Ecosystem Services and Assessment of Water Protection Forests

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Abstract: Beginning with the ecosystem services of water protection forests, this paper discuss the connotation and assessment methods of the ecosystem services from ecology and economy. Base this, economic assessment models of ecosystem services were analyzed.
Keywords: water protection forests, ecosystem services, assessment

With the increase of population and the development of social economy, men's requirement for quantity and quality of water resource is higher and higher. The contradiction between the supply and the demand of water resource becomes more and more acute. On the other hand, because of uneven distribution of rainfall and river runoff in time and space, and some illogical economic activities, flood and water logging disasters or drought disasters is increasingly serious. This makes a tremendous calamity to people's life and the development of social economy. Practices show: land vegetation, especially forest, plays an important role in keeping balance between supply and demand of water resource. As one of the important contents of forest ecological engineering construction, water protection forests will play an active role in the improvement of ecological environment, especially in water resource and water environment. At present, the study on the forest ecosystem function has made considerable achievements and has reached an agreement on the beneficial effect to water resource, but there exist a few disputed problems on the assessment of effect of ecosystem services on environment including theoretical basis and assessment methods. So it becomes an important and prompt problem how to assess objectively and exactly the ecosystem services of water protect forests.

1 Water protection forests and their ecosystem services

Water protection forests are a comprehensive protection forests system, whose purpose is to protect water resource and water environment, to modulate water quantity, to control soil erosion and to improve water quality. They include man-made forests, natural forests and other vegetation resources[2] in water protection regions. So water protection forests are the special forest species with a main purpose to water conservation. From the broad sense, ecosystem services is the natural environmental condition and avail formed and maintained by ecosystem and eco-process, on which men depend to survive. Its functions can be generally divided into two parts: one is ecosystem production, such as kinds of forest byproducts; the second is to support and maintain the environment that man depend on to survive, such as water conservation, soil and water conservation, climate regulation and so on. From narrow sense, ecosystem services is only the second. The ecosystem services of water protection forests is mainly from the narrow sense [4,16,17].

1.1 Modulating water and reducing drought and flooding disaster

During the process of rainfall, through three functionary floor of the canopy, litter and soil, forest can intercept, evapotranspire, infiltrate the rainfall. So it can reduce the amount and velocity of surface runoff, prevent soil erosion, turn the surface runoff into the underground, consequently reduce flood flow and weaken flood peak, increase the runoff replenishment of river in the dried-up period. Accordingly, water protection forests play an important role in regulating the distribution of runoff, increasing low flow in dry season and leaven drought and flooding disaster.

1.2 Preventing soil erosion

Through the function of the interception and energy elimination, the favorable water infiltration capability of the forest soil and the strong fixed soil capacity function of roots, Forest can effectively control the occurring and development of soil erosion. This has a nice role in reducing sand transpiration and alleviating the fill-up of the river and lake reservoir. According to the study of water protection forest ecosystem in Miyun Reservoir by the Beijing Forest University: under the natural rainfall, the sediment yield in the barren slope is the 4.10—12.40 times as the Black Locust forests and 19.16—44.77 times as the Chinese pine[3].

1.3 Improving and purifying water quality

In the regions of water protection, it is mainly non-point pollution to cause the waters contamination, namely under the infiltration and the erosion of rainfall runoff, sediments and their carrying deleterious material move to reservoir, lake or river following runoff, which lead to the water quality muddy and worsen. By regulation and transformation of rainfall runoff on the slope, water protection forests turn the surface runoff into the subsurface runoff or the underground water, consequently reduce the kinetic energy of the runoff, control soil erosion, minimize the output of the non-point pollution charge. It plays a role to protect water resource, to prevent contamination and improve water quality.

1.4 Purifying air and recreation in the forests

Water protection forests are commonly located around the river and lake reservoir catchment. Forest can absorb CO_2 and release O_2 through photosynthesis. At the same time, it can also absorb dust and purify air. In addition, forests can build the comfortable microenvironment by modulating air temperature, sunlight and wind power. These regions are commonly set up forest parks or nature protection area. With the improving of people's life, the action of regressing natural forest recreation will become a new tourism hotspot.

