DOI: 10.1007/s11431-006-8103-3

A database framework of digital forestry towards sustainable forestry development in China

ZHAO Jingzhu, WANG Yanchun & DONG Rencai

State Key Lab of Systems Ecology, Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing 100085, China

Correspondence should be addressed to Zhao Jingzhu (email: jzhao@rcees.ac.cn)

Received October 10, 2005; accepted April 12, 2006

Abstract Six forestry scientific and technological projects being actualized in China were the implementations of ecological construction and security, development of forestry biological technique and fine variety cultivation, protection and utilization of forest biological germplasm resources, development of forestry bio-industry and digital forestry, and construction of forestry innovation ability. Among them, digital forestry was an effective measure to improve the ability of forestry innovation, to realize resources sharing, and to develop sustainable forestry. Spatial database of digital forestry should be constructed according to the criteria and index system of forest sustainable management. Based on analyzing the status and advances of China's digital forestry construction, a database framework of digital forestry towards sustainable forestry development was studied and established preparatorily. The database was divided into four layers as theory layer, system layer, status layer, and parameter layer. It was concluded that during the process of digital forestry platform construction, the relative social, economic, and politic data should be considered and collected, which meant that the database should represent not only the current forestry development, but also the social, politic, and economic situations. Constructing China's digital forestry information platform under full utilization of idea and index system for sustainable forest management was urgent and important.

Keywords: database framework, digital forestry, sustainable forestry development, forest resources.

In the process of realizing the strategic target of forestry development in the new stage and advancing the sustainable forestry development, the importance of scientific and technological innovation was emphasized. Because of weak technological innovation ability and deficient scientific and technological achievements, six forestry scientific and technological projects were being actualized. These projects were the implementation of ecological construction and security, development of forestry biological technique and

fine variety cultivation, protection and utilization of forest biological germplasm resources, development of forestry bio-industry, digital forestry, and construction of forestry innovation ability. Among them, digital forestry was an effective measure to improve the ability of forestry innovation, to realize resources sharing, and to develop sustainable forestry.

Generally, digital forestry was defined as the science, technology, and art of systematically acquiring, integrating, analyzing and applying digital information to support sustainable forests. It was developed around the digital globe program initiated by former vice president Al Gore on January 31, 1998^[1]. Before this concept emerged, forestry information techniques were popular in developed countries. In North America, the National Forestry Database Program (NFDP) described forest management and its impact on the forest resource; developed a public information program based on the database; provided reliable and timely information to the provincial and federal policy processes. Those forestry databases were treated as prototype of digital forestry database. Therefore, it was convenient for the developed country, compared with China, to integrate digital forestry database. Chinese forestry department needs to do more.

Sustainable management of forests was the core of sustainable forestry development^[2]. The main means to sustainable management of forests contain establishing the standard and index system for sustainable management and carrying out these standards and index through audit and authentication^[3]. As the important scientific and technological measure of sustainable forestry development, spatial database of digital forestry should have its own characteristics and could be directly used for achieving the target of sustainable forest management. So, the index system for sustainable management should be considered in the process of establishing the spatial database of digital forestry, and it related closely to the validity and scientificity of the digital forestry platform.

In this paper, based on analysis of the characteristics, standard and index system of sustainable forest management, a database framework of digital forestry was designed towards sustainable forestry development in China.

1 Characteristics of sustainable forest management

Sustainable forest management was the action which contained administrative, economic, juristic, social, and scientific means^[4]. Although there were several foreign standard and index systems for sustainable forest management, they were not suitable for China's actual situation. So, it was necessary to establish the standards and index according to the situation of China. When the standards and index were chosen, the differences of population, social-economic development, and natural conditions of different regions should be fully considered as well as the characteristics of forest type and forest resource amount, quality, and management status. At present, there was a general opinion that the standard and index system of sustainable forest management contained seven basic items as status of forest resources, biodiversity, forest health and vitality, forest production function, forest protection function, demands for forest resources by social-economic development, and policies, laws and relative organizations of forest sustainable

management. These seven items included 8 standards and 72 indexes^[5,6].

