CONTENT PLANNING AND STRUCTURE DESIGN OF GLOBAL LAND COVER KNOWLEDGE ATLAS

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ABSTRACT:

From 2000 to 2020, three versions of the 30-meter global land cover data products (GlobeLand30) have been made accessible to the public. The dataset with 30-meter spatial resolution and 10-year temporal resolution are widely used for monitoring environment changes and resource management at global, regional and local scales. By analysing and extracting information and knowledge from the GlobeLand30 data, we have planned and designed a global land cover knowledge atlas, which aims to expand the available knowledge base for scientific research, management decision-making, and knowledge dissemination.

1. INTRODUCTION

1.1 GlobeLand30 Data

China has produced the freely available 30-meter global land cover product, GlobeLand30 data (Chen et al., 2014). The dataset is based mainly on Landsat TM5, ETM+, and OLI data, HJ-1, and GF-1 multispectral data. The 2000 and 2010 versions of the GlobeLand30 data were released in 2014, while the 2020 version was released in 2020. This data product includes ten land cover types, namely cultivated land, forest, grassland, shrubland, wetland, water bodies, tundra, artificial surface, bare land, perennial snow and ice. It illustrates the distribution patterns and spatiotemporal changes of these ten global land cover types. In 2014 and 2020, China donated the GlobeLand30 dataset to the United Nations for open access and international sharing. Since then, it has been widely utilized in scientific research and various services.

1.2 Knowledge Service

With the implementation of the Four-pronged Comprehensive Strategy, the construction of ecological civilization, and the go-global strategy, there is an increasing demand for geospatial knowledge of governance of mountains, rivers, forests, farmlands, lakes, grasslands and deserts, for planning, management, and decision-making research. The geospatial knowledge encompasses spatial patterns, regional differences, space-time laws, cause and effect mechanisms, and other relevant factors. By processing and statistically analysing the land cover data product from a professional perspective, researchers have been able to condense a set of relational structural knowledge points that explores spatial patterns, regional differences, trend characteristics, and causal mechanisms. The integration of these knowledge points forms a land cover knowledge system (Chen et al., 2019). The purpose of data mining is to discover knowledge and generate visual knowledge maps (Wang, 2011). Firstly, it is necessary to study the model algorithm of spatial data mining and knowledge discovery and develop specialized knowledge discovery tools. Secondly, analyzing the complex space-time laws of spatial data, as well as information correlations across different scales, organizational levels, and technical fields to help mine new knowledge about correlation patterns and interrelationships. Finally, visualizing knowledge and automatically generating various knowledge maps can facilitate the practical application of spatial data mining and knowledge discovery.

The National Geomatics Center of China initiated the GlobeLand30 international collaborative verification and data analysis project with the aim of providing not only simple data but also information analysis and knowledge services. The project has sequentially researched on the global spatial distribution pattern and change trend of surface water, urban and rural construction land, cultivated land, and wetlands. It provides detailed information for global ecological environment monitoring and protection, and the analysis report is made openly accessible to the public. Meanwhile, the Global Land Cover Knowledge Atlas is compiled to promote the widespread application of GlobeLand30 data and provide better knowledge serves by monitoring the global land cover distribution and change and Meanwhile, the Global Land Cover Knowledge Atlas is compiled to promote widespread application of GlobeLand30 data and provide promoted professional knowledge serves by monitoring the global land cover distribution and change.

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2. DESIGN IDEA AND CONTENT PLANNING

2.1 Design Idea and Train of Thought

The atlas focuses on global land cover and related knowledge about mountains, rivers, forests, farmlands, lakes, grasslands and deserts. It selects land cover elements that are closely connected to human production, life, and ecological space and fully extracted land cover knowledge. Then, using modern geographic information technologies and mapping methods, the atlas presents the spatial distribution pattern, change trends, and thematic application analysis results of global and regional land cover in a scientific, systematic, and intuitive manner. Furthermore, with a focus on the objectives of ecological civilization construction, resource and environmental carrying capacity, sustainable development, and the harmonious development of man and nature, the atlas addresses various themes related to ecological elements. It aims to provide knowledge services and decision support for the comprehensive protection, systematic restoration, and holistic management of ecosystems.

