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Review Article

A Review of Forest Resources and Forest Biodiversity Evaluation System in China

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China is a country rich in diverse forest ecosystems due to the large span of the country, complex topography, and multiple climate regimes. In this paper, the basic information of forest resources in China was briefly introduced and the current state in the measurements of forest biodiversity and the establishment of forest biodiversity index systems in related studies were reviewed. The results showed that a lot of studies on forest biodiversity have been conducted mostly at landscape or stand level in China and the commonly used biodiversity indicators were identified and compared. Several comprehensive forest biodiversity index systems were proposed. However, there are still some problems during the construction of forest biodiversity assessment system. Due to the late establishment of biodiversity monitoring system in China, the availability of data that could be included in a forest biodiversity index system is limited, which hurdles the precise assessment of forest biodiversity. It is suggested to develop long-term monitoring stations and keep data recording consistently. Concerns should also be given to the construction of the framework of the forest biodiversity index system and the determination of the indicators' weight. The results will provide reference for the establishment of national or regional forest biodiversity evaluation indicator systems in China.

1. Introduction

Forest biodiversity refers to all forms of life found in forests, including plants, animals, fungi, and microorganisms, and their roles in nature. It may be the richest of all the terrestrial ecosystems. Tropical forests alone contain some 50 percent of all known vertebrates, 60 percent of plant species, and possibly 90 percent of the world's total species [1]. Currently, forest biodiversity is increasingly threatened due to the activities linked to human beings. It is essential that all countries in the world work together to reduce forest loss and protect biodiversity. Following the United Nations Convention on Biological Diversity (CBD), held in Rio De Janeiro in 1992, a range of national and international processes have been established to maintain biodiversity [2]. CBD always emphasizes the importance of prediction and prevention in order to eliminate the root causes of biodiversity reduction or loss and put forward specific requirements on the implementation of biodiversity monitoring and assessment for the contracting parties. The United Nations Environment Programme (UNEP) also urged all countries to enhance the construction of biodiversity monitoring system, establish biodiversity evaluation indices, and carry out the corresponding assessments on biodiversity.

China is one of the megadiverse countries in the world, which has more than 35,000 species of higher plants (ranking 3rd in the world) and 6,347 species of vertebrates (13.7 percent of the total in the world) [3]. The forest resources, with numerous species and vegetation types, provide various products and ecological services for the residents. However, the rapid industrialization and urbanization processes have placed great pressure on the limited forest resources. Forest degradation, resource depletion, loss of biodiversity, and resilience in ecosystems have become the major environmental issues. In order to protect and reasonably use forest resources, the Chinese government has implemented six key forestry projects such as the Natural Forest Conservation Project, the Project of Returning Farmland to Forest, Shelterbelt Development Program, and the Wildlife

Conservation and Natural Reserve Construction Project. Large-scale afforestation projects were carried out and forest resources management was strengthened. Now, China has become the fastest growing country in forest resources in the world, with an increase of 4 million hectares on average per year [4]. The positioning observation on forest ecosystems in China started relatively late compared to other developed countries; however, multiple monitoring stations have been established by Chinese Academy of Science, Ministry of Environmental Protection of China, and Chinese Academy of Forestry within the recent years. The problem that needs to be solved is that the construction on the forest biodiversity evaluation system and the selection of forest biodiversity indicators at different scales were still limited.

The objectives of this paper are to briefly introduce the basic information of forest resources in China and then review the evaluation indicators and forest biodiversity index systems in related studies. The results will provide reference for the establishment of national or regional forest biodiversity evaluation indicator systems in China.

2. Forest Ecosystem in China and Current Status

2.1. Forest Types. China is a country rich in diverse forest ecosystems due to the large span of the country (from south to north 5500 km and from east to west 5200 km), complex topography, and multiple climate regimes. The distribution of forests across the country is uneven. The majority of forests are distributed in the northeastern and southern parts of China and in the southeastern periphery of the Tibetan Plateau, with a few forested areas scattered in the higher mountains and along the rivers in the desert area of the western part of China [5, 6]. According to the morphological characters of their trees, forests in China can be classified into three categories, that is, coniferous, broadleaved, and mixed coniferous-broadleaved forests, which make up 49.8%, 47.2%, and 3%, respectively, of the total [7].

2.1.1. Coniferous Forest. Coniferous forests are distributed widely throughout the country. However, zonal coniferous forests occur mainly in northeast and northwest China, as well as in the subalpine areas of southwest and southeast Tibet. They include boreal coniferous and subalpine coniferous forests, warm-temperate coniferous forests, subtropical coniferous forests, and tropical coniferous forests.

2.1.2. Mixed Coniferous and Deciduous Broadleaved Forests. The mixed forest of *Pinus koraiensis* and some broadleaved species are a zonal type in temperate China and are mainly distributed in the Changbai Mountains and Xiaoxinggan Mountains of northeastern China, extending to the Amure State in Siberia and the northern part of Korea. The mixed forest of *Tsuga* and broadleaved species are mainly distributed in mountainous areas of subtropical China.

