce the surface erosion, some banded vegetation spaces and water channels are mostly perpendicular to the direction of main streams. Main settlements are constructed in network to satisfy the needs of production and living at mesoscale. Settlements at small scale distributed in paralleled

Fig. 8.44 Nested pattern of landscape network in Taihu plain area



relationship with main river system, the road network connecting settlements also presents the characteristics of layout in paralleled relationship (Fig. 8.44).

8.5.3 Linpan Pattern in Western Sichuan

From a perspective of large scale, the *Linpan* network in western Sichuan is composed of the main ecological corridors crossing the region, which act as connections and the settlements attached to them, which act as the nodes of network. From a perspective of mesoscale, the networks developed with the settlements and the vegetation spaces as the main nodes and formed network units through the organization mode of stepping-stone system based on network at large scale, among them the connections would not only be specific water systems or vegetation connections, but also would be potential ecological connections. From a perspective of small scale, the production spaces are divided and gradually develop as new settlement nodes with traffic location advantage through the network construction of grid road system on the basis of stepping stones at mesoscale (Fig. 8.45).

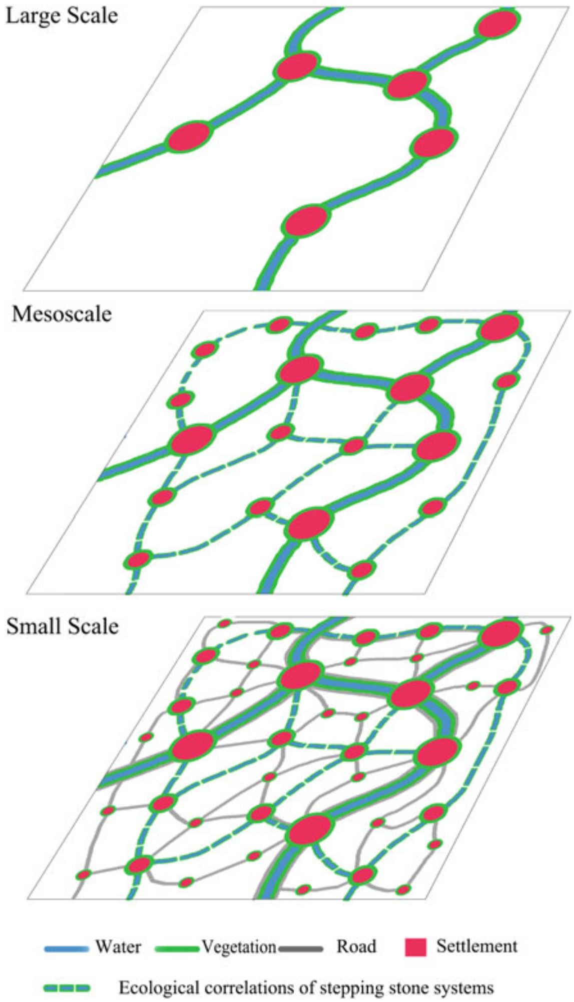


Fig. 8.45 Nested pattern of Linpan network in western Sichuan

8.5.4 Pattern of Eastern Zhejiang Hilly Area

The network pattern in hilly area of eastern Zhejiang Province is limited by topography on a large scale, in which production spaces are located at the waist of hills, therefore, network pattern usually consists of the main rivers and their branches flowing at the foot of hills and the composite spaces of settlements and vegetation at the shoulders of hills. From the perspective of large scale, all these are integrated into the pattern of total landscape network. From the perspective of mesoscale, the composite spaces with settlement and vegetation could be identified as the combinations of network units organized by the system of stepping stones. From the perspective of small scale, a large number of discrete nodes are integrated into the overall network due to the improvement of road network, but most of them keep close spatial contacts with the nodes in the system of stepping stones nearby (Fig. 8.46).

8.5.5 Pattern of Southern Anhui Polder Area

Landscape character of Southern Anhui has been developed as the unique polder areas with features of typical network due to the reasons of climate, topography, and special history. From the perspective of large scale, the network pattern mainly includes water systems separating the spatial units in polder areas, production, and living spaces enclosed with water system, and settlement nodes with large area would be developed under the intersection configuration of water spaces. From the perspective of mesoscale, networks are embodied as the water regulation and storage system based on natural water bodies in the polder area and settlement nodes around. From the perspective of small scale, network patterns are the greenery networks based on production spaces division, traffic system improvement, and landscape environment transformation (Fig. 8.47).

8.5.6 Pattern of Southern Jiangxi River Valley

The plain in valley is suitable for settlements distributed along both sides of the valley in the area of low mountains in Southern Jiangxi, which is formed under the hydrodynamic process of flowing across the valley, and landscape spaces in the plain integrated with vegetation, water system, and settlement network are also typical network patterns. Network patterns at large scale are embodied in network form of the main river-branch system which shapes the valley terrain, and the development of settlement networks under the constrictions of terrain in the process of history coordinated the large settlements mostly locating in the interwoven space of ecological zone enclosed by the river system and mountainous. From the perspective of mesoscale in

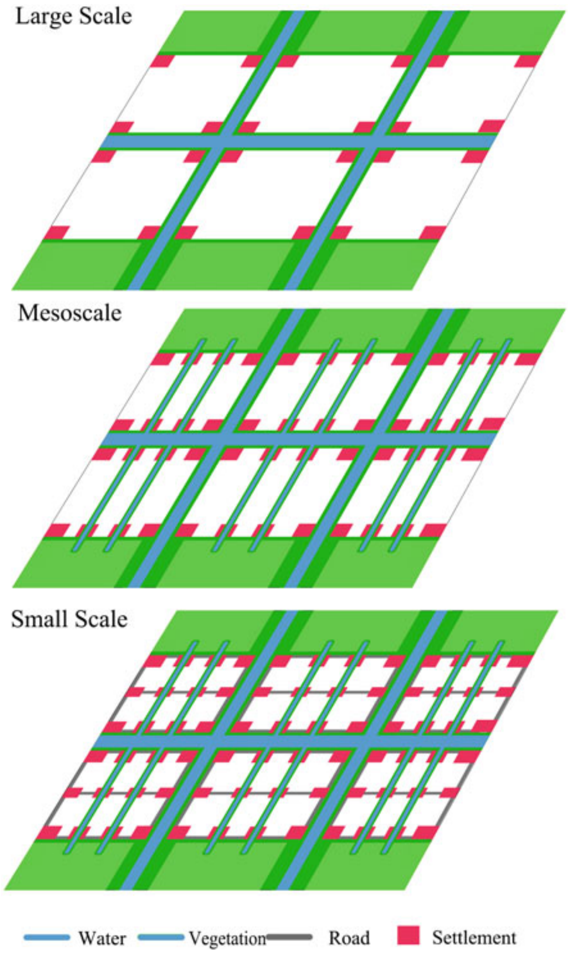


Fig. 8.46 Nested pattern of network in eastern Zhejiang hilly area

the context, network patterns are enriched by water systems flowing from the mountains, and the pattern of settlement nodes at low grade is established with the similar rules of settlement networks at large scale based on network patterns at large scale. From the perspective of small scale, the constructions of road networks perpendicular to the direction of water systems improve the connections between settlements systematized and enrich the forms and spatial compositions of network pattern at small scale (Fig. 8.48).

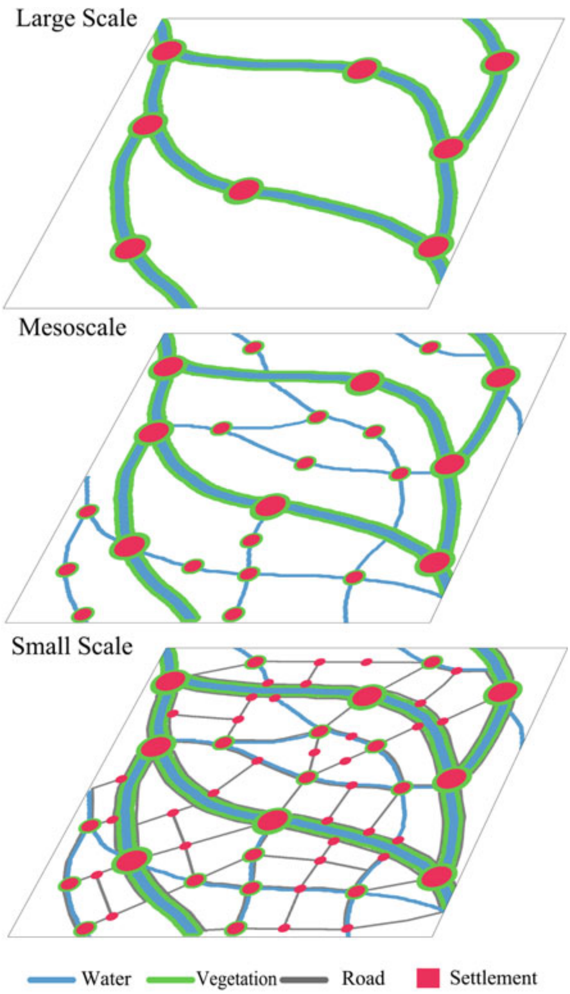


Fig. 8.47 Nested pattern of network in Southern Anhui polder area

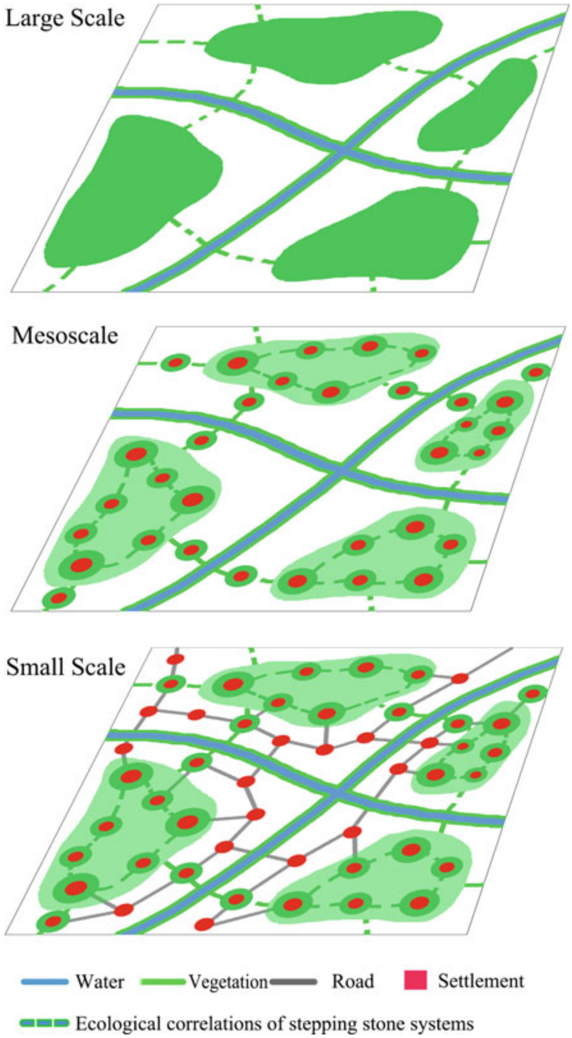


Fig. 8.48 Nested pattern of network in Southern Anhui valley area

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Chapter 9
Prospect of Landscape Pattern Language

9.1 Progress of Landscape Pattern Language Research

9.1.1 Theoretical Framework of Landscape Pattern Language

Since the research on landscape pattern language was proposed in 2008, the basic theoretical frameworks and methods of landscape pattern language have been initially established under the support of three projects of National Nature Science Foundation of China in 15 years, by which it could be used to express local landscape and spatial reasoning and as a creative approach to landscape planning and design (Bu and Sun 2003; Dai and Yuan 2015; Lv 2017; Wang and Lv 2013, 2014; Wang and Wang 2011; Wang and Han 2014; Wang et al. 2012; Wang 2005, 2009, 2011, 2012, 2013a, b, c, 2014, 2015, 2017). The theory and methods of landscape pattern language are derived from a wide range practice of landscape ecological planning and design, from which the approaches and models of ecological planning and design are explored through recognizing and further solving problems in practice. The system of spatial units is the basic form and vocabulary of landscape pattern language, through which the organization mechanism and laws of landscape spaces are understood with the help of logic and structure of language, and the design vocabulary and mechanism of local landscape are established and become an important framework and design language for understanding, inheriting, and shaping landscape. Through the analysis and summary of research results and progresses of related ecological planning and design practice, landscape language and pattern language domestic and overseas, after deepening research on the relationship between man and nature and with three development stages of natural determinism, interaction theory, and cultural adaptation theory, the practice of ecological planning and design is considered to be a new way of ecological planning and design as the main characteristic of modern era based on the theory of cultural adaptation. The theory of landscape language is one of the specific outcomes of the development of cultural adaptation theory and has

Y. Wang, *Landscape Pattern Language*, EcoWISE,
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become an important theoretical tool for understanding nature and human ecology. Landscape pattern language is a new important field of the theory of landscape language, which is the outcome of integrating three major thoughts which include the theory of landscape language proposed by Anne W. Spirn, the theory of pattern language proposed by C. Alexander and the research models of pattern proposed by Simon Bell. The framework of theory, analysis, and implementation of landscape pattern language provides a new perspective and reference for spatial research of landscape.

