Forest ecological importance classification based on ecosystem services assessment

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***Abstract*—To effective use forest ecosystem services, forest classification management is applied in forestry. Through a case study, based on ecosystem services assessment with the support of GIS, we proposed ecological importance grade (FEIG) to assess forest ecological importance, and compared the spatial distribution of assessment results with that of forest types. The results showed that FEIG supported with GIS can be applied in forest ecological importance classification. This study could be used as a reference in forest ecosystem management.**

Key-words: Forest; Ecological importance; Ecosystem service; Spatial distribution

I. INTRODUCTION

The ecosystem services are critical to the functioning of the Earth's life-supporting system, and contribute to human welfare, both directly and indirectly[1]. In the past few decades, with the environment problem becoming serious, human societies are becoming focus on the ecosystem services, and have been studying the concept, evaluation methods, and dynamics of ecosystem services[2-6]. Forest provides many kinds of ecosystem services, including timber product, water conservation, soil conservation, carbon fixation, oxygen released, nutrient accumulation, atmosphere environmental purification, species conservation, forest recreation, negative-ion supply and action of forest against natural calamities. In order to achieve regional economic and society sustainable development, forest services must be considered, and utilized maximally in forest ecosystem management.

In forest ecosystem management, forest can be classified the commercial forest and non-commercial forest, according to ecological fragility, ecological importance, financial internal rate of return, convenience index for management, and forest land productivity. Forest ecological importance is only determined by the distance between forest land and river, water body, railway, highway, natural reserve, forest park and landscape and famous scenery.

In this study, we attempted to ascertain forest ecological importance by the forest ecosystem services, and find the difference between the two ecological importance classification resulted by different methods. In this study, the sub-compartment, which is the basic unit in forest management, was taken as the basic evaluation unit. The use of GIS and suitable basic study unit guarantee our study can contribute to the practical forest management.

We considered this work can demonstrate the method of integration between the forestry management and the evaluation of forest ecosystem services, and will be helpful for making the effective use of forest ecosystem services to prevent the environmental problems.

II. DESCRIPTION OF STUDY AREA AND MATERIALS

The study area (Benxi County) is located in the eastern mountainous area of Liaoning province, China, with an area of 3344km2 (E 123°34'53″—124°45'42″ and N 40°48'50″—41°33'50″). The elevation ranges from 250 to 1050m. The areas of mountain and forest land are account for 81.3% and 82.7% of the total land of the county, respectively. Bedrock in this area is composed of gneiss, limestone, and sand shale [13]. Soils are mainly brown forest soils and are of 20-40cm in thickness. The climate of this region is featured as north temperate humid and semi-humid zone. Average annual precipitation is 800-1000mm, and over 61.1% of the precipitation occurs in June and August.

We took Benxi County as the study area for the following reasons: (1) the county's luxuriant forest resource is composed of many forest ecosystems; (2) the county is situated in the watershed of the Liao river, which provides water resources for many downriver cities and farmland in the plain; and (3) the forest ecosystems in Benxi County are the typical forest in mountainous region and highland in the North of the China for its representative terrain and tree species.

In order to discover the spatial distribution the difference between the two ecological importance classification resulted by different methods, an integrated spatial database embodied within a GIS was developed as the foundation for the forest ecosystem services assessment. The spatial database was developed with Arc/Info at the scale of 1:50 000, which includes the data of forest, soil, and precipitation. Forest data (including tree species, volume, and canopy density) was obtained from the forest sub-compartment investigation data conducted by Forest Bureau of Benxi in August, 2005. Soil data (including soil thickness, maximum water storage of soil) and litter data (litter thickness, litter amount, maximum water storage of litter) corresponding with each forest type were obtained by field investigation and indoor experimentation.

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Precipitation data was obtained by the Weather Bureau of Benxi County. In this study, we divided the forest into nine forest types with the dominant tree species as the forest types division in practical forest management.