(1) The atlas systematically describes the thematic content related to the community of life such as mountains, rivers, forests, farmlands, lakes, grasslands and deserts.
The atlas selects knowledge related to the community of life such as mountains, rivers, forests, farmlands, lakes, grasslands and deserts. It connects loose knowledge points by crafting engaging narratives and displays the symbiotic relationship between man and nature through thematic maps. It reveals how holistic conservation and governance of mountains, rivers, forests, farmlands, lakes, grasslands and deserts impacts the overall health and sustainable development of human beings.

(2) The atlas utilizes advanced map and geographic information visualization methods.
Through the application of a variety of visualization methods, including maps, images, shading, three-dimensional landscapes, pictures, charts, and text, the atlas objectively and vividly depict the spatial distribution and change characteristics of land cover elements from different perspectives and at different levels. By employing innovative visualization methods, it seamlessly combines scientific rigor, practical applicability, informative presentation, and artistic elements to effectively disseminate knowledge.

2.2 Content Planning

(1) Systematicness
An atlas is not merely a compilation of individual maps but is characterized by a unified overall design, a complete ideological system, a systematic logical sequence, an organic internal structure, and strict technical specifications (Chen, 2005). It is a map system that integrates a series of interconnected, unified, coordinated, and standardized maps based on a common theme and mapping requirements, following a scientific structural system, systematic representation, and strict map sheet order, fulfilling specific mapping purposes and objectives (Wang et al., 2014, Wang et al., 2019).

The compilation of an atlas is designed and produced as a comprehensive system. Ensuring the systematic arrangement of groups and maps is a fundamental requirement. (Lu, 1997; Wang et al., 2014). Emphasizing integrity, systematic organization, and interrelation of different categories of global land cover, the content should comprehensively and systematically reflects the distribution and evolution of various land covers (cultivated land, forest, grassland, shrubland, wetland, water bodies, tundra, artificial surface, bare land, perennial snow and ice) on Earth, as well as the characteristics of the global natural, cultural, and geographical environment. Each land cover type is divided into a group, and each group encompasses distribution pattern maps, change and evolution maps, typical types and key areas maps, as well as utilization and protection maps. The arrangement of map sheets follows a logical and systematic approach, starting from general to specific, global to local, and prioritizing natural phenomena before humanistic factors. By doing so, the atlas achieves a coordinated and comprehensive expression mode, characterized by high scientific, practical, and artistic quality.

The systematic selection of topics and the logical layout of the atlas ensure the contents are comprehensive, scientific, and accurately depict global natural and cultural phenomena, as well as the interrelationships, interdependencies, and influences among them. Additionally, the complementary nature and interconnectivity of each map group ensures the comparability and the logical organization of the atlas.

(2) Globality
In recent years, China has actively participated in the global system reform and construction, advocating the concept of co-construction and sharing in global governance, promoting world peace and development, and building a shared future for all life on Earth. Utilizing 30-meter global land cover data, the design and selection of atlas content should adopt a global perspective, focusing on the distribution, pattern, evolution, and mechanism of natural and cultural elements across the globe, continents. The aim is to highlight these aspects as the main knowledge content. For example, the introductory maps group select maps depicting world administrative divisions, topography, climate zones, and other relevant information. The utilization of data should also reflect its global nature. In addition to using the global 30-meter land cover data, other sources such as global 1:1,000,000 basic geographic information data, global SRTM digital elevation model data, global image data, Coburn climate zoning data, eco-geographical zoning data, World Bank statistics, UNESCO statistics, and more can be incorporated. Furthermore, the compilation of this atlas also hopes to play an important role in studying global climate and environmental change, facilitate the implementation of the "Belt and Road" initiative, and support the realization of the UN 2030 Agenda for Sustainable Development.