9.1.2 Vocabulary and Logic of Landscape Pattern Language

The theoretical system of landscape pattern language is mainly constructed by three parts of spatial vocabulary, morphology, and syntax, among which the spatial morphology and syntax are the grammar of landscape pattern language.

Spatial vocabulary mainly consists of words, phrases, and simple sentences of landscape as the basis of landscape spatial elements which correspond to the basic space unit, aggregated space unit, and holistic space unit. The words express the basic space with single elements and different forms playing independent role in landscape, which could be expressed in many different forms. The phrases express the aggregated spaces composed of several basic space units and play an important role to shape the meaning of landscape, which could be a repetition of a same landscape word or a combination of different forms of landscape words. Simple sentences express the holistic spaces which are composed of aggregated spaces and express the relatively complete meaning of landscape. In the process of extracting the word, phrase, and simple sentence of landscape pattern language, it is considered that there is no absolute positive correlation among three kinds of vocabularies corresponding to multiple scales in terms of quantity. The key to determining the amount of spatial vocabulary to be extracted is the richness of spatial types.

Spatial morphology is the relationship to combine landscape words or phrases in a specific context to form a relatively complete spatial sequence with inner relations, which controls the formation of typical spatial units and landscape patterns. Landscape morphology usually consists of process morphology of landscape formation and relationship morphology between landscape spaces. The former could be divided into the process of networking, fragmenting, striping, scattering, and coring. The latter could be divided into single morphology and composite morphology. The single morphology could be independent spaces acting as the basic components of independent landscape phrases or combinations of interrelated spaces which influenced each other determined by accidental, coordinated, and dependent relationships. The composite morphology is the rules of spatial sequence of landscape shaping through the inner relationships of spatial fusion, parallel, overlaid, nested, overlapping, intersecting, interwoven, interlocking and spatial continuousness, interruption, and other spatial internal relations. In addition, there are more complex spaces formed by composite words and recombination with the morphology of spatial parallel, interlocking, interwoven, and overlapping.

Space syntax is the relationship to organize landscape phrases and simple sentences to be a complete sentence as well as the relationship between sentences with the total means of landscape, which is the basic criterion and relationship for the transformation from basic spatial units and composite units to overall landscape. The syntactic principles of landscape space mainly include six principles of scale, time, locality, order, rhetoric, and modification.

9.1.3 Methods and Mechanism of Landscape Pattern Language

It has similar features and structures between landscape and language. The spatial form of landscape could be analyzed using the methods of morphology. The mechanism of landscape formation and spatial relationship could be analyzed on the relationship between man and nature, as well as spatial ecology. Based on these approaches to solve the problems in practice, it is clear that the framework of landscape pattern language is constructed on the theory of landscape language, landscape morphology, human–land interaction and human ecology, and spatial ecology and landscape ecology, which could be mainly divided into six steps of sample space selection, sample space processing, spatial vocabulary extraction, spatial lexicon analysis, spatial syntax analysis, and the system construction.

The researches on vocabulary of landscape pattern language are mainly considered in the typical landscapes of water habitat, ecological interface at moderate and small scale, landscape ecological network, land form, public open space, landscape axis in traditional village, and seminatural landscape, in which 862 words, 743 phrases, and 409 simple sentences as spatial vocabulary of landscape typical patterns have been established in our research (Wang 2011, 2017).

It is found that the words are generally extracted from the basic space units of simple elements, of which the overall forms and their types are relatively simple and the influences of context, cultural background, and other factors are relatively weak. The context has no substantive meaning for the words, so the typical words of various types of landscape elements have certain similarities and versatility in different types.

The context of phrases has already had a certain impact on aggregated spaces. For example, in the plain of Southern China, waterbodies usually exist in the configuration of grid networks without main direction of flowing, while in the north of China or areas with underdeveloped water network, waterbodies are usually in shape of linear spaces or branches. Usually, landscape of network consisting of waterbodies with ponds combination would not appear densely in arid areas in the north, which are only found in areas with more rich water resources in the south. The situation has made big differences in agriculture, especially in the combination of farmland except for water resources, and dry land in the north and paddy field in the south are also different due to differences in topography and farming modules (Wang et al.

2006). Therefore, as phrases, the characteristics of geographical conditions have been reflected in it, which play an important role of context. The phrases of landscape pattern language begin to form under the rules of formative process and spatial relations and the geographical and cultural background also have a certain influence on landscape patterns. Relatively speaking, the forms of typical phrases are diverse and the structure is relatively complex according to different context and cultural background.

The morphology of landscape pattern language mainly includes the process of spatial networking, fragmentation, belting, and coring according to landscape space dynamics, which also mainly includes single morphology, compound morphology, and the integrations of compound morphology according to landscape spatial relations (Wang et al. 2009a, 2011). It could be analyzed that space juxtaposition, interleaving, and superposition are common in complicated landscape context with the main characteristics of networking and superposition integrating to form a typical spatial pattern. There are two common reasons for space juxtaposition, one of which is the matrix composed of combinations with parallel spaces in addition to network composited of corridors in common networks, and the other is repeatedly appearance of certain space units in one landscape space and finally form a specific landscape space as the repetition reaching a certain amount; therefore, these repeating space units often appear in the form of space juxtaposition.

9.2 Challenge in Landscape Pattern Language

9.2.1 Problems in Landscape Pattern Language Research

9.2.1.1 Insufficient Research on Design Language

Ecological planning and design is a complex approach to shape sustainable landscape based on resources conservation, landscape protection, and integration of human and nature according to ecological principles, theories, methods, ecological processes, and spatial relationships using the concepts of human settlements, landscape architecture, and landscape planning and design. In recent years, with continuous and fast development of ecological planning and design theories and methods, this discipline of landscape architecture has strongly recognized the importance on the relationship of nature and human and accepted the approach of ecological planning and design as the basic concept and principle for designers, but it still lacks researches on basic methods and theories of ecological planning and design, which still plagues the planning and design of landscape practice without dependence, entry point, and key point (Wang et al. 2009c).

9.2.1.2 Insufficient Research on Adaptive Approaches

Cultural landscape is a historical landscape recording the interactions between man and nature, and it is a representative landscape type revealing the evolution of human ecological space at a certain stage, which condensed the unified human ecological process of the coordination between man and nature in history. Due to the lack of systematic research on the types, quality, and spatial reasoning of human ecological spaces, planning and design of landscape lacks the researches on systematic theory and methodology, which could be carried out with the limitation of isolated and sporadic case studies and practices (Wang 2011). Landscape pattern language attempts to understand cultural landscape and grasp their forming process in a specific environment based on land using, resource protection, cultural adjustment, and visual experience, and research the basic composition, morphological characteristics, space coupling process, and formative mechanism.

9.2.1.3 Insufficient Research on Quadrant of Total Landscape

The regionality and locality are the main characteristics of cultural landscape. For a long time, under the impacts of modernization, industrialization, and urbanization, the conservation of cultural landscape has focused on the protection of partial and small local spaces such as building styles, core areas in the village, scenic areas, historical blocks, and specific cultural landscape areas, which formed a series of isolated cultural landscape protection policies and phenomenon of landscape islands and artificial bonsai because of the lack of accordance and quadrant of holistic protection (Wang 2013a, b, c). Landscape pattern language attempts to explore the spatial coupling process and formative mechanism of local cultural landscape through the research of the types, forms, and internal processes of local cultural landscape and human ecological spaces to unify the process and spatial form in holistic protection of landscape.

9.2.2 Breakthrough of Landscape Pattern Language

9.2.2.1 Landscape Space as the Core at Multiple Scales

In the process of exploration for a long time and wandering in the field of garden and region, culture and ecology, as well as arts, landscape architecture has been forming a diversified directions and contributions, but it still has not gained inner power to develop deeply from the interweaving of nature and culture which is the source of the development of landscape architecture. Spirn (1998) believed that it is precisely a result of the lack of landscape design language, and it is not enough for landscape architecture just using design language of architecture or the language of ecology. Landscape pattern language tentatively explores the focus, methods, models of landscape as well as the objects, on which landscape architecture could describe effectively, discusses the key issues in theory and practice of ecological planning and design, and explores the way to break through the bottleneck of ecological planning and design (Wang 2013a, b, c).

9.2.2.2 Exploring Basic Pattern Vocabulary of Landscape

The research on ecological design language to establish landscape pattern language is based on three important issues. Firstly, ecological planning and design has become an important way to solve problems of land or landscape through acting as medium and an integrated approach between man and nature (Wang et al. 2015). Secondly, under the background of the multi-disciplinary theories introduced into landscape architecture, the fruitful development of ecology, the diversity of human culture, and diversified approaches, all contributions could help to create a space where nature and human could coexist and prosper together. Thirdly, landscape is the product of historical process of the interactions between man and nature, on which basic patterns of landscape pattern language of ecological design could be discussed deeply and creatively with typicality and representativeness (Wang et al. 2009b). Therefore, it would be help to establish the basic quadrant of landscape design language with the core of landscape spaces, foundation of multi-disciplinary, and framework of spatial ecological patterns.

9.2.2.3 Building Pattern Language of Landscape

The language of cultural landscape is spatial combination of basic space units, aggregated spaces, and holistic spaces to describe the meaning partly or totally, which is formed in the process of continuous understanding, utilization, and transformation of nature through human–land interaction. The pattern language of landscape reveals the basic compositions, typical patterns, spatial reasoning, and organization process of landscape and uses all vocabularies to shape the organic landscape through the imitation of nature and inheritance of culture according to the unique spatial process (Wang 2017). Pattern vocabulary is the basic vocabulary of ecological landscape expression and the foundation of ecological design, on which the study could form effective methods and approaches of ecological planning and design.

9.3 Research Innovation and Its Application

9.3.1 Innovations in Landscape Pattern Language

The innovation of landscape pattern language is mainly reflected in the new understanding and description of landscape spatial structure and its organization based on the core concept of landscape space at multiple scales. The use of pattern system provides a new perspective and approach to landscape analysis of spatial vocabulary, lexicon, and syntax and constructs the theoretic framework of landscape pattern language to express the locality, logic, and mechanism of landscape. The new analytical framework is proposed for constructing landscape pattern language, by which the methodology, procedure and standards of sample space selection, processing, spatial vocabulary extraction, lexicon and syntax analysis, and pattern language system construction are established. The implementation framework of landscape pattern language was established based on the accumulation of certain amount of vocabulary and analysis of the formative mechanism and combination law of landscape to guide landscape planning and design (Wang 2012).