2.1.3. Broadleaved Forests. Broadleaved forests include deciduous broadleaved forests, evergreen broadleaved forests, sclerophyllous forests, mixed deciduous and evergreen broadleaved forests, monsoon forests, tropical rain forests, and seasonal rain forests [7]. Deciduous broadleaved forests are distributed widely in temperate, warm-temperate, and subtropical China. The evergreen broadleaved forest is a zonal type in moist subtropical China. Rain forests and monsoon forests are found in the tropical zone.

2.2. Stress on Forest Resources. Over the past two decades, the rapid industrialization and urbanization processes placed heavy pressure on forest resources in China. Forest degradation, resource depletion, loss of biodiversity, and resilience in ecosystems become the major environmental issues. To conserve natural forests in the specified regions of China, the logging ban was imposed in 1998 to cover the natural forests in the upper reaches of the Yangtze River, the middle and upper reaches of the Yellow River, and the upper reaches of the Songhuajiang River, Sichuan, Yunnan, Chongqing, Gansu, Shaanxi, and Qinghai Provinces, which is also called the Natural Forest Conservation Program (NFCP) [8]. The implementation of the logging ban has kept the nature forests away from the issue of overlogging, but sharpened the conflicts between timber products supply and demand. The shortage of timber supply was then offset by artificial plantation and timber imports from other countries. The Chinese government gradually shifted timber production from natural forests to plantations and implemented several national reforestation/afforestation programs. However, other stresses on the limited forest resources still exist, including forest fires, pest damage, afforestation with monospecies, disappearance and habitat fragmentation, and environmental pollution [7].

2.3. Current Status of Forest Resources. According to China's 4th National Report to the Convention on Biological Diversity, the forest resources are continuously increasing since 1989, and China has become the fastest growing country in forest resources in the world, with an increase of 4 million hectares on average per year [9]. China's forest cover has been increased from 175 million hectares to 195 million hectares (7th National Forest Inventory, 2004–2008) (Figure 1) and the forest coverage rate increased from 18.21% to 20.36% compared to the data of the 6th National Forest Inventory (NFI) (1999–2003) [10]. The areas of primary forests only account for 5.6% of total forested area as of 2010. Key forestry programs, such as the Natural Forest Protection Program (NFPP) and the Shelterbelt Development Program, have contributed to most of China's afforestation. It is also noted that the monoculture plantations of nonnative trees accounts for most of the improvement in forest cover. The area of natural forest is 119.69 million hectares, an increase of 3.4 percent based on the 6th NFI. The plantations increased from 53.26 million hectares to 61.69 million hectares, an increase of 15.8 percent. The establishment of such plantations gives China the world's largest plantation estate and provides an opportunity for future large-scale substitution for wood from natural forests. However, the changes have negative impacts on ecosystem services, particularly watershed protection and biodiversity conservation [11]. Plantation monocultures

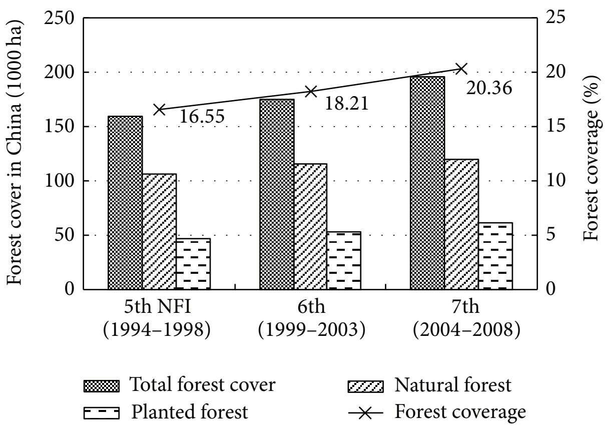

Figure 1: Changes of forest cover and coverage over time in China.

harbor little diversity; they provide almost no habitat for the country's many threatened forest species. Plantations generate less leaf litter and other organic inputs than native forests, which can lead to the decrease of soil fauna and flora. In addition, groundwater depletion can be exacerbated by deep-rooted nonnative trees that use more water than native species [11].

3. Research Progress of Forest Biodiversity Assessment in China

3.1. Indicators of Forest Biodiversity. Biodiversity includes diversity within species, between species, and of ecosystems. Three main components of biodiversity have been widely recognized, including composition, structure, and function [12]. These three components have been used as a basis to identify key factors and develop indicators for forest biodiversity. Compositional and structural factors determine and constitute the biodiversity quality of an area, and functional factors (i.e., the functions performed by different species, wood degradation, soil microbiology) contribute to ecological integrity. At the scale of a stand, biodiversity indicators are designed either based on the identification of key species, or based on the identification of key structures [13]. Ecologists have designed a huge range of indices and models for measuring diversity. However, it is difficult to decide the best method given the complexity of environments, habitats, and situations. The selection of a diversity index should be on the basis of whether it fulfills certain functions criteria-ability to discriminate between sites, dependence on sample size, what component of diversity is being measured, and whether the index is widely used and understood. Most studies on forest biodiversity assessment in China focused on the description of species diversity, since species play essential roles in ecosystems. Whittaker [14] described three terms for measuring biodiversity over spatial scales: alpha, beta, and gamma diversity. Alpha diversity refers to the diversity within a particular area or ecosystem and is usually expressed by the number of species (i.e., species richness) in that ecosystem. Beta diversity refers to the comparison of diversity between ecosystems and is usually measured as the amount of species change between the ecosystems. Gamma diversity is a measure of the overall diversity for the different ecosystems within a large region.