(3) Highlight Knowledge and Science Popularization
With the unified goal of knowledge dissemination, the atlas utilizes statistical analysis and data mining techniques to extract informative points from global land cover data. These knowledge points are presented in the form of maps, providing a clear and accessible framework that facilitates easy understanding and comprehension of the information. For example, the statement "China feeds 22% of the world's population with 7% of the world's cultivated land" leads to the inclusion of a cultivated land distribution map. This makes the atlas more innovative, vivid, and knowledgeable. One significant innovation of this atlas is the integration of land cover types with relevant knowledge. When discussing global waters, for instance, we can introduce Canada as the country with the largest water area, Finland as the "country of thousands of lakes," and the Amazon basin as the region holding the largest area and water resources in the world. This incorporation of knowledge enhances the professionalism and breadth of the

atlas. The atlas should comprehensively display global land cover and related knowledge based on authoritative data, authentic content, objective evaluation, and accurate results. By doing so, it will provide readers with a wealth of information and insights across various areas.

Indeed, an atlas plays a crucial role in popularizing science. It presents various themes through maps, images, shading, three-dimensional landscapes, pictures, charts, and text from multiple perspectives and forms. To complement the theme, precise and concise text titles or descriptions are included to enhance the overall presentation. In accordance with different themes, the text descriptions should strike a balance between being accessible to a wider audience while also providing scientific explanations.

3. STRUCTURE DESIGN AND LAYOUT DESIGN OF KNOWLEDGE ATLAS

An atlas, which serves as an "encyclopedia" for understanding the complex nonlinear geographical world, should possess the cognitive ability to analyze and synthesize information. (Wang, 2021; Wang et al., 2022). To align with people's cognitive systems, the atlas adopts a hierarchical tree design of "atlas + group + sheet + map, picture, text, and chart," as depicted in Figure 1. Based on the types of land cover, the maps in the atlas are grouped into various categories, including the wetland map group, water bodies map group, and perennial snow and ice map group et al. Each map group is designed in a way that considers the function, distribution patterns, typical types, spatiotemporal changes, utilization and protection of each land cover type within the ecosystem. Each map sheet consists of corresponding maps, typical photos, and refined textual explanations and diagrams. The maps mainly encompass land cover maps, image maps, shaded maps, vector maps, etc. The spatial arrangement follows the order of "macro (global) first, followed by meso (continent), and then micro (typical region)." Regarding time sequencing, the atlas presents the current state before displaying changes over time. The content is organized according to the types of land cover, prioritizing natural land cover before cultural land cover. Additionally, the layout of the map adheres to the principle of presenting the map first, followed by relevant photo-text elements.