III. METHODS

We designed the forest ecological importance grade (FELG), which is the ratio of the whole no-market forest ecosystem services value and market forest ecosystem services value, as the following formula.

$$FEIG = V_{N-m}/V_M$$

. Where V_{N-m} is the value of whole no-market forest ecosystem services, V_m is the value of market forest ecosystem services.

In study area, water conservation of forest ecosystem is very significant for the whole drainage basin. Timber production is direct economic income, and critical to the economy development of the region. In this study, we took the value of forest water conservation as the value of the whole no-market forest ecosystem services, and took the value of timber production as the value of market forest ecosystem services.

A. the value of timber production

In the case study, we estimated timber production volume by the product of annual production ratio [7] and stock volume of trees in sub-compartment, and evaluated the timber production with the market price of timbers [8].

$$V_M = V_T = \sum_{i=1}^{n} S_i N_i P_i \quad (1)$$

Where: S_i is the living timber volume of the ith tree specie in the sub-compartment; N_i is the average annual net production ratio of the ith tree specie; P_i is the market timber prices of the ith tree specie.

B. the value of forest water conservation

Usually rainwater flow in a forest includes three stages: canopy interception C, litter containment L and soil containment S. The economic values of the forest services for water conservation by forest can be estimated by replacement cost technique. This technique is based on the cost of replacing a damaged asset to its original state and uses this cost as a measure of the benefit of restoration [3]. Then the economic value of forest ecosystem service for water conservation can be expressed as follows:

$$V_{N-m} = V_W = C_r \times (C + L + S) \quad (2)$$

Where C_r is the built cost of reservoir for storage of $1m^3$ water (0.67RMB per m^3) [7], C is the water storage of canopy interception which is observed when the maximum precipitation occurs [8]; L is the maximum water storage of litter; S is the maximum water storage of soil [8]. L relates to precipitation, forest types, and canopy density. L relates to forest type, litter amount, and water storage ratio which are all obtained by field investigation. S relates to forest soil types, soil thickness, and maximum water storage ratio per layer.

IV. RESULTS

A. the value of timber production

The total stock volume of living stumpage in Benxi County is about 18.02 million m^3. The stock volume of living stumpage increased about $176113m^3$ per year. The total economic value of timber production per year in Benxi County was about 67.52 million RMB.

B. the value of forest water conservation

The total capacity of water conservation by forest ecosystems in Benxi County is 246.29 million m^3. The total economic value of water conservation by forest ecosystems is 146.57 million RMB.

C. the index of forest ecologicla importance grade

On the average, the index of forest ecological importance grade is 2.17, which means the water conservation value is twice as much as the timber production value of forest ecosystem. The index of forest ecological importance grade ranges from 0.24 to18.22. The index of 90% forest lands ranges from 0.24 to 15.61. The index of forest ecological importance grade with maximum frequency is 1.22. (Fig. 1).

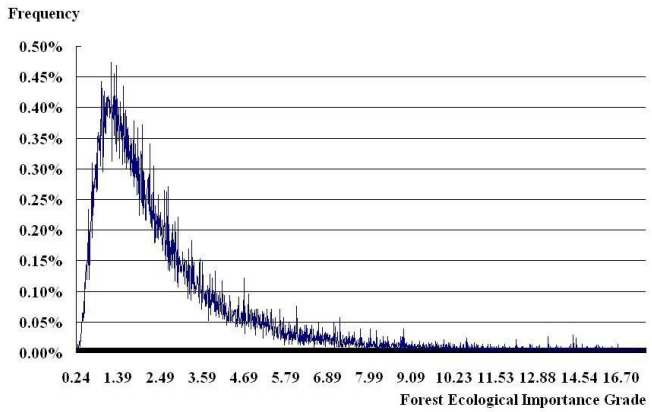

Fig. 1 the Frequency of Forest Ecological Importance Grade Index in Benxi County

D. Spatial distribution of forest type and forest ecological importance grade

According to the above evaluation and assessment, we had a clear idea of the forest type and forest ecological importance grade in Benxi County. Based upon GIS, we can demonstrate the spatial distribution of the forest type and forest ecological importance grade (Fig. 2, Fig 3).