The application of this standard and index system in evaluating the nationwide status of forest management would promote the transformation of China's forestry from direct timber production to maintaining multiple benefits of forest resources. At the same time, this system would provide a basic criterion for selecting construction projects of forestry production, and be available for avoiding some problems in the operation of construction projects.

Sustainable forest management was a comprehensive systematic engineering, and it should, at least, satisfy the following requirements: present forest management without compromising the forest management of future generations, forest management in one region without compromising the forest management in other regions, maximizing the forest ecosystem services, and maintaining the health, vigor, regeneration ability and productivity of forest. In general, ecology, society and economy should be considered in sustainable forest management which should be enforceable in ecology, realizable in economy, and acceptable in society.

2 Status and advances of China's digital forestry construction

At present, taking digital forestry centre as unit, information forestry, which mainly contains digital production of forest map, has been well developed and plays an important role in forestry production. At the 1st International Workshop on Digital Forestry, the experts discussed the definition and connotation of digital forestry. Digital forest was defined as the science, technology, and art of systematically acquiring, integrating, analyzing and applying digital information to support sustainable forests^[7]. Furthermore, digital forestry was an important process of forestry information construction, and effective on the promotion of information technology applying in forestry production.

From the aspect of science and technology research guide, the status of digital forestry in Digital China Project has been attached much importance. In the National High-Tech R&D Program (863 Program), the research objectives were establishing the information system platform for data acquisition, data management and data sharing, developing the method and knowledge database for forestry data treatment, developing the proprietary software of digital forestry, building the basic forestry spatial database and multi-resolution satellite images at all levels.

Now, in some provinces, the common technique platform of digital forestry has been established preliminarily^[8]. The standards and criterion for digital forestry data acquisition had been promulgated by Chinese Forestry Scientific Data Center^[9], and the structure and relative technical criterion had been also established. Then, with the background of the six forestry ecological construction projects in China, establishing the common technique platform of digital forestry and realizing the dynamic monitoring and management on forestry engineering construction would provide information service for decision-making department, forestry operator, production unit and scientific research department.

Constructing digital forestry, a comprehensive systematic engineering, involved not

only professional forestry operation, but also economic and social information; not only the application of single technique, but also the integration of relevant techniques and the integration of forestry operation and information technique; not only single project research, but also multiple projects integration. In such digital forestry, multiple characteristics of forestry could be expressed in digital form, and friendly to the public.

3 Design the database framework of digital forestry

The database framework of digital forestry should be designed to meet the need of sustainable forest management. And the scientificity, syntheses, operability of the standard and index system of the database should be also fully considered. The digital forestry database was divided into four layers as theory layer, system layer, status layer, and parameter layer.

3.1 Theory layer

The work to design the theory layer needs to simplify the complex true-life into a clear concept model. According to relevant analysis above, both sustainable forest management and sustainable forestry development were treated as the essential entity of database of digital forestry. Generally, sustainable forestry development included sustainable forest management, forest ecological construction, forestry products industry, etc.; and the core concept was sustainable forest management.

It was necessary to comply with the fundamental that sustainable forest management was the theoretical base to design the database framework of digital forestry. In other words, the key technique to construct digital forestry was the object-oriented database system of sustainable forest management. The relationship of theory layer is illustrated in Fig. 1.

Fig. 1. The theory layer of the digital forestry database framework.

3.2 System layer

While designing the system layers of the database, the status of forest management and forestry development, and functions and process of forest ecosystem should be analyzed at first, and the relative information on social, economic, and ecological background should be considered fully. Moreover, it should be ensured practicability, portability and credibility to enhance system development efficiency.

In this layer, as pointed out in other research^[10], the standard and index could be divided into geo-environmental index set, forest ecosystem index set, and social-economic index set. These index sets contained eight attribute databases with their themes of basic geo-environmental information, status of forest resources, biodiversity, forest health and vitality, forest production function, forest protection function, demands for forest resources by social-economic development, and policies, laws and relative organizations of forest sustainable management, respectively (Fig. 2).

Fig. 2. System layer of the digital forestry database framework.