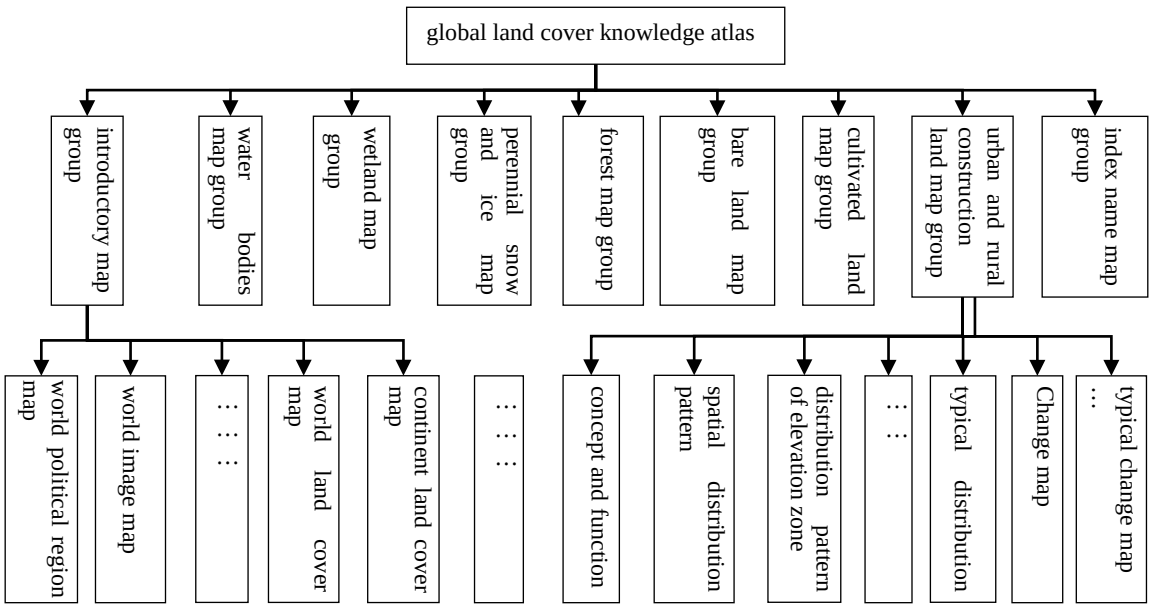


Figure 1. The content structure of the Global Land Cover Knowledge Atlas.

3.1 Atlas

The atlas consists of several connected thematic groups. These thematic groups include: introductory map group, water bodies map group, wetland map group, perennial snow and ice map group, forest map group, bare land map group, cultivated land map group, urban and rural construction land map group, index name map group. The introductory map group in the atlas serves as a global and general knowledge map that generally reflects the land cover types of the ecosystem. These land cover map groups reflects the distribution pattern, space-time change, evolution mechanism and other knowledge of each land cover type in the earth ecosystem.

3.2 Map Group

The map group, serves as the secondary structure of the atlas and is the most important branch within the tree structure. In this atlas, the nine map groups are organized based on the thematic category of land cover types within the Earth's ecosystem. The arrangement follows a logical sequence that prioritizes natural land cover before cultural land cover and ecological factors before production and human settlements. In terms of spatial scale, the atlas adopts a multi-level vision that encompasses macro, meso, and micro perspectives. It covers different scales ranging from the global level (macro) to continents, regions, countries, and typical regions and cities (meso and micro).

As the opening volume of the atlas, the introductory map group serves the purpose of providing an introduction and summary of the main land cover factors (both cultural and natural),which are designed to facilitate knowledge extraction and spatial analysis and present the overall distribution of land cover on a global and continental scale. The introductory map group offers a macro perspective on the relationship between man and nature, describing the overall distribution and evolution of various land cover types on the Earth's surface. The land cover map group, as

the main body of this atlas, primarily focuses on the spatial distribution patterns, characteristic features, causes, and changes since 2000. The atlas includes seven map groups dedicated to specific land cover types: water bodies, wetlands, perennial snow and ice, forests, bare land, cultivated land, and artificial surface. Due to the relatively small number, scattered distribution, and localized occurrence of shrublands and tundra, they are not expressed as separate map groups in this atlas. However, relevant knowledge and information about these land cover types are still included and presented within the introductory map group.

3.3 Map

As units of the atlas, maps with similar topics and close connections are grouped together. Generally, each map group expresses a unique theme.