The districts of national and local non-commercial forest is the middle and the east of Benxi County, in which the most of forest land with high forest ecological importance grade index lies, and a few of forest with high ecological importance grade are commercial forest, according to Fig.2 and Fig.3.

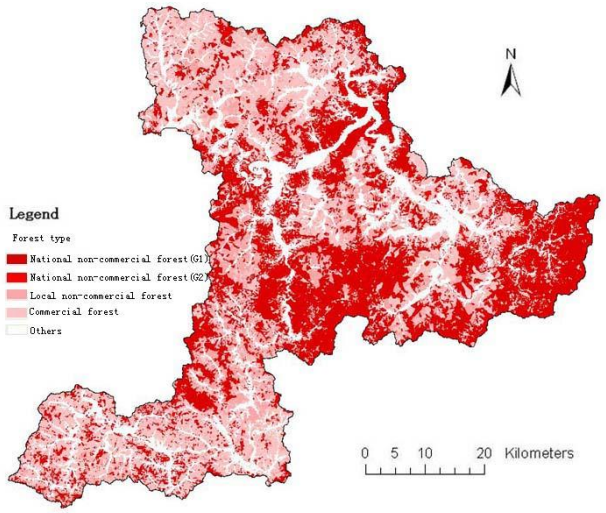

Fig. 1 the spatial distribution of forest type in Benxi County

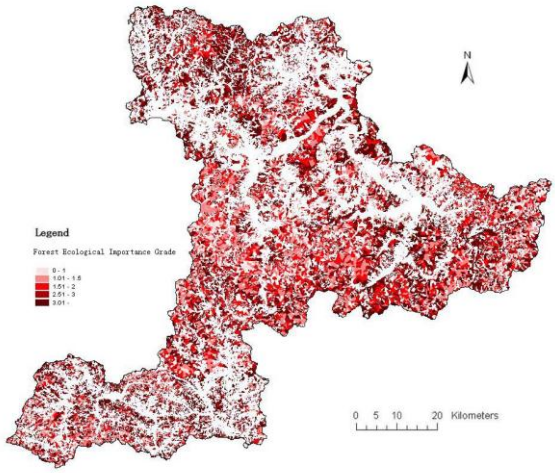

Fig. 2 the spatial distribution of FEIG in Benxi County

V. DISCUSSIONS

In this study, we have estimated the economic value of timber production and water conservation provided by forest ecosystems in Benxi County. Despite the lack of accepted sound evaluation methods, we can also discover the notable importance of water conservation, the value of which is 2.17 times of the timber production value.

In studies on the whole region, many methods to evaluate the storage of water conservation was applied, such as water balance [7], the change in productivity method [8], and annual runoff, which are used widely with the advantage of easy operation. To distinguish the capacity of different forest ecosystems in the same valley, we adopted the water conservation capacity of forest to evaluate the water conservation. Applying the method, the result was not the annual amount of water conservation, and was only the capacity of water conservation in a static state. But the method can Figure out the difference of water conservation by forests, and be used to reach the study object. We consider the method is reasonable and feasible in evaluation the water conservation of forests at county level.

Compared Fig. 2 with Fig. 3, we can find the most forest with high ecological importance degrade index are non-commercial forest, which signifies the classification non-commercial forest is reasonable from forest ecosystem services assessment. Considering the integrity of the whole valley, some non-commercial forest land with small ecological importance grade is accepted. Verified by ecosystem services theory, classifying technical criterion of the commercial forest and the non-commercial forest is scientific and reasonable.

Through the case study, it is clearly shown that the ecosystem services assessment supported with GIS can locate the ecological important area, and With the development of digital forestry [9], forest ecosystem services assessment will be widely applied in forestry decision-making process.

ACKNOWLEDGEMENTS

The author would like to extend his gratitude to Pro. Dai Limin, Dr. Zhang Hengming, Wang Shunzhong, Yu Dapao. Forest data were provided by Forest Bureau of Benxi.

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