The databases with different themes could influence and relate with each other according to their own rules, and this target could be realized completely under the current developing trend of GIS technique, which managed spatial data by relational database. For instance, the geo-database was a modern GIS data model that evolved from many years of research and developed by Environmental Systems Research Institute (ESRI)^[11]. Through applying rules and relationships with the geo-database data model, social and policies database related to forest management could be linked together by the same key field, linked census database with forest ecosystem database. For instance, if spatial analysts wanted to integrate fundamental geographic information, forest ecosystem and social-economic index set, the key field should be area code.

In forest ecosystem index, some environmental factors such as slope and aspect could be generated from the geo-environmental index. Thus, building the tight relationship between topography data and forest resources data was feasible on the platform of relational database management system (RDBMS).

3.3 Status and parameter layer

Through analyzing the standard and index system, status layer and parameter layer of the digital forestry database framework were designed as Table 1. Status layer was used to form the framework of digital forestry database, and parameter layer and its derived data were directly used to design of each attribute field^[12,13].

Status layer	Parameter layer	Data acquisition
Ecosystem diversity	Ratio of forest type to total forest area; Area and ratio of forest type according to age class or succession stage; Area and ratio of protected forest according to IUCN or other classification systems; Fragmentation of different forest types	Investigation and monitoring of forest resources; Biodiversity database
Species diversity	Forest species abundance; Status of endangered species	Investigation and monitoring of forest resources
Genetic diversity	Number of forest species with obviously- decreased distribution area; Population characteristics of representative species	Investigation and monitoring of forest resources
Forest productivity	Wooded area and area for timber production; Total stock; Area and growing-stock of artificial forest; Annual cutting volume; Annual non-timber harvesting	Investigation and monitoring of forest resources
Health and vigor of forest ecosystem	Area and ratio of disaster-affected forest; Area and ratio of forest affected by air pollution and ultraviolet radiation; Area and ratio of forest representing change in basic ecological process according to bio-composition decrease	Investigation and monitoring of forest resources
Ability of water and soil conservation	Obviously-eroded wooded area and ratio; Area and ratio of protection forest; Soil organic matter and other chemical characters, and related forest area and ratio; Soil physical characters, and related forest area and ratio; Obvious deviation of aquatic biodiversity from normal value, and related forest area; etc.	Investigation and monitoring of forest resources; Monitoring of water and soil conservation; Environmental monitoring
Carbon fixation	Total biomass and C pool of forest; Contribution of forest ecosystem to global C balance, including C absorption and release; Productivity and consume of forest products, and their effects on C cycle	Investigation and monitoring of forest resources; Environmental monitoring
Goods and services	Yield, output value and added value of timber and forest products; Yield and output value of non-wood forest products; Annual output and demand of timber and forest products; Ratio of output value of timber and forest products to GDP; Recovery rate of forest products; Annual output and demand of non-wood forest products; Area and ratio of forest for travel and rest; Amount and type of recreational facilities; Daily amount of visitor; Area and ratio of forest for culture protection and other mental demand; Non-expendability use of forest values	Common database of forestry
Forestry input	Capital construction and fixed asset related to forest growth, forest management, forest regeneration, artificial forest, forest production; Input for travel and rest in forest; Input for forestry research, development and education; Generalization and application of new forestry technique and improved forestry technique; Return rate of above-mentioned inputs	Common database of forestry

(To be continued on the next page)

(Continued)

Status layer	Parameter layer	Data acquisition
Employment	Direct and indirect employment opportunities offered by forestry, and its ratio to total social employment opportunities; Average wage and work injury incidence of main forestry employment department; Area and ratio of wooded area for basic living support	Social, economic, and politic database
Lawmaking and framework related to forestry	Forest property; Periodic forest programming, evaluating, and policy-auditing; Policy-making for forest management; Adopting optimum rules for forest management and harvesting; Improving forest management for protecting special environment, culture and other social value; Human resources training; Forestry infrastructure construction; Execution of Laws, rules and guidelines; Policy for investment and tax	Common database of forestry
Monitoring and evaluation	Ability of newest data acquisition; selection standard, coverage, and authenticity of related data; Calculation method and transformation technique of related data	Social, economic, and politic database
Research and development	On classification character and functions of forest ecosystem; On evaluation system and technique for social-environmental benefits of forest; On new technique system, and evaluating its effects; Enhancing the ability of forecasting the effects of human disturbance on forest; Ability of forecasting the effects of potential climate change on forest	Social, economic, and politic database

There were strong relations among the entire index in Table 1. Thus, in the process of database construction, the function and process of forest ecosystem should be considered to design a relative logic rule and construct the linkage among the index. Some problems should be paid more attention to:

(1) Forest biodiversity consisted of ecosystem diversity, species diversity and genetic diversity; so, their index should be recorded respectively in terms of their different spatial-temporal scales.

