Estimation of Biodiversity Conservation Value of Forest Ecosystem in Nyingchi Prefecture of Tibet

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Abstract The estimation was made for the conservation value of forest ecosystem biodiversity in Nyingchi Prefecture of Tibet. The results showed that the annual economic benefits of biodiversity in Nyingchi Prefecture were about 21.4 billion yuan, and the annual economic benefits of global biodiversity were about 3 trillion USD. It indicated that the ecological value of forest ecosystem in Nyingchi Prefecture is high, forest ecosystem has extremely important ecological value. Therefore, in the decision-making process, it is necessary to strengthen the protection of forest ecosystem, with particular emphasis on the restoration of damaged ecosystem.

Key words Biodiversity, Value estimation, Forest ecosystem, Nyingchi Prefecture

1 Introduction

Biodiversity is an essential indicator for measuring the vitality and persistence of ecosystem. It is a hot topic in both the ecology and biology. The expansion and the increase in intensity of human activities have caused the decline of biodiversity on a global scale. Biodiversity has become an important part of global change researches. With an area of more than 100000 km^2, Nyingchi Prefecture in Tibet has the largest virgin forest area in China. Its forest coverage rate is greater than 46% and its living wood growing stock is 882 million m^3. It is rich in flora and fauna and is the well preserved virgin forest in China. It plays a significant role in climate adjustment and soil and water conservation of Tibet. The first Grand Canyon in the world, the Yarlung Zangbo Grand Canyon, is located in Nyingchi Prefecture in Tibet. In 1994, the Yarlung Zangbo Grand Canyon was recognized as the real world's first Grand Canyon, in place of the Grand Canyon of Colorado in the United States and Colca Canyon in Peru. The Yarlung Zangbo Grand Canyon is 504.6 km long and the deepest point is 6009 m. With near 2000 higher plants, it is reputed as biological gene pool. Main tree species include birch, Populus szechuanica Schneid. Var. tibetica schneid., Matsutake, Ganoderma Lucidum Karst, Hericium, Cordyceps and so on. There are also many state level protected wild animals such as *Grus nigricollis*, snow leopard, *Ursus arctos pruinosus*, and *Pseudois nayaur*. Besides, there are many rare plants and animals, such as *Panthera tigris*, *Cervus albirostris*, king of mulberry tree with age of 2000 years, king of cypress, huge poplar, and *Mimosa pudica* Linn. Therefore, it is of strategic significance to study the biodiversity conservation value of Nyingchi.

Received: November 30, 2016 Accepted: January 12, 2017
Supported by Humanity and Social Science Project of Colleges and Universities in Tibet Autonomous Region in 2015 "Study on Ecological Economy Construction in Tibet: A Case Study of Nyingchi Prefecture" (sk2015-33).
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2 Overview of the study area

Nyingchi Prefecture (26°52′N - 30°40′N, and 92°09′E - 98°47′E), also known as Linzhi, is a prefecture-level city in southeast of the Tibet Autonomous Region. It is a transition area from the north of tropical zone and the Qinghai-Tibet Plateau, located in the Yarlung Zangbo River, reputed as the "south of Yangtze River" of Tibet. Mountainous terrain, topography, climate, hydrology and other natural conditions Nyingchi are extremely complex and diverse. There is various vegetation of tropical, subtropical, warm temperate, cold temperate and humid and semi-humid climatic zones, and the plant species are extremely rare in both Tibet and even in the whole China.

2.1 General situations of the forest resources According to the results of the second forest resources category I survey conducted by the Tibet Autonomous Region in 2004, the forest coverage rate in the whole prefecture was 46%. The living wood growing stock of the whole prefecture was 882424987 m^3, including stand volume 875671706 m^3, accounting 99.2% of the living wood growing stock, and sparse forest stock volume 6753281 m^3, accounting for 0.8% of the living wood growing stock.