In the introductory map group, there are a total of 12 maps spanning 16 pages. It includes maps the global political area, global image, global topography, global climate type, global eco-geographical division, global land cover, along with relevant knowledge points in the expansion page. Additionally, it features a one-page distribution map of 30-m land cover in Asia and Europe, as well as a half-page distribution map of 30-m land cover in Africa, North America, South America, and Oceania. The national political area is closely related to land cover elements as it is influenced by social, economic, and cultural policies of different countries. These factors contribute to the distribution patterns and development of land cover elements. Moreover, the national political area serves as the primary administrative unit for managing and collecting statistics on land cover elements. Therefore, the global political area map in the atlas primarily focuses on the national political area as it represents these aspects. It is also the first map in the introductory map group. The development of GlobeLand30 data relies on classified images obtained from various sources such as Landsat TM5, ETM+, OLI multispectral images, China's Environmental Disaster Reduction Satellite (HJ-1) multispectral images, and GF-1 multispectral images with a resolution of 30 meters and 16 meters, respectively. Hence, the global image map is chosen as the second map in the introductory map group while providing additional information about commonly used remote sensing satellites from domestic and international sources. Topography, climate, and ecological zoning not only impact land cover but also serve as important statistical units for land cover data. The introductory map group represents these influencing factors at a macro level. The group includes a significant map showing global and continental land cover, along with relevant knowledge. The map displays ten categories of land cover raster data and roughly overlays residential areas, boundaries, natural and cultural geographical names, and other features. Figure 2 shows the global land cover map within the introductory map group. The left side of the map highlights the distribution of various land cover types, global changes in artificial surfaces, and introduces significant features such as the global largest water bodies, wetlands, forests, tundra, and artificial surfaces through illustrations and descriptions related to land cover.

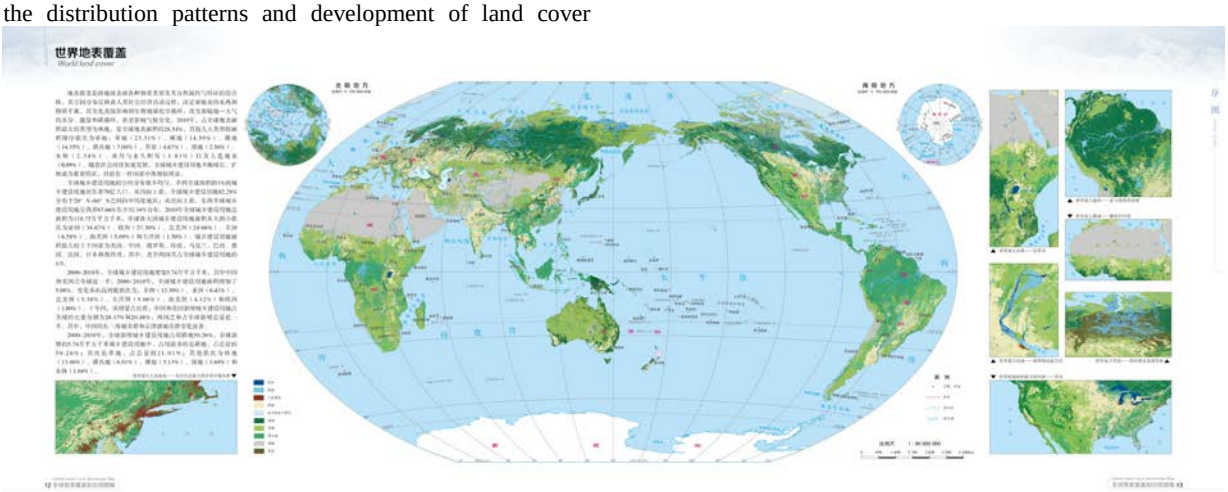


Figure 2. The global land cover map.

Consider the characteristics of various land cover, the land cover map group aims to explore and present the effect, distribution patterns, typical types, spatiotemporal changes, development, utilization and protection of seven types of land cover in the Earth's ecosystem, such as water body map group and urban and rural construction map group. Each map within the group has its own unique theme and content, while also contributing to the broader understanding of land cover patterns and their ecological significance. The following introduction outlines the design of two map groups: the water body map group and the urban and rural construction map group. The purpose is to help readers grasp the theme and significance of the entire land cover map group and gain knowledge.