9.3.2 Prospects of Landscape Pattern Language Application

Landscape pattern language would be effective in landscape planning and design. Firstly, the ecological processes in natural and socio-ecological system are integrated into an organic whole through spatial units of landscape. Secondly, it reveals the formative mechanism of landscape from the part to the whole by taking spatial units as the vocabularies, the scale nesting and transformation as the important process, and the spatial relationship as the mechanism. Thirdly, it is the right way to recognize the locality and an important way for the inheritance and continuation of local landscape by using the theories and methods of landscape pattern language. Fourthly, designers could establish their individual design language and style through construction of personal vocabularies and spatial reasoning with the help of landscape pattern language. Finally, the advancement and changes of design vocabulary and spatial logics are a continuous and gradual process which provides an effective path for landscape design innovation and design with language of the era.

9.4 Prospects of Landscape Pattern Language Research

9.4.1 Theory and Method of Landscape Pattern Language

The language of ecological planning and design is composed of landscape elements, space units, basic combination, and ecological process. Landscape elements and space units are the basic components of ecological planning and design, and basic combinations are the key design modules of landscape function. Ecological processes are the laws and syntax that must be followed in ecological planning and design, which are most important rules for ecological practice. Total landscape or total human ecosystem with integrality, continuation, and organic characteristic could be designed based on the integration of ecological elements and spatial units and the organization of basic combinations and spatial unit modes. Landscape pattern language is to study the basic compositions and morphological characteristics of ecospace, focus on landscape patterns of the typical units, and reveal the internal mechanisms of ecological space coupling, which are the basic features of space organization and optimization, and the spatial laws followed in ecological planning and design.

9.4.2 Spatial Coupling and Spatial Reasoning

Landscape is a historical synthesis of interactions between man and nature, which is the result of combining actions by landscape factors in a specific natural environment; therefore, it is the combining actions that foster a variety of space types of landscape, such as natural, seminatural landscape in cultural environment, residential and living landscape space, productive landscape space, and cultural landscape network, and finally, it forms a landscape space with integrity, continuity, and wholeness through the specific spatial relationships. The formation of each landscape type has its own influencing factors, actions, processes, and mutual adjustment, and the mechanisms and processes are the laws of human ecological process of landscape formation and the basis of the study of landscape pattern language.

9.4.3 Human Process and Cultural Landscape Space Coupling

This research discusses the structure and models of cultural landscape pattern language based on the processes of human adapting to physical landscape and its transforming. Firstly, it was reflected on the compositions, spatial forms, and unit combination models of physical landscape and their pattern language in the environment. Secondly, it was reflected on the compositions of landscape pattern language and models of residential space which represent the overall landscape characteristics and patterns formed in the long-term historical process and under the support of local knowledge after comprehensive consideration of natural environment, land use, buildings and settlement forms, and water resource utilization (Ndubis 2013). Thirdly, the compositions of landscape pattern language, modes of land form, and spatial texture are the environmental memory formed by the self-creation and self-sustainment of the productive landscape to reflect man's understanding, application, and transformation of nature. Fourthly, landscape pattern language reflecting the nature–human complex space was shaped with residential and living spaces as the center and coupled production and ecological spaces to form a complex cultural landscape. Fifthly, landscape pattern language and spatial networks are the most important ecological features of ecosystem, in which the interacting processes and coupling relationships of landscape correspond to scales.

9.4.4 Scales and Scaling of Landscape Pattern Language

Scale is the basic feature of landscape space and its pattern language. The analysis of scale correlation and comparative study of pattern language at three scales are necessary to do more researches systematically based on the research foundations of landscape spaces survey, measurement, mapping, landscape graphic database, and landscape pattern language at multiple scales, which focus on scale characteristics, scale effect, and scale response of landscape pattern language. The first is researched on the determining mechanisms of dominant scale process of pattern language, which discuss the nested structure of landscape pattern language from basic pattern, combination pattern to complex pattern corresponding to small, moderate, and large scales, and discuss the decisive role of environment and its processes at different scales coupling to landscape pattern language and the disturbance process driven by enriching the diversity of pattern vocabulary combined with the dominant process. It determines the characteristics of pattern language and reveals the main drivers and mechanism of the similarity and difference of pattern language at different scales according to the dominant processes of homogeneity, heterogeneity, and transmission. The second is researches on context and conditions evaluation of scaling in landscape pattern language considering the universality of pattern vocabularies, local vocabularies, and multi-scale vocabularies, which could be transferred between regions and scales. The main context and scaling conditions are revealed to explore the effective applications of scientific principles of pattern language and ecological planning and design through the researches on scale and scaling, environment and its constraints, and language and spatial logics. In view of the diversity and complexity of scaling conditions and contexts of landscape pattern language, this research reveals the transformation models of landscape pattern language and constructs the transformation rules and guidance according to classifications through the study of typical spaces and their modes of pattern language transformation.

9.4.5 Nested Structure and Its Adaptation

Landscape space is a nested body of macroscopic, mesoscopic, and microscopic scales, on which pattern language also is a nested body formed by basic, combination, and complex pattern organized by spatial logic. Firstly, researches on the logic relation of pattern language scale coupling and nested mechanism discussed the nested approaches and ways to the unified form and function of pattern language at single scale or multiple scales. It reveals the logical relationship, spatial sequence, and internal symbiotic relationship, on which pattern language relies on the process of forming the whole landscape, and clarifies the spatial organization principles and rules of pattern language expression semantics. Secondly, the cases reflecting the nested structure of pattern language and its multiple types are widely distributed and well preserved based on the unique locality and nested structure of landscape space, which explores the diversity of nested patterns and provides feasible researches for the application of pattern language in view of the semantic transformation, extension, or deviation of pattern language due to scale transformation.

For landscape architecture, a big question is the gap between history and the future because we learn from history but design for future, in which planner or designer acts as a bridge. The relationship is reflected in the preservation and inheritance of pattern language and its adaptive design in modern context through the theoretical and practical study of landscape pattern language. In order to cope with the changes of modern context, landscape pattern language encourages to create new vocabularies and logics of pattern language to do adaptive design and establishes the principles, methods, and approaches of pattern language and scaling mechanism to adapt to the changes. The adaptive research on scaling and nested mechanism is optimized through the combination of traditional pattern vocabularies and adaptive new vocabularies to construct the scaling rules and guidance of landscape pattern language and scientifically guide the practice of landscape ecological planning and design.

9.5 Optimization and Inheritance

Landscape pattern language is the records and reflections of spatial processes and combined forms of local culture landscape with the rapid development of modernization, urbanization, and industrialization. The development of new technologies and industries has encouraged new spatial processes and coupling characteristics, which act as the driven forces for innovation of landscape pattern language for the protection, inheritance, and development of landscape in modern context. Landscape pattern language keeps advancing with the times in both temporal and spatial dimensions, which is embodied in the continuous change and innovation of design vocabulary. The '*4I*' system is an important trend of landscape development in the twenty-first century (Shen et al. 2015). How to fully combine the characteristics of the times to form a pattern language that meets the needs of the new era, or how to think about the features of pattern vocabulary of landscape language in the twenty-first century have become the important questions and challenges to landscape pattern language.

9.5.1 Integration

The direction of landscape architecture in the twenty-first century would be the integrity with ecological, symbiotic, and benefic characteristics of landscape which is described as the community of livings. The nature of ecology reflects the organic integrations of various functions and their landscape spaces, and the integration of each system meets the needs of protecting the environment. From perspective of landscape pattern, landscape integration highlights the symbiotic relationship of spaces between multiple scales. From perspective of landscape process, networks of infrastructure and coexistence of artificial and natural spaces all require the construction under the guidance of integrated conditions of development. From perspective of perception, landscape integrity is more about the communication and integration between human-to-human and human-to-nature.

Cyclic symbiosis emphasizes the coexistence and balance of the old and new, and the elimination and reuse of wastes have become a major focus of development today. From perspective of landscape pattern, circulation and symbiosis are manifested as the coexistence mode of traditional and modern elements and patterns of ecological circulation network. From perspective of landscape process, more emphasis is placed on the recycling process of construction, resources, and energy in landscape shaping. From perspective of perception, it could stimulate the ecological consciousness and spatial–temporal memory in the contrasts and conflicts of materials and endow people new landscape experiences and feelings of juxtaposition and coexistence of traditional and modern materials.

The comprehensive benefits mainly highlight the organic integration and interaction of landscape elements, functions, and values in limited spaces. From perspective of landscape pattern, the coupling mode of living, production, and ecological space is the foundation of ecological construction and also the development direction of spatial organization in the twenty-first century. From perspective of landscape process, the integration of space and intensification of land are the key points of landscape architecture research in the twenty-first century, and the maximum economical use of land resources is also a necessary condition for sustainable development. Landscape integration is the guiding principle of landscape architecture at present and in the future.

9.5.2 Identification

With the acceleration of economy, technology, and globalization, local construction is faced with the challenges of regional characteristics and lack of landscape character and landscape personality, which were driven by cultural convergence under the collisions and impacts of global material, energy, and information exchange as external factors, and eagerness for quick success, quick profits and insufficient decision-making in urban design leading to assimilation of landscape convergence by copying and imitation as internal factors.

Regional identification is mainly reflected in landscape character or personality which is different from surrounding areas totally or partly (Han and Wang 2014). From perspective of landscape pattern, it is reflected in the re-understanding and re-excavation of regional value of the site, so as to inject regional characteristics into the construction of cultural and ecological spaces. From perspective of landscape process, the fragmented restoration of eco-environment and thematic construction of landscape space could change the current situations of landscape fragmentation and patchwork in the living environment and create a coordinated and unified human landscape within the region (Wang et al. 2015). From perspective of perception, regional identification would focus on the unique regional experience brought by landscape planning and design, such as the perception of local materials, memories of original site, and stimulation of homesickness.

Epochal identification emphasizes the embodiment and expression of the dynamic development and changing process of human society in landscape architecture. Landscape is the carrier of historical and cultural process, and its vitality lies in the ability to evolve and present new historical characters with the time. From perspective of landscape pattern, epochal identification lies in the expression of preservation, transformation, and integration models with modern forms of historical space and cultural elements in the current era. From perspective of landscape process, applications of historical and human thoughts in landscape shaping are highlighted. From perspective of perception, it arouses resonance to historical and cultural background of the place and then triggers inspiration and reflection of landscape.

Identification is the source of vitality in landscape architecture which shapes the transformation of regional characteristics and accelerate the precipitation of landscape characteristics under the trend of global assimilation. In the twenty-first century, landscape identification with strong character and personality is a powerful bed stone for the relationship between urban and rural heritage, as well as a strong guarantee for the development of landscape architecture.

9.5.3 Information

The applications of information technology in landscape architecture mainly include computer-aided design, design language, and design style influenced by information and digital experience of landscape. It is undoubtedly the major trend of landscape architecture through integration of landscape design expression, monitoring management, experience interaction, and others in the twenty-first century, but it is an important challenge for designers to provide people with digital landscape experience conveniently and comfortably. Compared with the twentieth century, landscape designers could use information technology to investigate, collect, process, and analyze landscape data comprehensively so as to obtain more real and effective information and deeper understanding of landscape.

Landscape management and landscape users could get more intelligent and human feedbacks and interactions in the process of landscape monitoring and experience so as to help people comprehend the connotation expressed by landscape more conveniently and timely (Wang and Wang 2013). The information of landscape architecture in the twenty-first century would be mainly reflected in demands for virtual reality, sharing, efficiency, and convenience.

Virtual reality and sharing represent the interactions and communications between human and virtual landscape. From perspective of landscape pattern, the superposition, interlacing, and collocation of real and virtual space are the basis for realizing this purpose. From perspective of landscape process, the interesting and human experience of virtual landscape would be the keys to digital expression of landscape. For example, 3D image, digital display, and multimedia technology would be used to realize the effects of expression and operation of landscape. From perspective of perception, it emphasizes the comprehensive experience of landscape brought by science and technology, including visual, tactile, auditory, and other sensories, so as to create a controllable landscape space beyond the traditions and imaginations.

Efficiency and convenience are mainly reflected in the control of landscape order by information technology. From perspective of landscape pattern, information is used to integrate the relationship between various landscapes, such as agro-landscape developed under the utilization of modern biotechnology, planting technology, and information monitoring technology. From perspective of landscape process, it emphasizes the formation of operation mode, intensive land use, and production mode of landscape. From perspective of perception, it is mainly manifested as the fast and convenient experience brought by information technology to obtain the timely and effective information.