2.2 Forest vegetation

2.2.1 Vegetation type. (i) Subalpine dark coniferous forest. The forest stock volume of the subalpine coniferous forest in Nyingchi Prefecture is the largest, and the stock volume of fir and dragon spruce is more than 75%. According to the differences in the constructive species, common species include fir forest community, dragon spruce community, and California Redwood community.

(ii) Coniferous and broad-leaved mixed forest. Yunnan hemlock is the main constructive species of hemlock and broad-leaved mixed forest, distributed in the valleys of moist mountainous areas. They often form mixed forests with *Pinus armandii* Franch. and various deciduous broad-leaved trees, and some pure forests are formed locally. Firs and dragon spruces and birch forest are mainly firs and dragon spruces, accompanies with broad-leaved

trees such as poplars, Betula albo-sinensis, *etc.*, forming coniferous and broad-leaved mixed forest; the shrub layer has Rhododendron, bamboo, *etc.*, distributed in the whole prefecture.

(iii) Mountain cypress forest. It includes cypress forest and *Cupressus gigantea* sparse woods. The cypress forest takes Tibetan cypress as the constructive species, often forming mixed forest with other tree species. Some areas have a small area of pure forest, mostly distributed in Bomi County. The *Cupressus gigantea* sparse woods are distributed in the middle reaches of the Yarlung Zangbo River and the Niyang River Valley, from the east of Longxian to Milin and Nyingchi. It is a residual forest community and should be protected and developed.

(iv) Mountain temperate pinewood. It is a forest type composed of Alpine pine, Pinus armandii and Pinus yunnanensis. It has a strong adaptability to environmental conditions, accounting for 21% of the forest growing stock in Nyingchi. It mainly consists of Alpine pine, Pinus armandii and Pinus yunnanensis.

(v) Evergreen broad-leaved Sclerophyll forest. Alpine oak forest is the evergreen broad-leaved Sclerophyll forest, widely distributed in Nyingchi, with Sichuan and Yunnan alpine oak as the constructive species, distributed at sunny slope and semi-sunny slope at 2800 – 4200 m. The species and number of edible fungi are numerous, in the low altitude area, they take on arbor type; in high altitude area, they form brushwood.

(vi) Mountain deciduous broad-leaved forest. There are Alnus cremastogyne forest, Nepal alder forest, and seabuckthorn forest. Populus euphratica forest consists of birch and poplar species, with Betula albo-sinensis, Betula utilis, poplar, and Cathay poplar as main constructive species. It often takes on type of mixed forest, distributed in area with altitude of 3000 – 4100 m. Alnus nepalensis is distributed in1200 – 2500 m moist mountainous areas and alluvial soils in both sides of streams. It is more common in young and middle age forests, and the trees grow rapidly. They can be used as pioneer species at the altitude below 3000 meters. Seabuckthorn forest is distributed along the rivers and streams, and best developed in the two sides of the rivers and beaches, and widely distributed in the whole Nyingchi area.

(vii) Mountain subtropical evergreen broad-leaved forest. The evergreen broad-leaved forest is typical vegetation of subtropical moist mountain. The constructive species are mainly *Fagaceae*, *Lauraceae*, *Theaceae*, *Magnoliaceae*, and *Araliaceae* evergreen trees, mainly distributed in 1100 – 2400 meter mountains.

(viii) Tropical forest. The tropical forest is distributed in south of Chayu and Medog below 1100 meters. It is the northernmost tropical forest in Eurasia, and takes *Dipterocarpaceae*, *Combretaeeae*, *Samydaceae*, *Flacourtiaceae*, *Malpighiaceae*, *Annonaceae*, *Dilleniaceae*, *and Rubiaceae* plants as main constructive species.

2.2.2 Tree species resources. Nyingchi Prefecture is vast and tree species are rich. According to incomplete statistics, there are more than 3364 species, 162 genera, 983 families of angiosperms, 35 species, 15 genera, 7 families of gymnosperms. It is the main constructive tree species of subalpine coniferous forest, and the endemic species are rich. Common arbor trees are as follows.

(I) Gymnosperms.