Alpha diversity indices are commonly used in the studies of forest biodiversity assessment in China compared to other indices. Alpha diversity indices can be classified into four categories: species richness index, species evenness index, species diversity index, and species dominance index. Species dominance, evenness, and diversity are closely related to each other, which reflect the composition, structure, and levels of a community. Species richness can be expressed as the number of species, Margalef richness index, Gleason richness index, or Menhinick richness index [15–17]. The application of these indices will vary depending on the different plant communities. For example, Margalef richness index and Gleason richness index were relatively stable compared to Menhinick richness index for temperate forest communities [18]. Thus, once these indices were selected, more reliable conclusions can be drawn based on less sample plots while comparing multiple plant communities. In addition, species richness can be affected by the size of the sample plots and ignores the difference of the contribution between common species and rare species to community diversity; therefore it should be used in combination with other indices (e.g., evenness index) in order to reflect the community biodiversity more precisely [19]. Among the vegetation diversity studies in China, the commonly used species diversity indices include Shannon-Wiener index, Simpson index, Hill diversity index, and probability of interspecific encounter PIE [20]. Based on the application of these indices in plant community diversity at different climate zones of China, Shannon-Wiener index and Gini index performed better than others [21, 22]. Pielou evenness index was mostly used by Chinese researchers, followed by Alatalo evenness index [23–26]. Liu et al. [15] and Ma et al. [21] indicated that Pielou evenness index and Alatalo evenness index all can reflect the difference of species structure or community structure among different vegetation types in Beijing Donglin Mountain area. It should be noted that Pielou evenness index is inappropriate for comparisons of samples where species richness varies considerably [27]. Some studies applied D_1 or $D = \sum P_i^2$ to calculate species dominance [28, 29].

Alpha diversity indices have been applied in different types of forests at different geographical locations in China. For example, Hao et al. [23] analyzed the species diversity of higher plants in *tilia*-Korean pine forest on northern slope of Changbai Mountains, Northeast China. The study area was within the range of Changbai Mountain Nature Reserve which was included into the World Network of Biosphere Reserves in 1980. The authors concluded that Shannon diversity index is 2.8228 for woody plants and 2.9766 for herbs. The Shannon evenness is 0.7292 for woody plants and 0.6436 for herbs, respectively. Zhao et al. [25] compared the tree species diversity in the gaps of broad-leaved Korean pine forest and under closed canopy based on the investigation of 89 gaps in Changbai Mountain Nature Reserve and Jilin Jiaohe Experiment and Administrative Bureau. They indicated that there was a significant difference between tree species diversity in gaps and under canopy. The biodiversity in regeneration layer was higher in gap community compared to under forest canopy, while the dominance of certain species increased from gaps to close canopy. Another study [30] regarding the species diversity of gaps and nongaps stands was conducted in an evergreen broadleaved forest (EBLF) in southern China. Species richness, diversity index, species evenness, and ecological dominance index were computed and the relationship between species diversity and gap size was discussed. The results indicated that the species diversity in gaps was higher than that of nongaps, which is similar to other studies on the biodiversity of forest gaps [31, 32].

The commonly used beta diversity indices include Whittaker index, Cody index, Routledge index, and Wilson and Shmida index [33]. A few studies have been conducted to analyze forest biodiversity using beta diversity indices in China. For example, He et al. [34] studied community diversity and its patterns along latitude and longitude based on 61 plot samples (20 m by 20 m) of evergreen broadleaved forests (EBLF) from 10 areas in the eastern part of the middle subtropical China. They concluded that community richness ranged from 15 to 98 species, with a diversity order of the shrub layer > tree layer > herb layer. The difference in species richness and diversity between EBLF was far greater than that between temperate deciduous forests and species-poor evergreen species. Xu [35] compared the plant species diversity of EBLF in the eastern and western part of China and analyzed the large-scale diversity pattern of species richness, alpha and beta diversity index along longitudinal and latitudinal patterns. The author indicated that the community species richness of EBLF exhibits a decreasing trend with the increase of latitude and increases at first and then decreases as longitude increases. Alpha diversity pattern is similar to the species richness pattern in a large scale. Beta diversity index patterns fluctuate with the increased longitude and latitude due to the high species turnover rate caused by a high mountain or severe environmental conditions. Zhao [36] evaluated the pattern of beta diversity derived from species abundance and its environmental association in a 24-hectare rugged subtropical evergreen broadleaved forest plot in East China. The results showed that species similarity has monotonic decline along the distance gradient and was not sensitive to scales within the analyzed distance range. Both species similarities in plots with rougher and plainer topographies had the steepest decrease occurring in the first 100 m and distance had independent effect on beta diversity. Habitat heterogeneity, especially elevation and convexity differences, tends to be the key factors that influence beta diversity.