Landscape information is the technical guarantee of landscape shaping based on information architecture, in which it is integrated with multi-disciplinary and plays a role in macromanagement, analysis of human experience, and is also the driving forces for the development of landscape architecture in the twenty-first century.

9.5.4 Intelligence

With the rapid development of science and technology, it has promoted the development and innovation of landscape architecture which cannot be separated from the support of science and technology and the application of new ideas that adapt to the development of the contemporary wisdom in the twenty-first century. It would be the main direction of the development of landscape architecture to apply intelligence rationally to the construction of landscape and meet the growing needs of contemporary people. Considering the cost of labors and material resources faced by traditional maintenance and operation of landscape, it requires landscape architecture to have the ability and wisdom to coordinate the sustainable development of nature, technology, and society with the orientation of acceptance of the trends of landscape ecological development. The intelligence of landscape architecture in the new era would be the connecting hub of integration, identification, and information.

Intelligent integration mainly reflected in sustainability and innovation of landscape architecture, which is technical support and concept guidance for the internal perfection and sustainable status of ecosystem in the process of integrated landscape construction, such as the emphasis on the formation of spatial patch and its functional organization. Intelligent identification mainly reflected in the inheritance of historical context and development of landscape architecture. Intelligent information mainly reflected in intelligent response of landscape architecture to human needs. Intelligence will integrate and screen the information so as to determine the appropriate landscape technology and sustainable development direction of landscape experience, which is reflected in the distribution of experience spots in space.

Intelligent landscape mainly includes the sustainable development of landscape, coordination between history and modern landscape, and information monitoring and landscape response. It emphasizes to maintain the development in order and the health of landscape through the maximum balance of its own system and shows the strong characteristics of regional landscape, and landscape character and landscape personality of the new era.

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Appendices: Samples of Landscape Pattern

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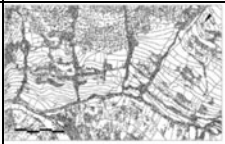
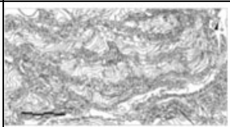
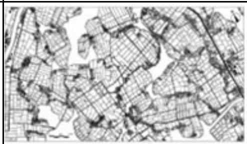
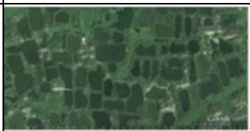
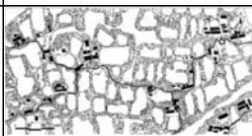
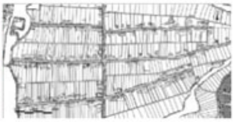
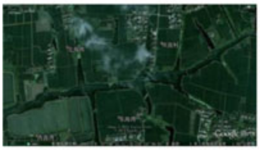
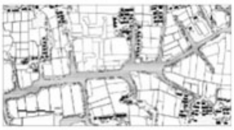
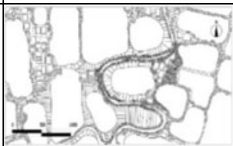
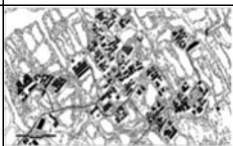
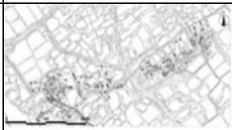
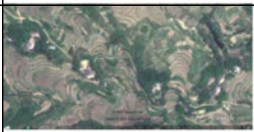
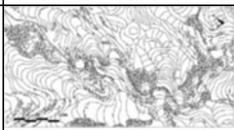
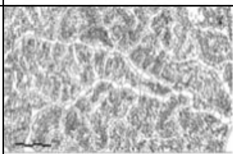
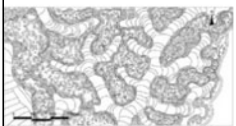
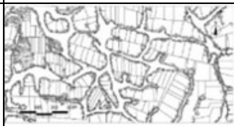
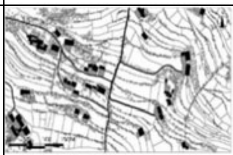
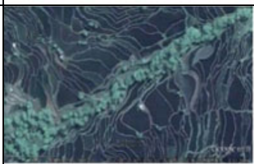
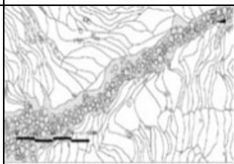
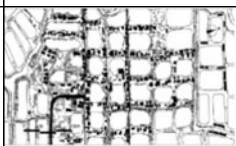
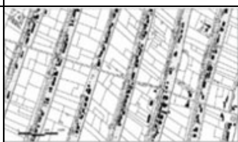
No.	Remote sensing images	Pattern	Location
1			Longwang Village, Shuanglong Town, Wushan County, Chongqing, China
2			Yujiliang, Longtan Township, Lizhou District, Guangyuan City, Sichuan Province, China
3			Yingshan Village, Xianfeng County, Hubei Province, China
4			Luohan Village, Majie Village, Majie Township, Yuanyang County, Honghe, Yunnan province, China
5			Pailou Village, Lianghui Township, Fuling District, Chong qing, China
6			Gaotian Village, Suchen Town, Hailing District, Taizhou city, Jiangsu Province, China
7			Chencuo Village, Nantong Town, Minhou County, Fuzhou City, Fujian Province, China

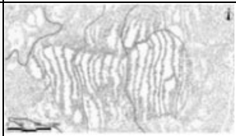
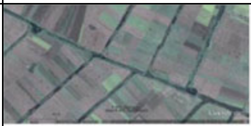
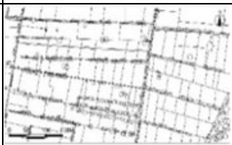
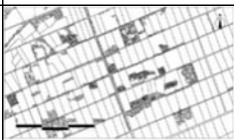
No.	**Remote sensing images**	**Pattern**	**Location**
8			Tongcheng Town, Tianchang City, Anhui Province, China
9			Chang 'an Village, Changzhou Town, Changzhou District, Wuzhou, Guangxi Zhuang Autonomous Region, China
10			Yuqi Town, Huishan District, Wuxi City, Jiangsu Province, China
11			Sunjiabang, Pingwang Town, Wujiang District, Suzhou city, Jiangsu Province, China
12			Xijiang Village, Linqiong Town, Chengqionglai City, Sichuan Province, China
13			Tian Haoli Village, Hefu Town, Nanxun District, Huzhou City, Zhejiang Province, China
14			Tangsifang Village, Shuiyang Town, Xuanzhou District, Xuancheng City, Anhui Province, China

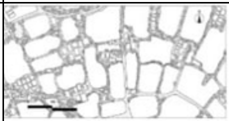
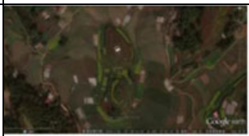
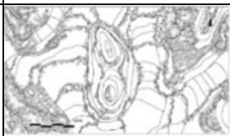
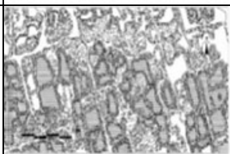
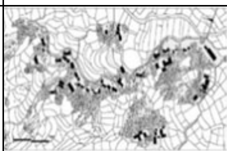
No.	Remote sensing images	Pattern	Location
15			Panjiazhuang, Liudu Town, Wuhu City, Anhui Province, China
16			Lei Mountain Village, Huangjiabu Town, Yuyao City, Zhejiang Province, China
17			Baqing Village, Muzhou Town, Xinhui District, Jiangmen city, Guangdong Province, China
18			Wei Village, Shidun Township, Wuwei County, Wuhu City, Anhui Province, China
19			Minzhu Village, Guizhuang Town, Taicang City, Jiangsu Province, China
20			Wugu Village, Miaoqiao Town, Zhangjiagang City, Jiangsu Province, China
21			Zhoujiatian Port, Shushan Town, Wuwei County, Wuhu City, Anhui Province, China

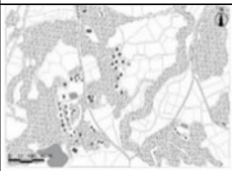
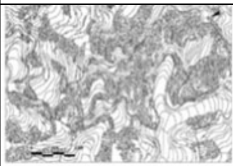
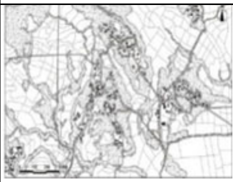
No.	**Remote sensing images**	**Pattern**	**Location**
22			Fengbian Village, Baiqiang Town, Gaochun District, Nanjing city, Jiangsu Province, China
23			Longquan Village, Hongxiang Township, Wuwei County, Wuhu City, Anhui Province,China
24			Lijiang City, Yunnan Province, China
25			Shunde District, Foshan city, Guangdong Province, China
26			Jiatang Town, Changshu city, Jiangsu Province, China
27			Dongsheng Village, Luoshe Town, Deqing County, Huzhou City, Zhejiang Province, China
28			Hefu Town, Nanxun District, Huzhou City, Zhejiang Province, China

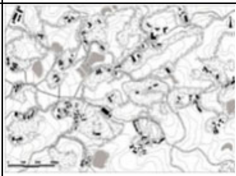
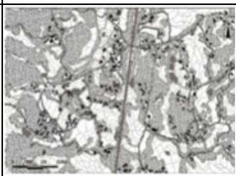
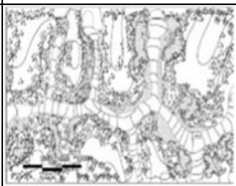
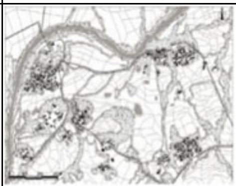
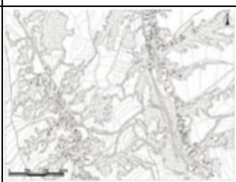
No.	**Remote sensing images**	**Pattern**	**Location**
29			Fangli Village, Linhu Town, Nanxun District, Huzhou City, Zhejiang Province, China
30			Caofang Village, Liudu Town, Wuwei County, Wuhu City, Anhui Province, China
31			Youtan Village, Ansheng Township, Liangping County, Chongqing, China
32			Dongping Village, Bailu Township, Chongren County, Fuzhou City, Jiangxi Province, China
33			Tangpu Village, Nantong Town, Minhou County, Fujian Province, China
34			Maoshan Village, Xingzhou Village, Wucheng Town, Xiuning County, Huangshan City, Anhui Province, China
35			Longhui County, Shaoyang City, Hunan Province, China

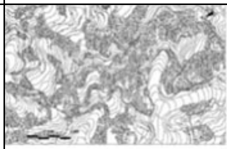
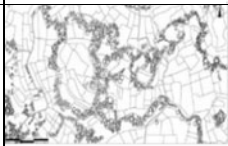
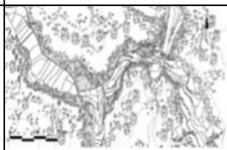
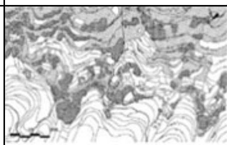
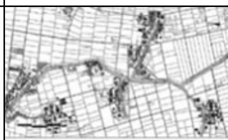
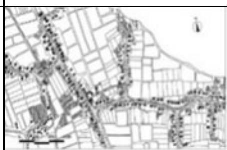
No.	**Remote sensing images**	**Pattern**	**Location**
36			Gaobu Town, Shaoxing City, Zhejiang Province, China
37			Tongcheng Town, Tianchang City, Anhui Province, China
38			Yangjiapu Village, Suzhou Town, Dunhuang City, Gansu Province, China
39			Lijiapo, Shanwo Township, Fuling District, Chongqing, China
40			Niujiazhai Village, Niujiazhai Township, Yuanyang County, Honghe Prefecture, Yunnan Province, China
41			Renhou Village, Tangxia Town, Pengjiang District, Jiangmen city, Guangdong Province, China
42			Qidong Group 5, Qianchan Town, Tongzhou District, Nantong city, Jiangsu Province, China