(i) *Pinaceae*. There are mainly *Abies georgei* Orr var. smithii (Viguie et Gaussen) Cheng et L., *Abies squamata* Mast., *Abies forrestii* Coltm.-Rog., *picea baifouriana* Rehd. et Wils, *Picea brachytyla* var. complanata, *Tsuga dumosa* (D. Don) Eichl., *Larix griffithiana*, *Pinus yunnanensis*, *Larix kaempferi* (Lamb.) Carr., *Pinus densata*, *Pinus armandii* Franch., *Cedrus deodara* (Roxb.) G. Don.

(ii) *Cupressaceae*. There are mainly *Cupressus gigantea* Cheng et L. K. Fu, *Cupressus torulosa* D. Don, *Platycladus orientalis* (L.) Franco, *Sabina saltuaria*, and *Sabina tibetica*.

(iii) *Podocarpaceae* Endl. It is mainly *Podocarpus neriifolius* D. Don., growing in 800 – 1000 m mixed forest, belongs to key plants under the state protection, and originates in Medog.

(iv) *Cephalotaxaceae*. It is mainly *Cephalotaxus hainanensis*, growing in 850 – 1200 m mountain forest, belongs to key plants under the state protection, originates in Medog, and its leaves, branches, stems, and barks contain various alkaloids which have anticancer function.

(v) *Taxaceae*. There are mainly *Amentotaxus argotaenia* (Hance) Pilger and *Taxus yunnanensis*.

(II) Angiosperms.

(i) *Lauraceae*. There are mainly *Lauraceae* and *cinnamomum camphora*.

(ii) Besides, there are *Platanaceae*, *Aceraceae*, *Elaeagnaceae*, *Juglandaceae*, *Salicaceae*, *Betulaceae*, *Fagaceae*, *Meliaceae*, *and Anacardiaceae*.

(III) Rare and endangered plants.

At present, rare and endangered species in China are divided into three levels: endangered, rare and vulnerable. Endangered species refers to species that are at risk of extinction in the main distribution area. Rare species refers to some representative Chinese-specific monotypic families, monotypic or few species of genera. Vulnerable species refer to vulnerable or threatened species, namely, those endangered by human or natural factors. At present, following species in Nyingchi Prefecture have been included in the national list of rare and endangered plants:

(i) Class A plants under the state protection: *Alsophila spinulosa* (Wall. ex Hook.) R. M. Tryon, *Cupressus giganteam*, *Taxus yunnanensis* Cheng et L. K. Fu, *Amentotaxus argotaenia* (Hance) Pilger, and *Alcimandra cathcartii* (Hook. f. et Thoms.) Dandy.

(ii) Class B plants under the state protection: *Cephalotaxus hainanensis*, *Pseudotsuga forrestii Craib*, *Picea brachytyla* (Franch.) E. Pritz. var. complanata (Mast.) W. C. Cheng ex Rehder, *Tetracentron sinense* Oliv., *Circaeaster agristis* Maxim, *Coptis teeta* Wall., *Shorea* assamica Dyer, *Tetramelaceae*, *Trillium govanianum*, Ophioglossum reticulatum, *Ophioglossum* vulgatum L., *Phoebe zhennan* S. Lee, *Cinnamomum camphora* (L.) Presl., *Tricholoma matsutake* (S. Ito & S. Imai) Singer,

Cordyceps sinensis (Berk.) Sacc., *Magnolia rostrata* W. W. Smith, and *Terminalia myriocarpa* Vaniot Huerck et Muell.-Arg.

2.2.3 Other biological resources. (i) Medicinal plants. Nyingchi Prefecture is rich in medicinal plant resources, and the Tibetan Plateau is one of the important medicinal herb production areas. There are more than 1000 kinds of medicinal plants, the average annual purchase volume is up to 20000 kg. Common medicinal plants include *Fritillaria*, *Rheum officinale*, *Saussurea involucrate*, *Aconitum kongboense Lauener*, *Astragalus membranaceus* (Fisch.) Bunge., *Codonopsis pilosula* (Franch.) Nannf., *Berberis thunbergii* DC., *Angelica sinensis*, *Gastrodia elata* Bl., Tree Peony Bark, *Bupleurum chinense*, *Cordyceps sinensis* (Berk.) Sacc.