Since many native forests in China have been altered by management of varying intensities, it is necessary to compare biodiversity between managed and unmanaged forests in order to maintain biodiversity and sustainable forest management. Old-growth forests are well known for their high biodiversity [37]. They are often home to many rare species, threatened species, and endangered species of plants and animals. Levels of biodiversity may be higher or lower in old-growth forests compared to that in second-growth forests, depending on specific circumstances, environmental variables, and geographic variables [38]. For example, studies focusing on silvicultural management have shown that managed sites have higher richness of understoryed plants than in reserves of 80-year old nonmanaged areas [39]. Paillet et al. [40] compared biodiversity between managed and unmanaged forests in Europe and pointed out that species richness was higher in unmanaged than in managed forests. Research comparing biodiversity between managed and unmanaged forests remains spectacularly scarce in China. Only a few studies were found to analyze the structural and compositional responses to timber harvesting for old-growth forests [41, 42], which can be treated as the biodiversity comparison studies between managed and unmanaged forest sites. For example, Gu and Dai [41] examined the number of trees and tree species at three broadleaved-Korean pine (*Pinus koraiensis*) mixed forest sites in Changbai Mountain, China. The three sites were an old-growth forest plot without cutting, a forest plot managed in 1987 (older-cut site), and a forest plot managed (cut) in 1997 (newer-cut site), respectively. The authors found that both numbers of trees and species in the old-growth forest plot (basal area 56 m^2) were lower (4,441 trees of 14 species) than the other two managed sites (6,314 trees of 16 species for the newer-cut site and 8,438 trees of 21 species for the older-cut site).

3.2. Forest Biodiversity Evaluation System. In addition to the measurement of forest biodiversity, several biodiversity evaluation systems have been put forward. The Pressure-State-Response (PSR) model was developed by Anthony Friend in the 1970s, and subsequently adopted by the OECD's State of the Environment (SOE) group. The PSR model provides a classification into indicators of environmental pressures, indicators of environmental conditions (state) and indicators of societal responses. The researchers in China combined the theory thought in PSR model and the characteristics of biodiversity in China, and established a series of evaluation index systems. For example, Yang et al. [43] put forward a biodiversity index system for Yunnan province based on the PSR model and calculated the comprehensive value of biodiversity and ecological environment in Yunnan Province.

Besides the PSR model, other methods such as Analytical Hierarchy Process (AHP) and Delphi method were used in the establishment of forest biodiversity index system. For example, Zeng et al. [44] proposed a biodiversity index system from three levels including genetic diversity, species diversity, and ecosystem diversity and came up with the corresponding evaluation methods and standards. Xu et al. [45] established a biodiversity evaluation index system, which included 8 indices from two aspects: biodiversity value (number of species, special species, endangered species, rare plants, ecosystem, and conservation area) and factors affected biodiversity (invasive species and damage degree of vegetation). It is noted that the weights of the indices were determined based on the viewpoints of experts and the problem of data deviation was not truly solved. The selection of indicators was mainly determined by the interests of experts or the data available [46].

A forest biodiversity index system was established at forestry bureau level [47]. The index system includes two levels, forest ecosystem (A1) and plant species (A2). The sublevel of forest ecosystem contains forest type diversity (B1), forest age structure diversity (B2), proportion of public-welfare forests (B3), proportion of nature forest (B4), forest naturalness (B5), forest coverage (B6), and forest fragmentation (B7). The sublevel of plant diversity includes plant species abundance (B8), plant species diversity (B9), and abundance of endangered species (B10). The forest biodiversity index system was applied in Wangqing Forestry Bureau in Jilin Province, northeastern China, and the composite index of forest biodiversity was 66.8 which indicated medium grade of biodiversity (90–100 extremely rich, 80–89 very rich, 70–79 slightly rich, 60–69 moderate rich, and under 60 poor). The system has proven to be operable; however, there are still some problems associated with the evaluation index system, such as incompleteness and subjectivity of the weight of the indicators.

Wan et al. [48] proposed a comprehensive biodiversity evaluation system at national scale with five indicators including species richness, ecosystem diversity, completeness of vegetation vertical zone spectrum, species endemism, and degree of nonnative species invasion based on the principles of scientific, representative, and practical applicability. They applied the evaluation system to the diversity assessment of 31 provinces in China and acquire the data of local floras, fauna, environment communique, ecological survey reports, and published papers. Finally, the assessment units were grouped into four classes with very good, good, average, and poor. It is noted that the province-based evaluation system can only reflect the differences among different provinces in China. It is obvious that some parts of the province, especially with poor ranking are still rich in biodiversity. Therefore, the biodiversity system is still not flawless.