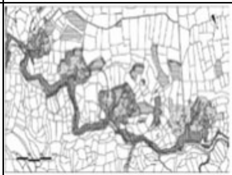
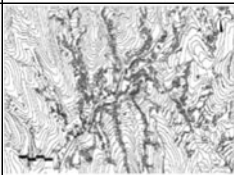
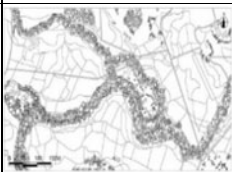
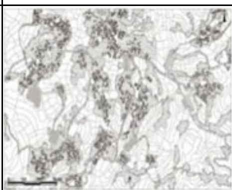
No.	**Remote sensing images**	**Pattern**	**Location**
43			Qiaoya Village, Jinping Town, Yiyang County, Luoyang City, Henan Province, China
44			Bund of Chenjiahe, Fudu Town, Wuwei County, Wuhu City, Anhui Province, China
45			Wantan Town, Zhongmou County, Zhengzhou City, Henan Province, China
46			Zhuanglang County, Pingliang City, Gansu Province, China
47			Changle Town,Shengzhou City, Zhejiang Province, China
48			Yichuan County, Luoyang City, Henan Province, China
49			Huaiyang County, Zhoukou City, Henan Province, China

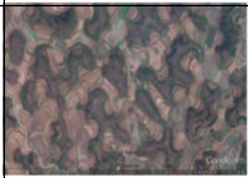
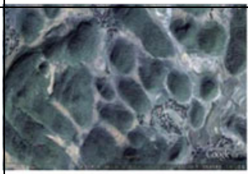
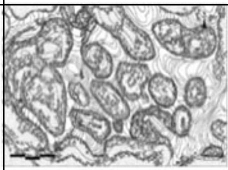
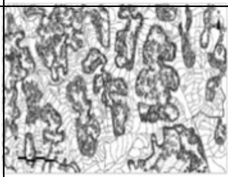
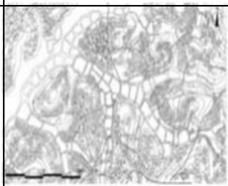
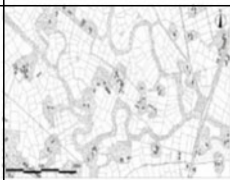
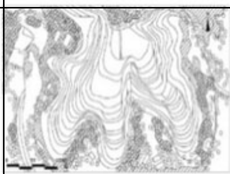
No.	**Remote sensing images**	**Pattern**	**Location**
50			Pengjiang District, Jiangmen city, Guangdong Province, China
51			Donglin Village, Deyuan Town, Pixian County, Chengdu city, Sichuan Province, China
52			Qingshui Township, Xunhua City, Qinghai Province, China
53			Longshui Town, Dazu District, Chongqing, China
54			Zhai Village, Baicheng City, Jilin Province, China
55			Yuhang District, Hangzhou city, Zhejiang Province, China
56			Nanhua Village, Panlong Town, Liangping County, Chongqing , , Chinaa

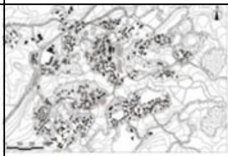
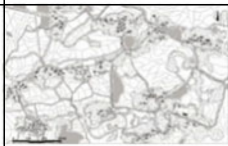
No.	**Remote sensing images**	**Pattern**	**Location**
57			Liangxi Town, Foshan City, Guangdong Province, China
58			Dawei, Sizhuang, Taizhou City, Jiangsu Province, China
59			Zhujiazui, Zhujia Village, Anlan Town, Banan District, Chongqing Municipality, China
60			Tao Zui Village, Xiang 'an Town, Wuwei County, Wuhu City, Anhui Province, China
61			Qingshitan Town, Lingchuan County, Guangxi Zhuang Autonomous Region, China
62			Xialing Jiao, Beihai City, Guangxi Zhuang Autonomous Region, China

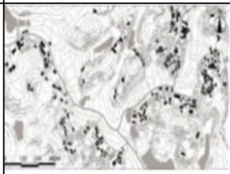
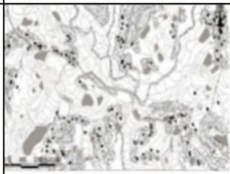
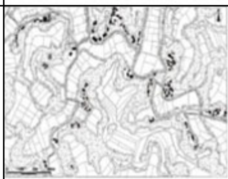
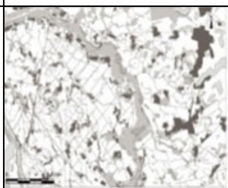
No.	Remote sensing images	Pattern	Location
63			Qiting Village, Macheng City, Hubei Province, China
64			Yaoba Town, Hejiang County, Sichuan Province, China
65			Heweiling, Xingguo County, Jiangxi Province, China
66			Chenggu County, Hanzhong City, Shaanxi Province, China
67			Zhouhu Town, Anfu County, Jiangxi Province, China
68			Sunjiatun, Chaoyang City, Liaoning Province, China

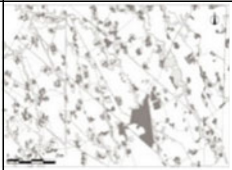
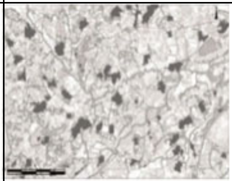
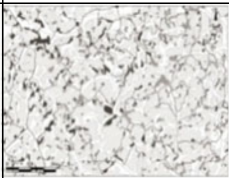
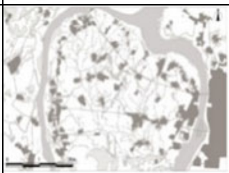
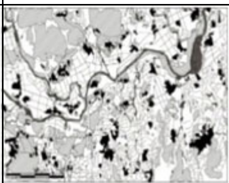
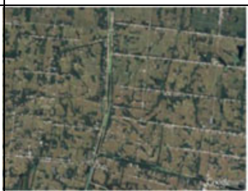
No.	**Remote sensing images**	**Pattern**	**Location**
69			Zhujiazui, Zhujia Village, Anlan Town, Banan District, Chongqing, China
70			Dingjia Ziku, Fuhong Town, Qingbaijiang District, Chengdu City, Sichuan Province, China
71			Nanzhang County, Xiangyang City, Hubei Province, China
72			Huating Village, Longgang Township, Banan District, Chongqing, China
73			Caopu Village, Nantong Town, Minhou County, Fuzhou City, Fujian Province, China
74			Hujiaqiao Village, Wuzhen Town, Tongxiang City, Zhejiang Province, China
75			Hunan Village, Tongli Town, Wujiang District, Suzhou City, Jiangsu Province, China

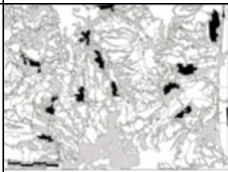
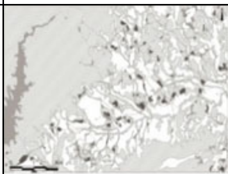
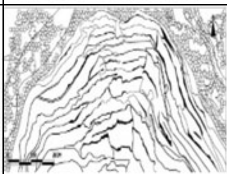
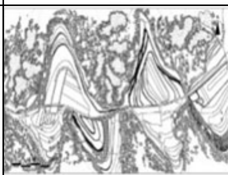
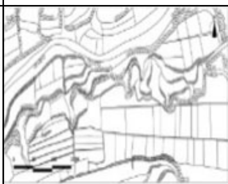
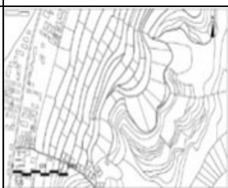
No.	**Remote sensing images**	**Pattern**	**Location**
76			Nihe Town, Lujiang County, Hefei City, Anhui Province, China
77			Nihe Town, Lujiang County, Hefei City, Anhui Province, China
78			Ge Tashan Village, Miaowan Township, Loujun County, Taiyuan City, Shanxi Province, China
79			Huangjiagou, Longtan Town, Fuling District, Chongqing, China
80			Jingzhou District, Jingzhou City, Hubei Province, China
81			Anshantang, Guigang, Guangxi Zhuang Autonomous Region, China

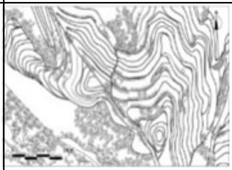
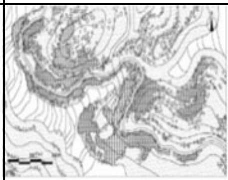
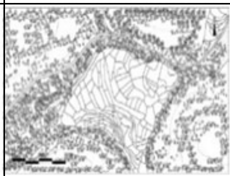
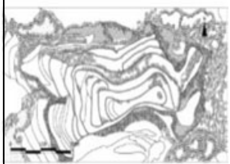
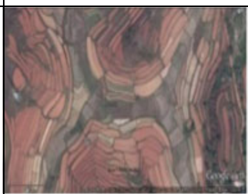
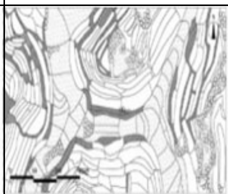
No.	**Remote sensing images**	**Pattern**	**Location**
82			Pumiao Town, Yongning District, Nanning City, Guangxi Zhuang Autonomous Region, China
83			Zhuqian Cave, Zhijin County, Bijie City, Guizhou Province, China
84			Zongyang County, Anqing City, Anhui Province, China
85			Lao Village, Lanshan Town, Huazhou City, Guangdong Province, China
86			Wenjia Temple, Deyuan Town, Pi County, Chengdu City, Sichuan Province, China
87			Fengjie County, Chongqing, China

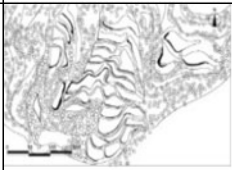
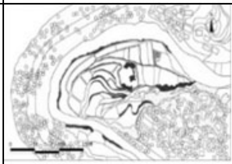
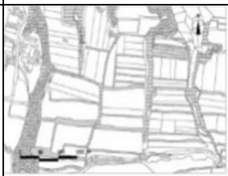
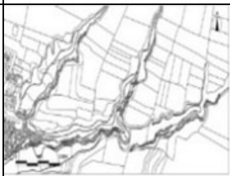
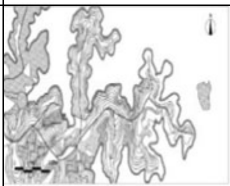
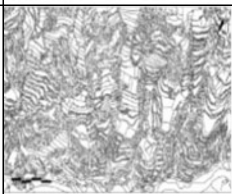
No.	**Remote sensing images**	**Pattern**	**Location**
88			Zhengcun, Guigang City, Guangxi Zhuang Autonomous Region, China
89			Huangshan Village, Tongcheng City, Anhui Province, China
90			Xiachen Village, Lujiang County, Anhui Province, China
91			Wenshan Zhuang and Miao Autonomous Prefecture, Yunnan Province, China
92			Tangchang Town, Pixian County, Chengdu City, Sichuan Province, China
93			Chawu, Anqing City, Anhui Province, China
94			Dafengkeng Village, Lishao Town, Luoding City, Guangdong Province, China

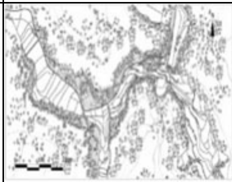
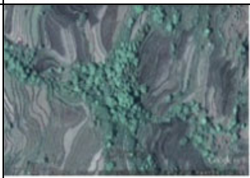
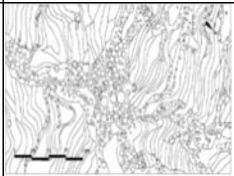
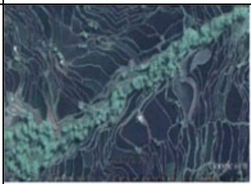
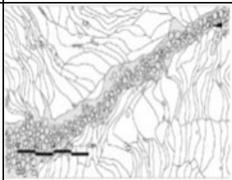
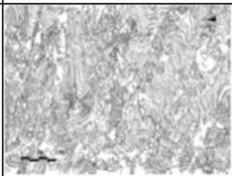
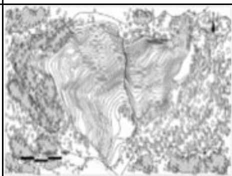
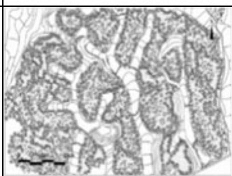
No.	**Remote sensing images**	**Pattern**	**Location**
95			Shixin Village, Heshui Town, Xingning City, Guangdong Province, China
96			Xinjing Village, Hongshan Town, Hengnan County, Hengyang City, Hunan Province, China
97			Lanxi Yao Nationality Township, Jiangyong County, Hunan Province, China
98			Da San Mei Temple, Jianyang City, Sichuan Province, China
99			Tushan Village, Nanxun District, Huzhou City, Zhejiang Province, China
100			Majiadun, Langxi County, Xuancheng City, Anhui Province, China