The water body map group begins by exploring the significance of water bodies in the Earth's ecosystem and human civilization, and highlights the relationship between them, emphasizing the idea that great rivers have historically given rise to great civilizations. This serves as the starting point for the map group. The first map in this group is a global water body distribution map, accompanied by relevant knowledge about water bodies across the world. It provides an overview of the distribution patterns and characteristics of various types of water bodies, such as lakes, rivers, seas, and oceans. Following this, the map group focuses on specific major basins around the world, such as the Amazon basin and Congo basin. It presents detailed maps and knowledge about the water bodies within these basins, further enhancing understanding of their importance and unique features. The map group also highlights distinctive rivers and lakes worldwide. For example, it shows the Danube River, which flows through the largest number of countries, or Lake Baikal, known as the largest freshwater lake in Eurasia. It also feature countries with notable water bodies, like Finland, often referred to as the "country of thousands of

lakes." Next, the map group turns its attention to global water body changes. It displays maps and provides knowledge about how water bodies undergo natural and cultural transformations over time, such as Poyang Lake, Victoria Lake (refer to Figure 4) and the Three Gorges Reservoir. Finally, the map group covers the development and utilization of water bodies. It showcases famous water conservancy projects and water diversion projects, demonstrating the ways water bodies are harnessed for various purposes.

Figure 4 takes Lake Victoria, the largest lake in Africa and the second largest freshwater lake in the world, as an example to explain the trends and reasons behind the surface water changes. It spans across Kenya, Uganda, and Tanzania, situated in the middle of the East African Plateau, with the equator passing through its northern region. The northern part of Lake Victoria is approximately 1,134 meters above sea level, covering an area of 69,400 square kilometers and boasting an average depth of 40 meters.

The climate around Lake Victoria is classified as a tropical grassland climate. It exhibits an annual average temperature of about 26 ℃, with significant seasonal variations. The rainy season occurs from March to May and October to November each year, characterized by substantial rainfall and a daily maximum temperature ranging from 30 ℃ to 32 ℃. On the other hand, the dry season lasts from June to September and December to February annually. During this period, temperatures are higher, with a daily maximum temperature exceeding 36 ℃.Between 2001 and 2006, Lake Victoria experienced relatively dry conditions, while a period of increased rainfall occurred from 2006 to 2011 (Awange et al., 2014). With a drainage area of approximately 261,800 square kilometers, Lake Victoria plays a crucial role in the lives of around 30 million people residing within its catchment area. Therefore, studying the fluctuations in its water surface area is of great significance for the sustainable utilization of local water resources.

As we can see in Figure 4, from 2001 to 2011, the water coverage of Lake Victoria exhibited fluctuations. Initially, there was a decreasing trend in the overall area of the lake covered by water from 2001 to 2006. However, from 2007 to 2011, there was an increasing trend in the overall water coverage. This pattern closely aligned with the regional rainfall trend (Awange et al., 2014). In other words, the changes in the water surface area of Lake Victoria during this period strongly correlated with the observed rainfall patterns in the region.