Cheng [49] analyzed the current forest biodiversity index system used in forest resources inventory in China and pointed out the disadvantages of such index system. In China, forest ecosystem diversity is used as the monitoring index of forest biodiversity. Forest ecosystem diversity is evaluated based on vegetation diversity, forest type diversity, age diversity, and species diversity. The problems are that only forest ecosystem is considered in the evaluation process, while diversity within species and between species is omitted. In addition, the indices are relatively simple, which cannot provide robust reference for effective protection and sustainable forest management. The author put forward new indices based on the practice of forest inventory, which provide reference for the accurate evaluation of forest biodiversity in China. However, due to the complexity of gene, the author did not include any genetic indicators in the index system.

In short, the establishment of forest biodiversity index system mainly focuses on the evaluation of forest ecosystem diversity and the variations of species diversity within the ecosystems. However, due to the limited knowledge of genetic biodiversity, the understanding on the species in the forest and forest ecosystem diversity are still insufficient, which present some difficulties in evaluating the entire forest biodiversity [50]. In addition, the methods of determining the weights of indicators (e.g., AHP, Delphi) are subjective and uncertain, which limit the precision and reliability of the evaluation results.

4. Discussion

Due to the late establishment of biodiversity monitoring system in China, there exist some problems associated with data collection for biodiversity assessment and policy-making. The data used in most studies were from publications, government statistics, institute owned data, or field collection [51]. Sometimes, the data recording were not consistent and compatible (e.g., data collected at different years), which hurdles the precise assessment of forest biodiversity. Therefore, it is necessary to perfect the establishment of long-term monitoring stations and construct national or regional-level biodiversity assessment system. The Chinese government has been aware of the necessity of establishing a sound long-term biodiversity monitoring system and achieved some progress so far. Currently, a total of 2,389 environmental monitoring stations have been established to form a relatively complete environmental monitoring system. Four regional forest resources monitoring centers were set up in the northeast China, east China, northwest China, and central south regions [51].

With regard to the study method, the selection of the measurement indices for forest biodiversity is still vague and unclear. There is a diversity of alpha diversity indices, including log alpha, log normal lambda, Q-statistic, Simpson, McIntosh, Berger-Parker, Shannon-Wiener, and Brillouin. However, how to choose these indices should be considered before applying them directly in any research. Several principles can be applied while selecting the indices, including appropriateness of each index for the data, discriminant ability of the index, statistical comparability, and widespread utility of the index [52]. Currently, more and more biodiversity studies in China are prone to use species richness indices (e.g., the number of species in a sample plot and Margalef richness index), Simpson's index, Shannon-Wiener index, Pielou evenness index, and Alatalo evenness index [53, 54]. It is noted that the successional stage of a community and its community type should be considered while evaluating the biological diversity of a forest community. For different biological community, the relatively stable indices should be used to measure biodiversity.

Currently, several forest biodiversity index systems have been proposed; however, there are still some problems in determining the weights of the evaluation criteria. On one hand, researchers continuously put forward new indices in order to perfect the index system but enlarge the number of indices, which will result in the difficulties of evaluation. On the other hand, due to the lack of effective and scientific method of indicator selection, most indices were chosen based on the experience of the researchers, which make the selection prone to be subjective. In recent years, with the application of linear algebra, fuzzy mathematics, and set theory, the determination of the indices' weight is changing from qualitative and subjective to quantitative and objective, which can help determine the weights of indices more scientifically and reasonably [50]. In all, the evaluation indices should try to cover all the important aspects of biodiversity (i.e., diversity within species, between species, and of ecosystems). However, due to the limitation of objective factors, the number of indices used and the settings of parameter values should also be balanced with the actual operation.

5. Conclusions

The research on the assessment of forest biodiversity is diverse and very complicated; therefore it is nearly impossible to elaborate all the aspects of this issue. In this paper, the forest ecosystems and their current status in China were briefly introduced and some related studies on evaluation system of forest biodiversity were reviewed. The results showed that a lot of studies on forest biodiversity have been conducted mostly at landscape or stand level in China and the commonly used biodiversity indicators were identified. Several comprehensive forest biodiversity index systems were proposed. However, there are still some problems associated with forest biodiversity assessment. Due to the late establishment of biodiversity monitoring system in China, the availability of data that could be included in a forest biodiversity index system are limited, which hurdles the precise assessment of forest biodiversity. It is suggested to develop long-term monitoring stations and keep data recording consistently. Concerns should also be given to the construction of the framework of the forest biodiversity index system and the determination of the indicators' weight. The results will provide reference for the establishment of national or regional forest biodiversity evaluation indicator systems in China.

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References

[1] J. Burley, "Forest biological diversity: an overview," *Unasylva*, vol. 53, no. 209, pp. 3–9, 2002.

[2] C. McElhinny, P. Gibbons, C. Brack, and J. Bauhus, "Forest and woodland stand structural complexity: its definition and measurement," *Forest Ecology and Management*, vol. 218, no. 1–3, pp. 1–24, 2005.

[3] Ministry of Environmental Protection of China, *National Biodiversity Strategy and Action Plan in China (2011–2030)*, China Environmental Science Press, Beijing, China, 2011.