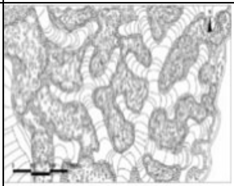
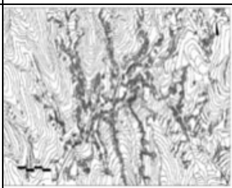
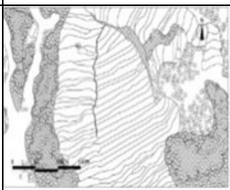
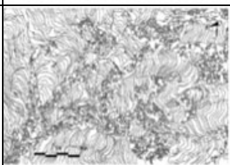
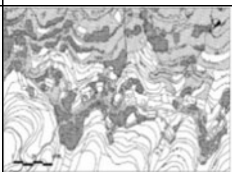
No.	**Remote sensing images**	**Pattern**	**Location**
101			Chenhe Village, Shangan Town, Dayi County, Chengdu City, Sichuan Province, China
102			Shangxiang Village, Lanxi City, Zhejiang Province, China
103			Houchong, Hengyang County, Hengyang City, Hunan Province, China
104			Dongliang Village, Linchuan District, Fuzhou City, Jiangxi Province, China
105			Dutou Village, Anfu County, Ji 'an City, Jiangxi Province, China
106			Da Chetang Village, Gaoyou City, Jiangsu Province, China

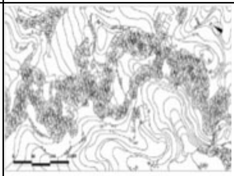
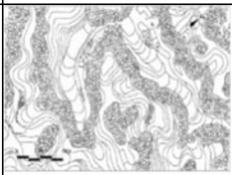
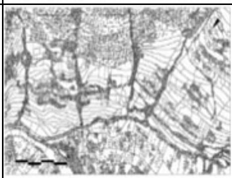
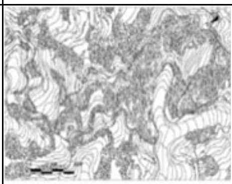
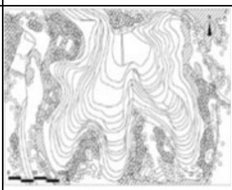
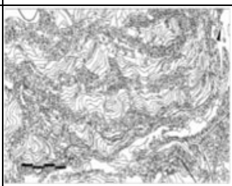
No.	**Remote sensing images**	**Pattern**	**Location**
107			Lijiazhuang Village, Anqiu City, Shandong Province, China
108			Honglian Village, Liangxi Town, Kaiping City, Guangdong Province, China
109			Wenxian County, Longnan City, Gansu Province, China
110			Heshui County, Qingyang City, Gansu Province, China
111			Zhuanglang County, Pingliang City, Gansu Province, China
112			Gannan Tibetan Autonomous Prefecture, Gansu Province, China

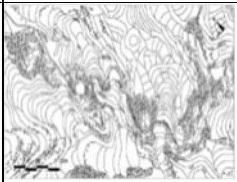
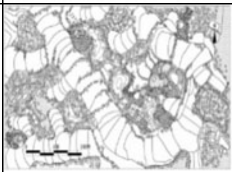
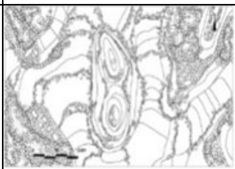
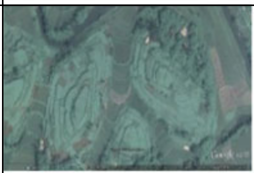
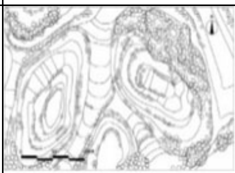
No.	**Remote sensing images**	**Pattern**	**Location**
113			Lintao County, Dingxi City, Gansu Province, China
114			Wula Village, Baishui Town, Guanling County, Guizhou Province, China
115			Libo County,Qiannan Buyi and Miao Autonomous Prefecture, Guizhou Province, China
116			Heshui County, Qingyang City, Gansu Province, China
117			Zhuanglang County, Pingliang City, Gansu Province, China
118			Nanning City, Guangxi Province, China

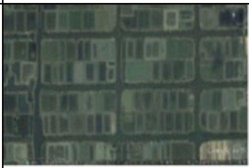
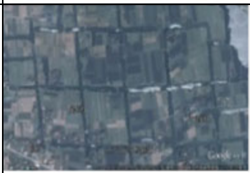
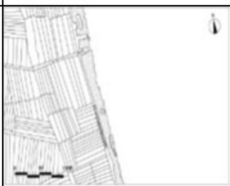
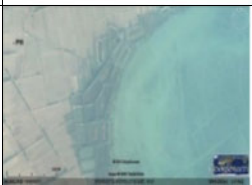
No.	**Remote sensing images**	**Pattern**	**Location**
119			Qiandongnan Miao and Dong Autonomous Prefecture, Guizhou Province, China
120			Qiandongnan Miao and Dong Autonomous Prefecture, Guizhou Province, China
121			Yichuan County, Luoyang City, Henan Province, China
122			Yichuan County, Luoyang City, Henan Province, China.
123			Nanzhao County, Nanyang City, Henan Province, China
124			Yingshan Village, Xianfeng County, Hubei Provinc, China

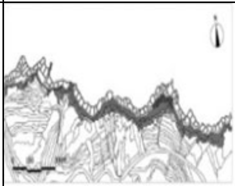
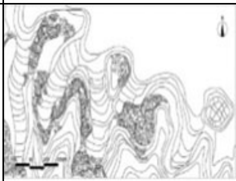
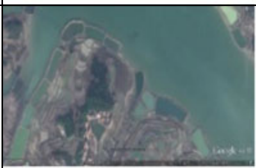
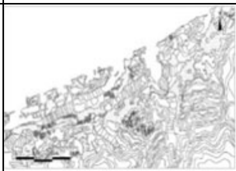
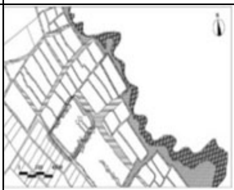
No.	Remote sensing images	Pattern	Location
125			Nanzhang County, Xiangyang City, Hubei Province, China
126			Bajiaoling Village, Xinjie Town, Yuanyang County, Honghe County, Yunnan Province, China
127			Niujiaozhai Village, Niujiaozhai Town, Yuanyang County, Honghe Prefecture,Yunnan Province, China
128			Luohan Village, Majie Village, Majie Township, Yuanyang County, Honghe County, Yunnan Province, China
129			Yuanyang County, Honghe Hani and Yi Autonomous Prefecture, Yunnan Province, China
130			Chibi City, Xianning City, Hubei Province, China

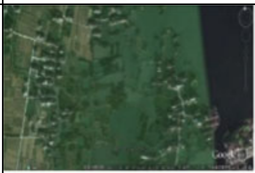
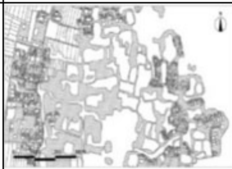
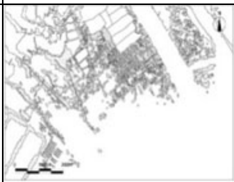
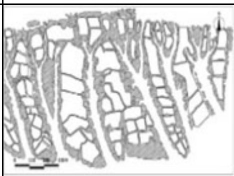
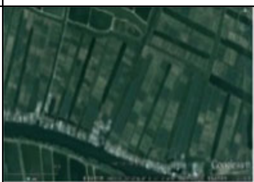
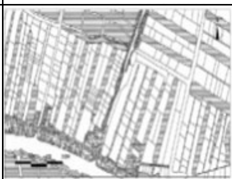
No.	Remote sensing images	Pattern	Location
131			Longhui County, Shaoyang City, Hunan Province, China
132			Wenquan Town, Jimo City, Qingdao City, Shandong Province, China
133			Ge Tashan Village, Miaowan Township, Loujun County, Taiyuan City, Shanxi Province, China
134			Chaotian District, Guangyuan City, Sichuan Province, China
135			Muji Dazhai Village, Niujiaozhai Village, Niujiaozhai Town, Yuanyang County, Honghe County, Yunnan Province, China
136			Huating Village, Longgang Town, Banan District, Chongqing Municipality, China

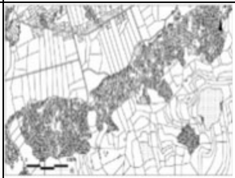
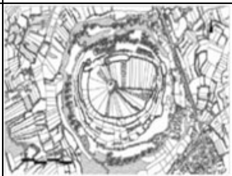
No.	**Remote sensing images**	**Pattern**	**Location**
137			Jinjiawan Village, Anlan Town, Banan District, Chongqing, China
138			Qinglong Village, Linshi Town, Fuling District, Chongqing, China
139			Longwang Village, Shuanglong Town, Wushan County, Chongqing, China
140			Zhujiazui, Zhujia Village, Anlan Town, Banan District, Chongqing, China
141			Fengjie County, Chongqing Municipality, China
142			Pailou Village, Lianghui Township, Fuling District, Chongqing, China

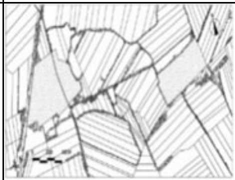
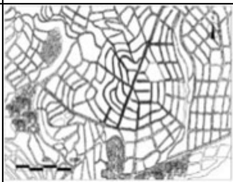
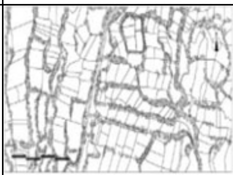
No.	**Remote sensing images**	**Pattern**	**Location**
143			Youtan Village, Ansheng Town, Liangping County, Chongqing, China
144			Longshui Town, Dazu District, Chongqing, China
145			Longshui Town, Dazu District, Chongqing, China
146			Longshui Town, Dazu District, Chongqing, China
147			Fengbian Village, Baiqiang Town, Gaochun District, Nanjing city, Jiangsu Province, China
148			Tangsifang Viiage, Shuiyang Town, Weidong Township, Xuanzhou District, Xuancheng City, Anhui Province, China

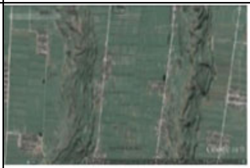
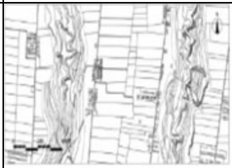
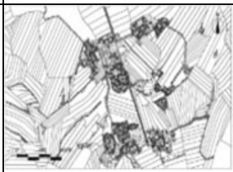
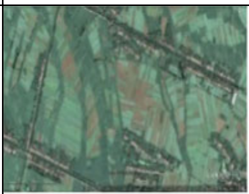
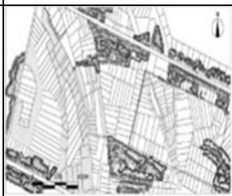
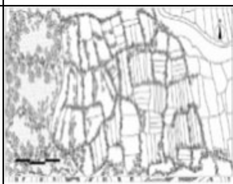
No.	Remote sensing images	Pattern	Location
149			Nanxi Village, Yangjiang Town, Gaochun County, Nanjing City, Jiangsu Province, China
150			Guanghua Village, Shiqiao Town, Dangtu County, Ma 'anshan City, Anhui Province, China
151			Sangyuanyu, Yingjiang District, Anqing City, Anhui Province, China
152			Xiadipo Village, Dianbai District, Maoming City, Guangdong Province, China
153			Weiming Village, Shangyu City, Shaoxing City, Zhejiang Province, China
154			Yinzhuang, Sihong County, Suqian City, Jiangsu Province, China