2 Assessment of water protection forests ecosystem services

First, we should estimate ecological process of water protection forests, especially the ecological process and ecological consequence related to human economy activities. From ecology, we should adopt integrate indexes or comprehensive mark method, and then further calculate indirect and non-market economical value of these ecological consequence. From this sense, the assessment of ecological services of water protection forest is divided into two categories, one is ecological assessment, the other is economical assessment.

2.1 Ecological assessment

2.1.1 Scientific building assessment index system of water protection forests

Water protection forests ecosystem services include various contents and are affected by many natural factors and artificial factors as well as. Up to the present, there isn't yet a direct value to reflect exactly the magnitude of its ecosystem services. So we can adopt the method combining subjective and objective estimation, and build a set of assessment index system, and reflect ecosystem services of water protection forest. The estimated index selecting methods in common use have KJ, Delphi, expert consultation, main component analytical method, autocephaly analytical method and AHP. In long-term science study and practice application, Researchers at aboard and home put forward many indexes and index system to estimate forests ecosystem services, but owning to lack of systematization and completeness, there hasn't formed a recognized index system. On the basis of study on assessment index system of sustainable development all over the world, Lei Xiaozhang[5] et al., put forward comprehensive assessment index system of ecological forest engineering, which combines the developing

situation of Chinese ecological forest engineering and applies SSMII as software support of building assessment index system.

2.1.2 Determination of the index weight

Because the dedication value (weight) of each index factor for target is different, so we should first defining weight. At present, the most used methods is: experts assessment method, frequent statistics method, AHP method, AHP-Delphi method, GEM method and so on, among which AHP is widely used in the environment resources assessment in resent years. But this method only switches people's subjective thought to objective numeral handling method and can't remove completely subjective color. Its reliability of the results mainly depends on the extent of subjective judge according with the objective substance. In order to reduce the deviation of the subjective judge, on the one hand, we should invite experts to judge, on the other hand we should use measuring data as possible as we can.

2.1.3 Technical design of quantifying indexes (Convergence treatment)

Because the dimension of each index is different, it is no sense to add together directly. Even if the dimension is same, the big value has more profound effects on the comprehensive index than small value after adding directly. So, we should apply a certain method to change value of each index to the same level and eliminate the effect of dimension. This change usually is called the assessment function of index value.

2.1.4 Assessment methods of ecosystem services

After determining the weight and assessment functions of index, we can calculate integrate score. The methods often used is: integrate assessment index method, index analysis method and relative degree analysis method [6,7].

2.2 Economical assessment of ecosystem services

At present, the value assessment of ecosystem services of water protection forest is the effective way to reduce and avoid the short-time economical activity which do harm to ecosystem services, on the other hand it's an emergent job of existing social situation. General surveying the study results of economical assessment for forest benefits at abroad and home, there have three economical indexes used in the assessment of forest ecosystem services, namely: shadow price, willingness to pay(WTP) and consumer surplus. The assessment method of economical value of forest ecosystem services can be divided into two[8,11,12,13]: (1)substitute marketing technology, the economical value of environment benefits can be expressed by shadow price and consumer surplus. The famous methods is: cost payment method, the market valuation method, option cost method, travel cost method and so on. (2)simulating market technology, using WTP and NWTP to express the economical value of environment goods. The only method is contingent valuation method.

3 Assessment model

Aiming at the economical assessment of ecosystem services of water protection forest. The paper briefly states assessment model of ecosystem services of water protection forest on the basis of consulting the universal assessment methods of forest ecosystem services abroad and home.

3.1 The benefit of water conservation

Commonly, we adopt equivalent replacement of beneficial method to value forest water conservation benefit. First, it is to calculate quantity of forest conserving water. There are two methods: one is to express by the river runoff curve integral difference of the woodland and non-woodland. This method is strict in theory, but there is very difficult in practical measurement. Some scholars want to derive it by forest water balance, but because the measurement of forest evapotranspiration is very difficult, there is very big disparity. The other method is to express by forest interception rainfall. The

method is not very strict in theory, but it is practicable. In applying, we commonly adopt the second method to calculate the quantity of forest conserving water, then to define a price standard of forest water conservation according to sluicing cost of reservoir engineering. The product of the two is namely the value of forest yearly water conservation.