[4] Ministry of Environmental Protection of China, *China's Fourth National Report on Implementation of the Convention on Biological Diversity*, China Environmental Science Press, Beijing, China, 2009.

[5] J. Ni, X.-S. Zhang, and J. M. O. Scurlock, "Synthesis and analysis of biomass and net primary productivity in Chinese forests," *Annals of Forest Science*, vol. 58, no. 4, pp. 351–384, 2001.

[6] L. Dai, Y. Wang, D. Su et al., "Major forest types and the evolution of sustainable forestry in China," *Environmental Management*, vol. 48, no. 6, pp. 1066–1078, 2011.

[7] Biodiversity Clearing-House Mechanism of China, "Forest biodiversity," 2013, http://english.biodiv.gov.cn/images_biodiv/ecosystems/forests-en.htm.

[8] Regional Office for Asia and the Pacific, "Forests out of bounds: impacts and effectiveness of logging bans in natural forests in Asia-Pacific," Bangkok, Thailand, 2013, http://coin.fao.org/coin-static/cms/media/9/13171037773780/2001_08_high.pdf.

[9] Ministry of Environmental Protection of China, *China's Fourth National Report on Implementation of the Convention on Biological Diversity*, China Environmental Science Press, Beijing, China, 2009.

[10] National Forestry Bureau, "Major results of the seventh national forest inventory (2004–2008)," 2012, http://www.forestry.gov.cn/portal/main/s/65/content-326341.html.

[11] J. Xu, "China's new forests aren't as green as they seen," *Nature*, vol. 477, no. 7365, p. 371, 2011.

[12] R. F. Noss, "Indicators for monitoring biodiversity: a hierarchical approach," *Conservation Biology*, vol. 4, no. 4, pp. 355–364, 1990.

[13] D. B. Lindenmayer, C. R. Margules, and D. B. Botkin, "Indicators of biodiversity for ecologically sustainable forest management," *Conservation Biology*, vol. 14, no. 4, pp. 941–950, 2000.

[14] R. H. Whittaker, "Evolution and measurement of species diversity," *Taxon*, vol. 21, pp. 213–251, 1972.

[15] C. Liu, K. Ma, S. Yu et al., "Plant community diversity in Dongling Mountain, Beijing, China—IV. Effects of sample size on diversity measures," *Acta Ecologica Sinica*, vol. 17, no. 6, pp. 584–592, 1997.

[16] M. Gao and L. Chen, "Studies on the species diversity of Quercus Liaotungensis communities in Beijing Mountains," *Chinese Journal of Plant Ecology*, vol. 22, no. 1, pp. 23–32, 1998.

[17] Y. Wen, C. Yuan, X. Li et al., "Development of species diversity in vegetation restoration process in mid mountain region of Damingshan, Guangxi," *Chinese Journal of Plant Ecology*, vol. 22, no. 1, pp. 33–40, 1998.

[18] M. Yue, "Species diversity of higher plant of Quercus Liaotungenis forst in Qinling Mountain and the Loess Plateau," *Acta Botanica Boreali-Occidentalia Sinica*, vol. 18, no. 1, pp. 124–131, 1998.

[19] D. Wang, S. Ji, and F. Chen, "A review on the species diversity of plant community," *Chinese Journal of Ecology*, vol. 20, no. 4, pp. 55–60, 2001.

[20] J. Huang, X. Gao, K. Ma et al., "A comparative study on species diversity in zonal forest communities," *Acta Ecologica Sinica*, vol. 17, no. 6, pp. 611–618, 1997.

[21] K. Ma, J. Huang, S. Yu et al., "Plant community diversity in Dongling Mountain, Beijing, China—II. species richness, evenness and species diversities," *Acta Ecologica Sinica*, vol. 15, no. 3, pp. 268–277, 1995.

[22] J. Xie and L. Chen, "The studies of some aspects of biodiversity on scrubs in the temperate zone in China," *Chinese Journal of Plant Ecology*, vol. 21, no. 3, pp. 197–207, 1997.

[23] Z. Hao, S. Zhao, D. Tao et al., "Species diversity of higher plants in lime korean pine forest on northern slope of Changbai Mountain," *Chinese Journal of Ecology*, vol. 12, no. 6, pp. 1–5, 1993.

[24] Y. Han, X. Li, and Y. Liu, "A study on the dynamics of species diversity of the secondary succesional communities of

evergreen broad-leaved forests on Jinyun Mountain," *Journal of Southwest China Normal University*, vol. 25, no. 1, pp. 62–68, 2000.

[25] X. Zhao, C. Zhang, and J. Zheng, "Correlation between gap structure and tree diversity of mixed-broad-leaved Korean pine forests in northeast China," *Chinese Journal of Applied Ecology*, vol. 16, no. 12, pp. 2236–2240, 2005.

[26] P. Chen, *Studies on stand structure and species diversity of evergreen broad-leaved forests in Yanping district, Nanping, Fujian [M.S. thesis]*, Fujian Agricuture and Forestry University, Fuzhou, China, 2009.

[27] R. Alatalo, "Problems in the measurement of evenness in ecology," *Oikos*, vol. 37, no. 2, pp. 199–204, 1981.