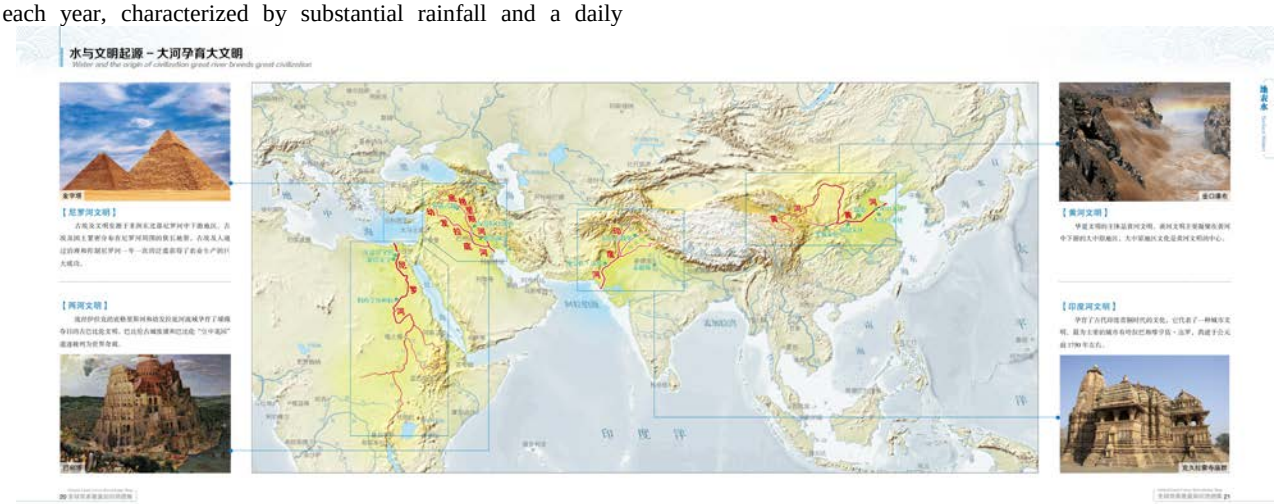


Figure 3. Water and the origin of civilization: the great river breeds great civilization.

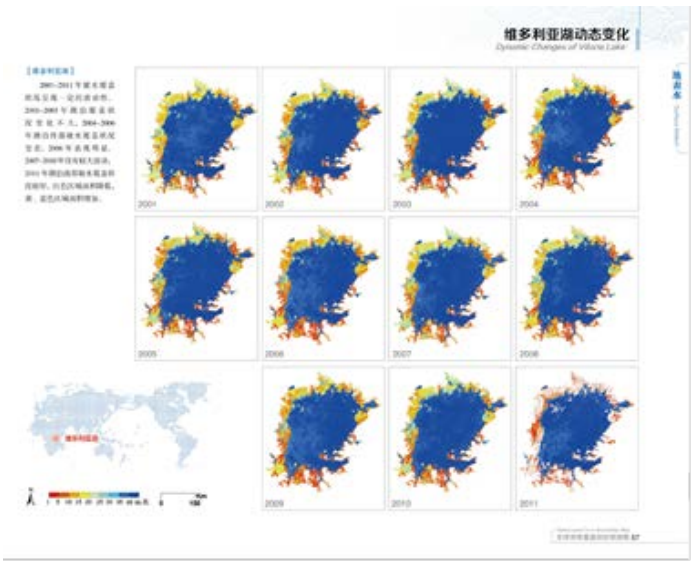
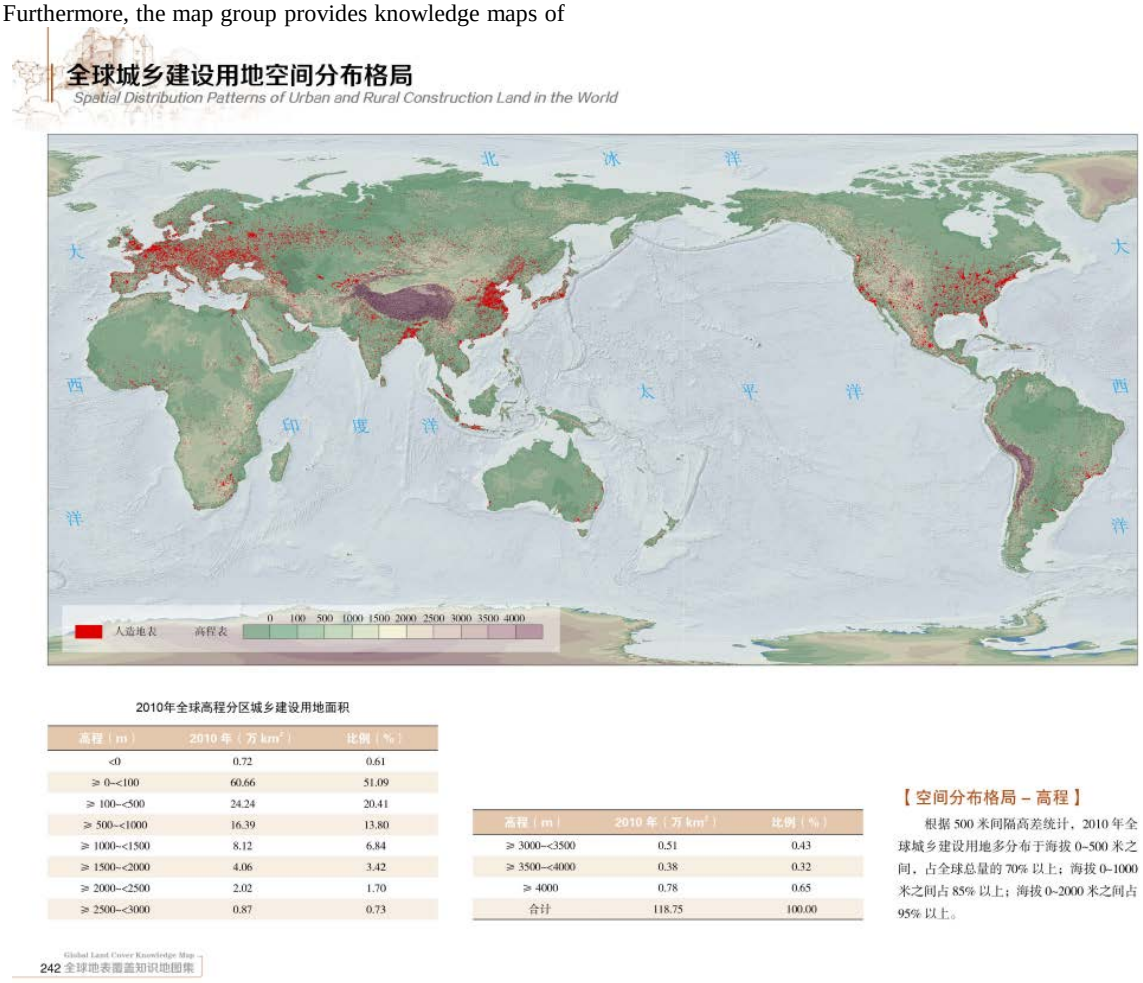