(2) Among forest productivity index, the wood production, such as timber, stock value, was calculated. Non-wood production was considered in the sets of goods and services.

(3) Metadata, which was descriptive information about data, played a very important role in data sharing. So it was necessary to standardize and manage metadata uniformly.

Data resources were the key problem of the digital forestry construction^[14]. In this design, data acquisition for the digital forestry database could be realized through the following approaches: relying on the National Scientific Data Sharing Engineering, taking Forest Resources Information Sharing Platform as entrance, investigating and monitoring forest resources, biodiversity resources, environmental resources, and status of water and soil conservation, and obtaining from other relative information on forestry, society, economy and politics.

4 Conclusion

Digital forestry database of high efficiency and perfection could improve sustainable

forest management and be useful in the process of sustainable forestry development. Under the new developing condition, establishing digital forestry database towards sustainable forestry development and constructing digital forestry ought to represent the new strategic idea of forestry development, and it was not equal to simple digitalization on managing object and current condition of traditional forestry. The database ought to represent not only the current forestry development, but also the social, politic, and economic backgrounds. So, constructing China's digital forestry information platform under full utilization of idea and index system for sustainable forest management is urgent and important.

Acknowledgements This work was supported by the Chinese Academy of Sciences (KZCX 3-SW-423 and KZCX 3-SW-438) and the National Natural Science Foundation of China (Grant Nos. 70325002, 70403014)

References

- 1 Zhao G, Shao G F, Keith M R, et al. A white paper. *J Forest, Digital Forestry*, 2005, 103(1): 47—50
- 2 Zhou B, Chen H W, Wang D M, et al. Differences between sustainable forest management criteria and forest certification ones. *World Forestry Research* (in Chinese), 2004, 17(4): 10—13
- 3 Jiang Y X. International progress in study of criteria and indicators for sustainable forest management. *World Forestry Research* (in Chinese), 1995, 2: 9—14.
- 4 Han H R. *Theory of Forest and Environment* (in Chinese). Beijing: China Forestry Publishing House, 2002. 9
- 5 State Forestry Administration. National Report on Forest Protection and Forest Sustainable Management of China. <http://www.mpci.org/>
- 6 Lu W M. *Reference Book for Standard and Index of Forest Sustainable Management* (in Chinese). Beijing: China Agricultural Science and Technology Press, 2004
- 7 Zhao G, Shao G F. Forestry is going digital. Report on the First International Workshop on Digital Forestry on June 13—19, 2004 in Beijing, China
- 8 Office of National High Technology Research and Development Program of China (863 Program). System Integration and Platform Construction of Digital Agriculture. <http://www.863.org.cn/>
- 9 Center of Forest Science Data. Standard and Criterion for Forest Science Database and Data Sharing Technology (in Chinese). Beijing: China Forestry Publishing House, 2004
- 10 Yuan Y B, Liu G, Han Z J, Wang X Q. Discussion about model of “Digital Territory” and its position in “Digital Earth”. *Geological Science and Technology Information* (in Chinese), 1999, 18(3): 90—94
- 11 David A, Michael Z. *Designing Geodatabases: Case Studies in GIS Data Modeling*. Redlands: ESRI Press, 2004
- 12 Li S S, Wen W S. Designing technology for forest resources geographic information system. *J Nanjing Forestry University (Natural Sciences Edition)* (in Chinese), 2002, 26(5): 53—56
- 13 Lu Y C, Lei X D, Li Z Y. Study on classification system and code for digital forest (in Chinese). *Forest Science & Technology Management*, 2002, 2: 22—27
- 14 The Administrative Centre for China's Agenda 21 (ACCA21). Report About National Data Sharing Project. <http://www.acca21.org.cn/>