[28] H. Xiong, X. Zhang, and X. Li, "Research on biodiversity of the evergreen broad-leaved forest near Manwan reservoir area in Yunnan province," *Mordern Agricultural Science and Technology*, no. 13, pp. 189–194, 2011.

[29] J. Kuang, B. Kuang, Z. Peng et al., "Species diversity of natural evergreen broadleaf forest community in Danxia landform area of Langshan Mountain," *Science of Soil and Water Conservation*, vol. 9, no. 1, pp. 94–98, 2011.

[30] S. Yan, *Gap dynamics and forest biodiversity in mid-subtropical evergreen broad-leaved forest of Fujian province [M.S. thesis]*, Fujian Agriculture and Forestry University, Fuzhou, China, 2002.

[31] D. Li, *Species diversity of different plant communities in west region of Yanshan Mountain [M.S. thesis]*, Agricultural University of Hebei, Baoding, China, 2009.

[32] Z. Wang, *Jinyun subtropical evergreen broad-leaved forest gap dynamics research [M.S. thesis]*, Southwest China Normal, Lanzhou, China, 2001.

[33] M. V. Wilson and A. Shmida, "Measuring beta diversity with presence-absence data," *Journal of Ecology*, vol. 72, no. 3, pp. 1055–1064, 1984.

[34] J. He, W. Chen, and L. Li, "Community diversity of the main types of the evergreen broad-leaved forest in the eastern part of the middle subtropical China," *Acta Phytoecologica Sinica*, vol. 22, no. 4, pp. 303–311, 1998.

[35] J. Xu, *Analysis on plant species diversity pattern of typical evergreen broad-leaved forest in China [M.S. thesis]*, East China Normal University, Shanghai, China, 2009.

[36] G. Zhao, *Beta diversity and functional diversity in an evergreen broad-leaved forest community in East China [dissertation]*, Zhejiang University, Hangzhou, China, 2010.

[37] B. V. Barnes, Z. Xu, and S. Zhao, "Forest ecosystems in an old-growth pine-mixed hardwood forest of the Changbai Shan Preserve in Northeastern China," *Canadian Journal of Forest Research*, vol. 22, no. 2, pp. 144–160, 1992.

[38] Wikipedia, "Old-growth forest," 2013, http://en.wikipedia.org/wiki/Old-growth_forest.

[39] J. J. Battles, A. J. Shlisky, R. H. Barrett, R. C. Heald, and B. H. Allen-Diaz, "The effects of forest management on plant species diversity in a Sierran conifer forest," *Forest Ecology and Management*, vol. 146, no. 1–3, pp. 211–222, 2001.

[40] Y. Paillet, L. Bergès, J. HjÄltén et al., "Biodiversity differences between managed and unmanaged forests: meta-analysis of species richness in Europe," *Conservation Biology*, vol. 24, no. 1, pp. 101–112, 2010.

[41] H. Gu and L. Dai, "Structural and compositional responses to timber harvesting for an old-growth forest on Changbai Mountain, China—Short Communication," *Journal of Forest Science*, vol. 54, no. 6, pp. 281–286, 2008.

[42] J. Zhao, X. Kang, and Z. Gong, "The effects of selective cutting on regeneration, biodiversity, and growth in boreal forest: a review," *Journal of Inner Mongolia Agricultural University*, vol. 29, no. 4, 2008.

[43] Y. Yang, J. Wang, K. Tian et al., "A study on evaluation method and measurement indicators system for biodiversity in Yunnan Province," in *Proceedings of the 6th National Biodiversity Conservation and Sustainable Utilization*, pp. 28–40, 2004.

[44] Z. Zeng, J. Luo, L. Yan L et al., "Biodiversity assessment indicators and standards," *Hunan Forestry Science and Technology*, vol. 26, no. 2, pp. 26–29, 1999.

[45] X. Xu, S. Wang, and K. Ma, "Biodiversity evaluation index system," in *Proceedings of the 7th National Biodiversity Conservation and Sustainable Utilization*, pp. 28–36, 2006.

[46] N. Dudley, D. Baldock, R. Nasi, and S. Stolton, "Measuring biodiversity and sustainable management in forests and agricultural landscapes," *Philosophical Transactions of the Royal Society B*, vol. 360, no. 1454, pp. 457–470, 2005.

[47] J. Li, X. Zheng, and X. Wang, "Study on forest biodiversity index system of northeast over-cutting forest region based on forestry bureau level," *Journal of Beijing Forestry University*, vol. 25, no. 1, pp. 48–52, 2003.

[48] B. Wan, H. Xu, H. Ding et al., "Methodology of comprehensive biodiversity assessment," *Biodiversity Science*, vol. 15, no. 1, pp. 97–106, 2007.

[49] Z. Cheng, "Study on forest biological diversity evaluation indices based on forest resources inventory," *Science and Technology of Tianjin Agriculture and Forestry*, no. 2, pp. 30–32, 2008.