Figure 4. Dynamic changes of Victoria Lak .

Mapping urban and rural construction land: This map group focuses on the role of urban and rural construction land within the ecosystem, which serves as the foundation of human civilization. The first section highlights this significance and the second proceeds to illustrate the spatial distribution patterns of global urban and rural construction land. It includes a depiction of the distribution pattern in the elevation zone (refer to Figure 5) as well as the distribution within the Coben-Giger climate zone. Furthermore, the map group provides knowledge maps of various typical urban and rural construction areas. These include the Bemsta Polder field in the Netherlands, urban and rural construction land in the central plains of the United States, typical southern rural settlements in China, typical northern rural settlements in China, coastal port cities, coastal river valley cities, hilly area cities, mountain cities, financial centers and port cities, plateau representative cities, and the largest urban agglomeration.



高程（m）	2010年（万km²）	比例（%）
<0	0.72	0.61
≥ 0~<100	60.66	51.09
≥ 100~<500	24.24	20.41
≥ 500~<1000	16.39	13.80
≥ 1000~<1500	8.12	6.84
≥ 1500~<2000	4.06	3.42
≥ 2000~<2500	2.02	1.70
≥ 2500~<3000	0.87	0.73
≥ 3000~<3500	0.51	0.43
≥ 3500~<4000	0.38	0.32
≥ 4000	0.78	0.65
合计	118.75	100.00

Figure 5. The distribution pattern of global urban and rural construction land in the elevation zone.

4. CONCLUSION

Inspired by the idea of system engineering, the atlas divides the rich, extensive, and interconnected content into nine relatively independent subsystems. This approach enables a global, systematic, logical, and knowledgeable content design. The atlas aims to effectively provide valuable information and knowledge of the distribution patterns, genetic mechanisms, development, and changes of global land cover. Due to time constraints, this atlas was designed using depth information and knowledge extracted from the 2000 and 2010 versions of GlobaLand30 data. In the subsequent phases, with the support of relevant projects, the mining and extraction of knowledge from Phase III surface coverage data will be completed. This will lead to the compilation and research of Phase III surface coverage knowledge maps.

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