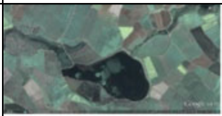
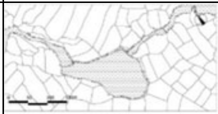
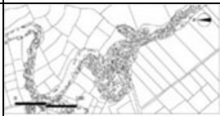
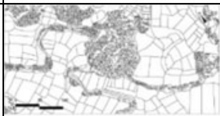
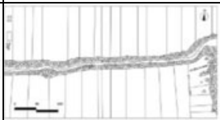
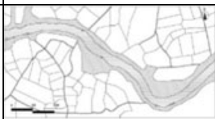
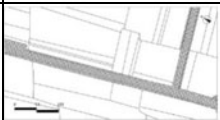
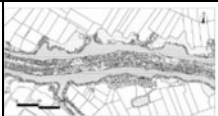
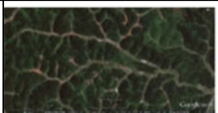
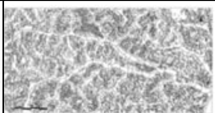
No.	Remote sensing images	Pattern	Location
155			Yueqing City, Wenzhou City, Zhejiang Province, China
156			Longshui Town, Dazu District, Chongqing, China
157			Jiayu County, Xianning City, Hubei Province, China
158			Ganxian County, Ganzhou City, Jiangxi Province, China
159			Zhangpu County, Zhangzhou City, Fujian Province, China
160			Cangnan County, Wenzhou City, Zhejiang Province, China

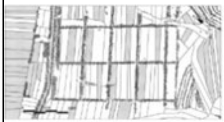
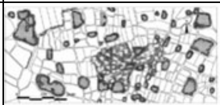
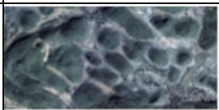
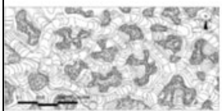
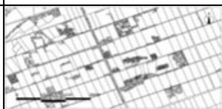
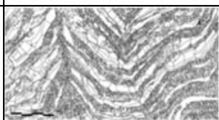
No.	Remote sensing images	Pattern	Location
161			Changfeng County, Hefei City, Anhui Province, China
162			Tangqi Town, Yuhang District, Hangzhou City, Zhejiang Province, China
163			Yueqing City, Wenzhou City, Zhejiang Province, China
164			Sanmen County, Taizhou City, Zhejiang Province, China
165			Gangkou Town, Zhongshan City, Guangdong Province, China
166			Zongyang County, Anqing City, Anhui Province, China

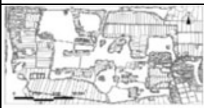
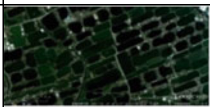
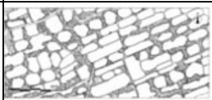
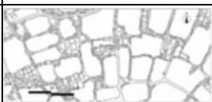
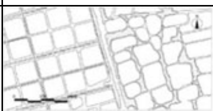
No.	Remote sensing images	Pattern	Location
167			Lijiao Village, Fengming Town, Pengshan County, Meishan City, Sichuan Province, China
168			Qilong Village, Longzheng Town, Renshou County, Meishan City, Sichuan Province, China
169			Tangchang Town, Pixian County, Chengdu City, Sichuan Province, China
170			Huaiyang County, Zhoukou City, Henan Province, China
171			Xiuying District, Haikou City, Hainan Province, China
172			Taiping Town, Harbin City, Heilongjiang Province, China

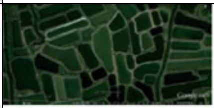
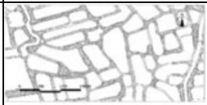
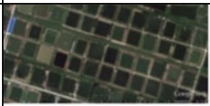
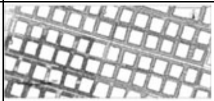
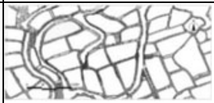
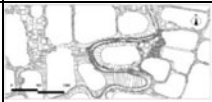
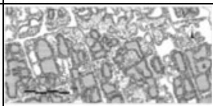
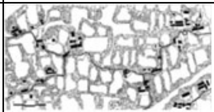
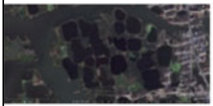
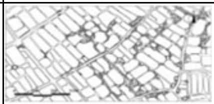
No.	Remote sensing images	Pattern	Location
173			Pingfang District, Harbin City, Heilongjiang Province, China
174			Chengmai County, Hainan Province, China
175			Xining City, Qinghai Province, China
176			Yongdeng County, Lanzhou City, Gansu Province, China
177			Jin 'an District, Lu 'an City, Anhui Province, China
178			Wenshan Zhuang and Miao Autonomous Prefecture, Yunnan Province, China

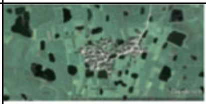
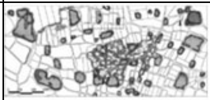
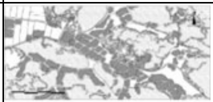
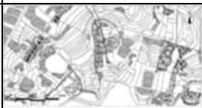
No.	**Remote sensing images**	**Pattern**	**Location**
179			Chencang District, Baoji City, Shaanxi Province, China
180			Changyi District, Jilin City, Jilin Province, China
181			Changyi District, Jilin City, Jilin Province, China
182			Zhengchang Town, Xiantao City, Hubei Province, China
183			Lijiang City, Yunnan Province, China
184			Lijiang City, Yunnan Province, China

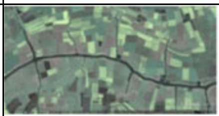
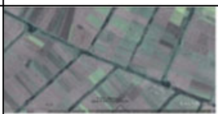
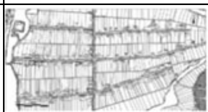
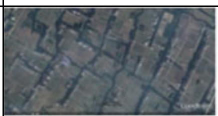
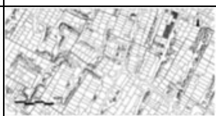
No.	Remote sensing images	Pattern	Location
185			Taochong Village, Baihu Town, Lujiang County, Hefei City, Anhui Province, China
186			Sancha Town, Dayi County, Chengdu City, Sichuan Province, China
187			Sancha Town, Dayi County, Chengdu City, Sichuan Province, China
188			Guowangzhuang, Luodian Town, Runan County, Zhumadian City, Henan Province, China
189			Xiazou Village, Huwei County, Dongxiang County, Fuzhou City, Jiangxi Province, China
190			Wangjiayingzi Village, Guanjiaying Manchu Township, Songshan District, Chifeng City, China
191			Yangjiacho, Changqiao Township, Changxing County, Huzhou City, Zhejiang Province, China
192			Maoshan Village, Xingzhou Village, Wucheng Town, Xiuning County, Huangshan City, Anhui Province, China

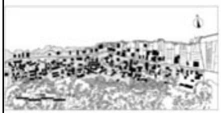
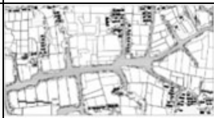
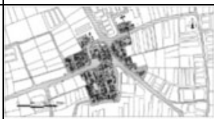
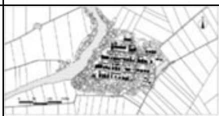
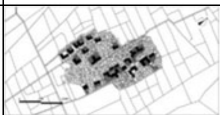
No.	Remote sensing images	Pattern	Location
193			Sandao Zhangfang, Jiefangyingzi Township, Wengniude Banner, Chifeng City, Inner Mongolia Autonomous Region, China
194			Anju District, Suining City, Sichuan Province, China
195			Xingxiang Town, Zhenjiang City, Jiangsu Province, China
196			Gao Bu Town, Shaoxing City, Zhejiang Province, China
197			Zhuqiandong, Zhijin County, Bijie City, Guizhou Province, China
198			Pumiao Town, Yongning District, Nanning City, Guangxi Zhuang Autonomous Region, China
199			Changle Town, Shengzhou City, Zhejiang Province, China
200			Yujialiang, Longtan Town, Lizhou District, Guangyuan City, Sichuan Province, China

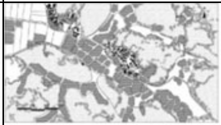
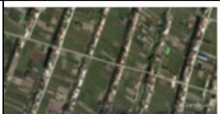
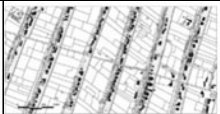
No.	**Remote sensing images**	**Pattern**	**Location**
201			Shangjiachong, Yicheng City, Hubei Province, China
202			Anju District, Suining City, Sichuan Province, China
203			Gaobu Town, Shaoxing City, Zhejiang Province, China
204			Chenggu County, Hanzhong City, Shaanxi Province, China
205			Shunde District, Foshan City, Guangdong Province, China
206			Shunde District, Foshan City, Guangdong Province, China
207			Pengjiang District, Jiangmen City, Guangdong Province, China
208			Pengjiang District, Jiangmen City, Guangdong Province, China
209			Xijiao Town, Foshan City, Guangdong Province, China

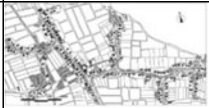
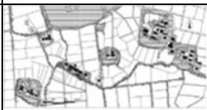
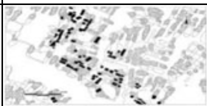
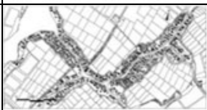
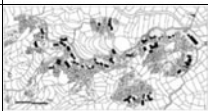
No.	Remote sensing images	Pattern	Location
210			Shunde District, Foshan City, Guangdong Province, China
211			Shunde District, Foshan City, Guangdong Province, China
212			Pengjiang District, Jiangmen City, Guangdong Province, China
213			Shunde District, Foshan city, Guangdong Province, China
214			Shunde District, Foshan City, Guangdong Province, China
215			Yuhang District, Hangzhou City, Zhejiang Province, China
216			Tianhaoli Village, Hefu Town, Nanxun District, Huzhou City, Zhejiang Province, China
217			The geographical coordinates of Tangqi Town, Yuhang District, Hangzhou City, Zhejiang Province, China
218			Wujiang City, Suzhou City, Jiangsu Province, China

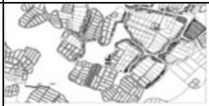
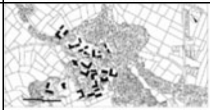
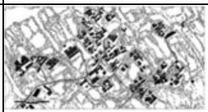
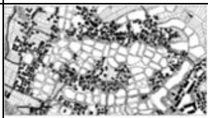
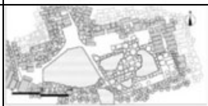
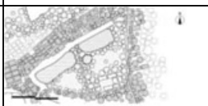
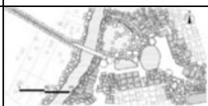
No.	Remote sensing images	Pattern	Location
219			Changfeng County, Hefei City, Anhui Province, China
220			Xingxiang Town, Zhenjiang City, Jiangsu Province, China
221			Sihui City, Zhaoqing City, Guangdong Province, China
222			Lishui District, Nanjing City, Jiangsu Province, China
223			Jingzhou District, Jingzhou City, Hubei Province, China
224			Yuhang District, Hangzhou City, Zhejiang Province, China
225			Changfeng County, Hefei City, Anhui Province, China
226			Nihe Town, Lujiang County, Hefei City, Anhui Province, China
227			Daibu Town, Liyang City, Jiangsu Province, China