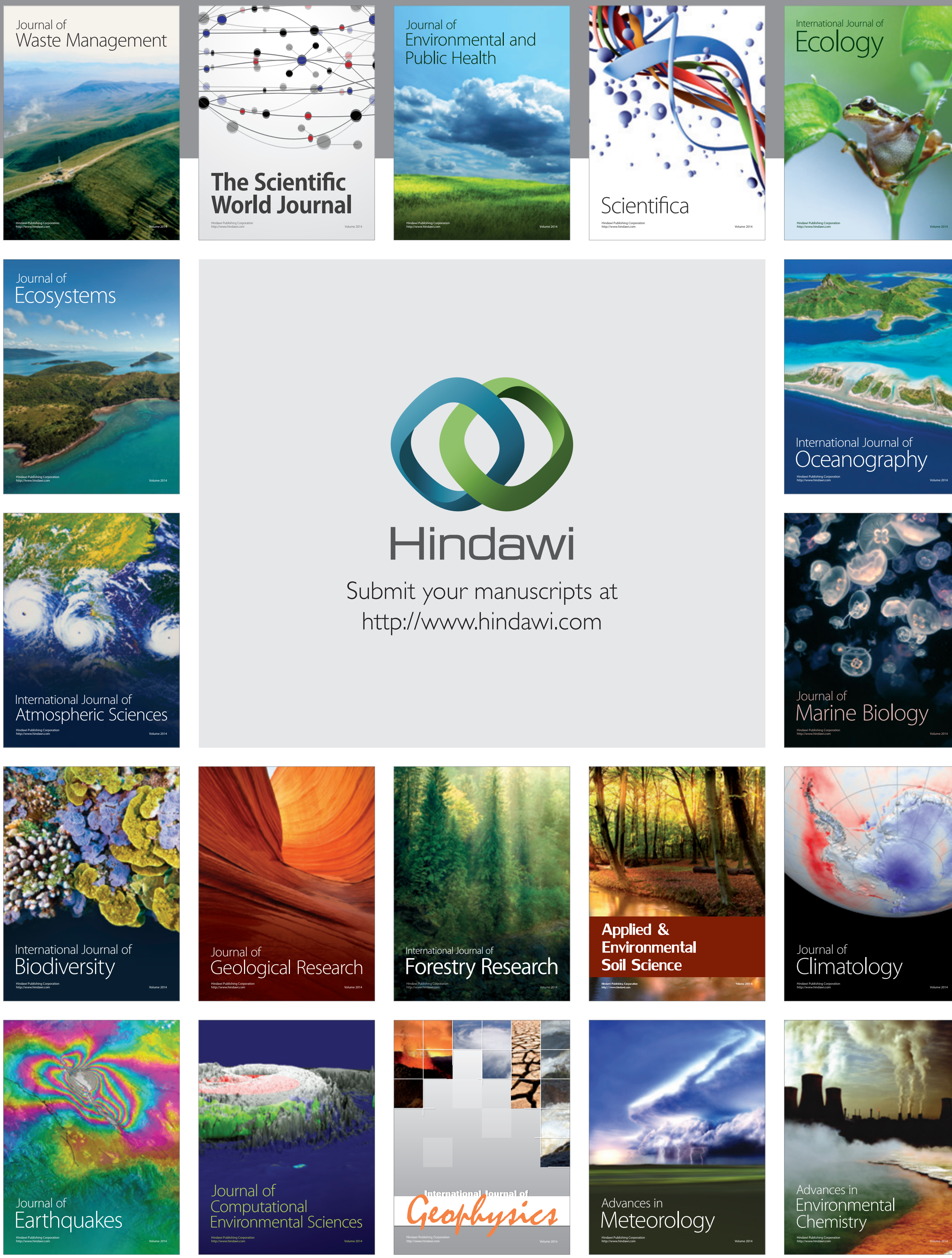
[50] L. Wu and Y. Zhang, "Literature review on forest biodiversity assessment and its dynamic measurement," *Rural Economy, Science and Technology*, vol. 21, no. 6, pp. 83–86, 2010.

[51] S.-B. Chen, G.-M. Jiang, J.-X. Gao, Y.-G. Li, and D. Su, "Review of indicators system developing for biodiversity monitoring," *Acta Ecologica Sinica*, vol. 28, no. 10, pp. 5123–5132, 2008.

[52] J. Danoff-Burg, "Choosing between diversity indices," Lecture notes. Columbia University, 2013, http://www.columbia.edu/itc/cerc/danoff-burg/MBD%205.ppt.

[53] Y. Zhang, C.-Y. Zhang, X.-H. Zhao, Y.-X. Wu, and H.-C. Zhou, "Spatial distribution patterns of tree species in a secondary forest in Changbai Mountain," *Chinese Journal of Ecology*, vol. 27, no. 10, pp. 1639–1646, 2008.

[54] Y. Yan, C. Zhang, and X. Zhao, "Species-abundance distribution patterns at different successional stages of conifer and broad-leaved mixed forest communities in Changbai Mountains, China," *Chinese Journal of Plant Ecology*, vol. 36, no. 9, pp. 923–934, 2012.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