Zhou Xiaofeng[9] derives the flood peak flow reduced by forest and runoff of low flow increased by forest according to the many years' analysis and located monitoring and correlation analysis of every main type forest water circle, and then use equivalent replacement of beneficial products to evaluate, its formula as follows:

$$V = V_1 + V_2 = \sum_{i=1}^{n} S_i (H_i - H_0) \bullet b \bullet B + M \bullet (P_1 \bullet \eta_1 + P_2 \bullet \eta_2)$$

where, V is value of forest conserving water (Yuan); V_1 is value of forest preventing flood (Yuan); V_2 is value of forest increasing water resource (Yuan); S_i is the ith forest type area (hm^2); H_i is the ith forest type's storing floodwater ability (m^3/hm^2); H_0 is the storing floodwater ability of non-woodland (m^3/hm^2); n is the number of forest type; b is the constructing reservoir cost to blocking 1 m^3 floodwater; B is the ration of benefit/input; M is the water quantity increased by forest (m^3); P_1, P_2 are the price of irrigating and water supply respectively; η_1, η_2 is the use coefficient of irrigation and water supply respectively.

3.2 The benefit of soil conservation

The benefits of forest conserving soil have two sides: one is to prevent soil loss; the other is to prevent soil nutrient loss caused by soil loss. Commonly according to comparing experiment study of woodland and non-woodland, we can derive annual soil erosion amount reduced by forest, and use equivalent replacement of beneficial products to evaluate.

$$V = V_g + V_f = K \bullet S \bullet G \bullet d + d \bullet S \bullet \sum_{i=1}^{n} P_{1i} \bullet P_{2i} \bullet P_{3i}$$

where, V is value of forest conserving soil and nutrient (Yuan); V_g is value of forest conserving soil (Yuan); V_f is value of forest conserving nutrient (Yuan); K is the cost of digging 1t sediment (Yuan); S is total area of forest (hm^2); G is the ratio of sediment entering reservoir and total sediment loss (%); d is the reduced erosion of woodland comparing non-forest (t/hm^2); P_{1i} is the content of N, P, K in the forest soil (%); P_{2i} is the proportion of pure N, P, K converting chemical fertilizer; P_{3i} is the local price of chemical fertilizer (Yuan/t).

3.3 The benefit of water quality improvement

On the relationship between forest and water quality, European American and Japan and so on countries have quite more study, while Chinese study is still in exploring stage and research results are less. There has not been any mature assessment model on assessment of forest improving water quality. According to water quality subject to level, Jiang Wenlai[1] construct fuzzy assessment matrix of water resource value to calculate integrate assessment of a certain level water resource value, and then calculate price vector of water resource according to actual conditions. The two multiply each other and educe the water resource price of a certain of water quality. By comparing water resource price of different level water quality, we can estimate water resource wealth loss, consequently can derive the benefits of forest improving water quality.

3.4 The benefits of air purity

The great function of forest to purify air and maintain air balance mainly materialize in green plants absorbing plenty of CO_2 and discharging a lot of O_2 yearly (not including other sterilization effect). The releasing quantity of O_2 can be attained by calculating annual increase of biomass, from producing 1 dry matter liberating O_2 quantity to calculate its yearly O_2 production and then conversing by the price of industry making O_2 [9,10].

$$V = M \bullet d \bullet p \bullet (1 + C) \bullet K$$

where, V is economical assessment value of forest releasing O_2 (Yuan); M is existing forest growth (m^3); d is timber absolute dry weight; P is industry making O_2 price (Yuan); C is the ratio of root, branch growth and timber growth (%) ; K is the releasing O_2 quantity for producing 1t dry matter.

3.5 Recreation benefits

At present, there are many kinds of methods to assess forests recreation value, such as direct cost method, cost payment method, option cost method, the market valuation method, travel cost method (TCM) , contingent value method (CVM). Among these methods, the most popular methods are TCM and CVM[8, 10, 14, 15].

4 Conclusion

Because of the many side of water protection forests ecosystem services, the complexity of ecosystem process and economy process and the uncertainty of nature ecological process, these increase the difficulty of ecosystem services assessment, meantime because existing theoretical basis and assessment methods are in developing and perfecting stage, it is impossible to assess exactly the water protection forests ecological services. But it is possible to make the assessment value accord with the objective reality by scientific methods, which can provide the scientific basis for the management of water protection forests, reasonable exploitation and use of water resource and sustainable development of ecological environment.

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