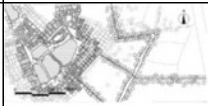
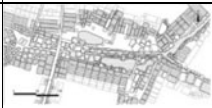
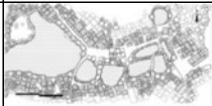
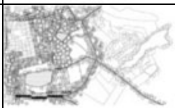
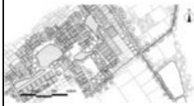
Num.	**Raw remote sensing images**	**Pattern of extraction**	**Location**
228			Xijiang Village, Linqiong Town, Chengqionglai City, Sichuan Province, China
229			Raoping County, Chaozhou City, Guangdong Province, China
230			Jingzhou District, Jingzhou City, Hubei Province, China
231			Zhoujiatianbu, Shushan Town, Wuwei County, Wuhu City, Anhui Province, China
232			Longquan Village, Hongxiang Township, Wuwei County, Wuhu City, Anhui Province, China
233			Bund of Chenjiahe, Fudu Town, Wuwei County, Wuhu City, Anhui Province, China
234			Liyushan Village, Huangjiabu Town, Yuyao City, Zhejiang Province, China
235			Minzhi Village, Guizhuang Town, Taicang City, Jiangsu Province, China

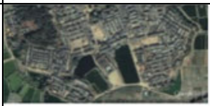
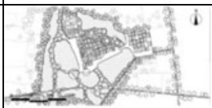
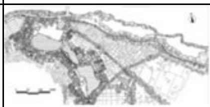
Num.	**Raw remote sensing images**	**Pattern of extraction**	**Location**
236			Jiatang Town, Changshu city, Jiangsu Province, China
237			Baita Village, Yunxiao County, Zhangzhou City, Fujian Province, China
238			Wugu Village, Miaoqiao Town, Zhangjiagang City, Jiangsu Province, China
239			Xiaogu Village, Xiaxu Town, Xinghua City, Taizhou City, Jiangsu Province, China
240			Malizhai Village, Xinjie Town, Yuanyang County, Honghe Prefecture, Yunnan Province, China
241			He Bawutai, Huangtan Town, Tianmen City, Hubei Province, China
242			Huxiang Village, Shiyang Town, Dujiangyan City, Sichuan Province, China
243			Renhou Village, Tangxia Town, Pengjiang District, Jiangmen city, Guangdong Province, China

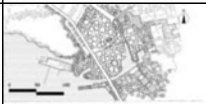
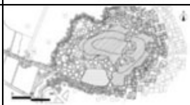
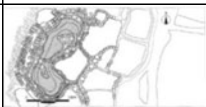
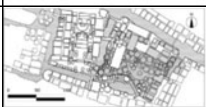
Num.	**Raw remote sensing images**	**Pattern of extraction**	**Location**
244			Sihui City, Zhaoqing City, Guangdong Province, China
245			Podingtian Village, Liping Town, Mayang Miao Autonomous County, Huaihua City, Hunan Province, China
246			Caofang Village, Liudu Town, Wuwei County, Wuhu City, Anhui Province, China
247			Mubu Village, Houtian Town, Xinjiang County, Nanchang City, Jiangxi Province, China
248			Jiaogou Village, Wutou Town, Xin 'an County, Luoyang City, Henan Province, China
249			Cao Wutai, Huangtan Town, Tianmen City, Hubei Province, China
250			Hujiaqiao Village, Wuzhen Town, Tongxiang City, Zhejiang Province, China
251			Qidong Group 5, Qianchan Town, Tongzhou District, Nantong city, Jiangsu Province, China

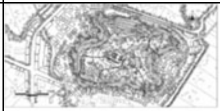
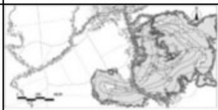
Num.	**Raw remote sensing images**	**Pattern of extraction**	**Location**
252			Hunan Village, Tongli Town, Wujiang District, Suzhou City, Jiangsu Province, China
253			Yong 'an Town, Dinghu District, Zhaoqing City, Guangdong Province, China
254			Shushan Town, Wuwei County, Wuhu City, Anhui Province, China
255			Jin 'an District, Lu 'an City, Anhui Province, China
256			Sunjiabang, Pingwang Town, Wujiang District, Suzhou, China
257			Deqing County, Huzhou City, Zhejiang Province, China
258			Hengnan Gang, Lili Town, Wujiang City, Jiangsu Province, China
259			Nanhua Village, Panlong Town, Liangping County, Chongqing, China
260			Yaolbei Village, Pingyao Town, Yuhang District, Hangzhou City, Zhejiang Province, China

Num.	**Raw remote sensing images**	**Pattern of extraction**	**Location**
261			Wujiang City, Suzhou City, Jiangsu Province, China.
262			Huilongsi Village, Shangan Town, Dayi County, Chengdu City, Sichuan Province, China.
263			Dongsheng Village, Luoshe Town, Deqing County, Huzhou City, Zhejiang Province, China.
264			Chang 'an Village, Changzhou Town, Changzhou District, Wuzhou, Guangxi Zhuang Autonomous Region, China.
265			Liantang Town, Gaoyao City, Zhaoqing City, Guangdong Province, China.
266			Chikan Town, Kaiping City, Guangdong Province, China.
267			Lixian Village, Yueshan Town, Kaiping City, Guangdong Province, China.
268			Xiancun Town, Zengcheng City, Guangzhou City, China.
269			Gaoyuan Village, Fengjiang Town, Jiexi County, Jieyang City, Guangdong Province, China.

Num.	**Raw remote sensing images**	**Pattern of extraction**	**Location**
270			Southwest Village, Kaiping City, Guangdong Province, China
271			Xiantian Yi Village, Chao 'an County, Guangdong Province, China
272			Shaer Village, Shaxi Town, Zhongshan City, Guangdong Province, China
273			Xixi Village, Kaiping City, Jiangmen City, Guangdong Province, China
274			Tangpu Village, Rongcheng District, Jieyang City, Guangdong Province, China
275			Xiancun, Haifeng County, Shanwei City, Guangdong Province, China
276			Wuwei Village, Hongcao Town, Shanwei City, Guangdong Province, China
277			Pengdong Village, Jiangdong Town, Chao 'an County, Chaozhou City, Guangdong Province, China
278			Jingmei Village, Jiangdong Town, Chao 'an County, Chaozhou City, Guangdong Province, China

Num.	**Raw remote sensing images**	**Pattern of extraction**	**Location**
279			Hualin Village, Yueshan Town, Kaiping City, Guangdong Province, China
280			Hei Village, Fengjiang Town, Jiexi County, Jieyang City, Guangdong Province, China
281			Pan Wu Village, Fuyang Town, Chao 'an County, Chaozhou City, Guangdong Province, China
282			Qinghutang Village, Kaiping City, Guangdong Province, China
283			Mingqiang Village, Kaiping City, Guangdong Province, China
284			Guantang Town, Chao 'an County, Guangdong Province, China
285			Shuixi Village, Baihe Town, Kaiping City, Jiangmen City, China
286			Shangbei Village, Longdu Town, Chenghai District, Shantou City, Guangdong Province, China
287			Magang Town, Kaiping City, Guangdong Province, China

Num.	Raw remote sensing images	Pattern of extraction	Location
288			Youchong Village, Lian 'an Town, Haifeng County, Shanwei City, Guangdong Province, China.
289			Mingyuewan Village, Suzhou City, Jiangsu Province, China.
290			Chong Long Village, Jiaomei Town, Longhai City, Zhangzhou City, Fujian Province, China.
291			Hugang Village, Jiedong County, Jieyang City, Guangdong Province, China.
292			Hantang Village, Kaiping City, Guangdong Province, China.
293			Nanlou Village, Chikan Town, Guangdong Province, China.
294			Jiangzao Village, Ma'an Town, Gaoyao City, Zhaoqing City, Guangdong Province, China.
295			Wujiangjun Temple, Wu Town, Tongxiang City, Zhejiang Province, China.
296			Zhouzhuang Town, Suzhou City, Zhejiang Province, China.

Num.	**Raw remote sensing images**	**Pattern of extraction**	**Location**
297			Heer Village, Xianjiang Town, Wenzhou City, Zhejiang province, China
298			Wujia Village, Xianjian Town, Wenzhou City, Zhejiang province, China
299			Hexi Town, Pingyang County, Wenzhou City, Zhejiang province, China
300			Xiaoruijia Village, Yaxi Town, Gaochun District, Nanjing City, Jiangsu Province, China

Epilogue

There would be a misunderstanding in landscape ecology since it was introduced and implemented in landscape architecture. On the one hand, landscape ecology is essentially the theory and method more suitable for spatial analysis and research at large scale. On the other hand, landscape architecture is unable to find an effective method suitable for ecological analysis of space at small and medium scale. This mismatch determines that landscape architecture could not express and represent the spatial ecological characteristics of landscape effectively when applying the theories and methods of landscape ecology. This limitation not only perplexes the research of the theory and method and their application in ecological practice, but also restricts landscape architecture to find its own teaching system and method in ecological characteristics of landscape.

Landscape pattern language is the theory and method used to research and characterize the ecological characteristics of landscape space, which is proposed by the author on the basis of combining the study of pattern language in architecture and landscape language in landscape architecture through the long-term teaching of landscape ecology, landscape ecological planning principles, and professional practice. By the researches of 20 years, a lot of theoretical researches and practical verifications of landscape pattern language have been carried out and gradually established the logic and systematical framework of landscape pattern language, and initially the methods and approaches were established to apply landscape pattern language.

These studies were funded by three general projects of the National Nature Science Foundation of China (NSFC): ***Spatial Fragmentation and Isolation of Traditional Culture Landscape and Its Formative Mechanism*** (No.50878162), ***Landscape Pattern Language and Its Formative Mechanism of Traditional Culture Landscape*** (No.51278346), and ***Scale Nested Structure and Scale-based Adaptation Design of Landscape Pattern Language*** (No.51978479). In this process, some students have carried out solid thematic researches in the study of landscape pattern language, mainly including doctoral students of Liying Han, Dong LV, Na Guo, Hui Wang, Ying Cui, Xiaodong Meng, Mangmang Wang and master students of Jing XU, Ying Zhang, Wen Fu, Qi Qu, Qin Zou, Yuchen Yang, Jiake Shen, Jia Gao, and Chunqi Zhang, all these students had graduated and gotten the doctor and master's degree

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in engineering. It is the rich working foundations that the theory and methods of landscape pattern language have constructed a complete system.

In this process, Prof. Rui Yang, Department of Landscape Architecture, Tsinghua University, and Prof. Weining Xiang, University of North Carolina at Charlotte, USA, and Director of the Research Center for Ecological Wisdom and Ecological Practice, School of Architecture and Urban Planning, Tongji University, are two consultants of our research team. They contributed their wisdom and ideas to the study and at the same time encouraged and promoted the further study and provided relevant international perspectives and contexts. Prof. Weining Xiang also makes full use of his international professional networks to provide a communication platform and opportunity for the promotion of landscape pattern language research. Prof. Wentao Yan, Hui Wang, and Xinhao Wang of the Research Center for Ecological Wisdom and Practice also put forward valuable suggestions.

Ecological practice is the important approach for the continuous verification, enrichment, and development of landscape pattern language. While teaching and researching, we also have carried out long-term interdisciplinary practical cooperation with Prof. Zhenwei Peng from Department of Urban and Rural Planning, School of Architecture and Urban Planning, Tongji University. The team completed successively the planning and design practice of Kangping Wolong Lake Ecological Reserve, Changbai County, Ecological Reserve in Jilin Province, Fushan District, Ecological Reserve in Yantai City, Nanyi Lake Ecological Reserve in Anhui Province, Haiyong Tourism Resort in Jiangsu Province, Qilianyu Island, and Yongle Islands in Sansha City, as well as some projects of urban ecological restoration planning, such as Shiyan, Taiyuan, Heishan. Diversified practices not only enriched the cognitive system of landscape pattern language, but also provided various ways to apply and verify the validity of landscape pattern language.

The knowledge fusion generated by interdisciplinary teams contributed to the healthy growth of landscape pattern vocabulary and spatial reasoning. The theory and method of landscape pattern language are still in the process of continuous renewal, development, and innovation, as well as verification to adapt the change of time and environment. I sincerely thank all those colleagues who have helped, cared for, and paid attention to the process of growing up of landscape pattern language.

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