(ii) Flower plants. The terrain of Nyingchi Prefecture is complex, there are mountains and valleys, plateaus and grassland, from Pasighat to the Namjagbarwa Peak, the altitude is above 150 meters to 7888 meters, the climate covers tropical to the cold zone. Various climate zones become unique survival and development environment for wild flowers. The common wild flowers are Rhododendron, Begonia, Peach, Magnoliaceae, Spiraea salicifolia L., Rosaceae, Potentilla fruticosa L, *Lilium brownii* var. viridulum Baker, Syringa Linn, *Primula* malacoides Franch., *Gentiana scabra* Bunge, Meconopsis, Cymbidium ssp., *Crassulaceae*, Iris tectorum Maxim., Punica granatum L., and *Chaenomeles sinensis* (Thouin) Koehne).

(iii) Edible fungi. Edible mushrooms are rich in protein and amino acids and delicious foods for people. In recent years, people have a further understanding of edible fungi, especially the outstanding medicinal value and health functions, its market potential is enormous. Nyingchi Prefecture has a wide range of edible fungi, up to 240 species, such as *Hericium erinaceus*, *auricularia auriculajudae*, agaric, Matsutake, *Boletus edulis*, and *Bankera violascens*. Matsutake is delicious, widely distributed, large output, the products are exported to East Asia and the coastal areas, the average annual output is up to 150 tons.

3 Research methods

3.1 Data source Forest area and other data mainly came from the 2008 survey of forest resources in Tibet, long-term observation data of Forest Ecosystem Observation Station of Tibet Agricultural and Animal Husbandry College and published data of adjacent areas, and the relevant economic indicator data came from the *Tibet Statistical Yearbook*. In addition, we carried out field survey for main forest species.

3.2 Calculation methods In this study, the calculation method applied the evaluation formula defined in the *Evaluation Procedure for Forest Ecosystem Service Functions* published by the State Forestry Administration in 2008.

$U_{biology} = S_{biology} \times A$

$S_{biology}$ is the opportunity cost of species loss per unit area (yuan/ha/a);

$U_{biology}$ is the annual conservation value of forest (yuan/a);

A is the stand area (ha).

According to *Evaluation Procedure for Forest Ecosystem Service Functions*, $S_{biology}$ was determined by Shannon-Wiener index; when Shannon-Wiener index was less than 1, $S_{biology}$ = 3000 yuan/ha/a; when 1 ≤ Shannon-Wiener index < 2, $S_{biology}$ = 5000 yuan/ha/a; when 2 ≤ Shannon-Wiener index < 3, $S_{biology}$ = 10000 yuan/ha/a; when 3 ≤ Shannon-Wiener index < 4, $S_{biology}$ = 20000 yuan/ha/a; when 4 ≤ Shannon-Wiener index < 5, $S_{biology}$ = 30000 yuan/ha/a; when 5 ≤ Shannon-Wiener index < 6, Sbiology = 40000 yuan/ha/a; when 6 ≤ Shannon-Wiener index, $S_{biology}$ = 50000 yuan/ha/a.

Table 1 Biodiversity statistics

Types	Community	Altitude m	Shannon-Wiener Index
Abies fabri (Mast.) Craib	Selaji Mountain	3600	3.381
Abies fabri (Mast.) Craib	Selaji Mountain	3800	2.289
Abies fabri (Mast.) Craib	Selaji Mountain	4000	2.754
Abies fabri (Mast.) Craib	Selaji Mountain	4300	2.869
Picea asperata	Nanyigou in Milin	3040	2.743
Picea asperata	Gangxiang in Bomi	2870	3.190
Picea asperata	Lulang Town in Nyingchi	3400	3.063
Picea asperata	Bayi in Nyingchi	3060	2.975
Bush	Selaji Mountain	4500	1.954
Bush	Selaji Mountain	4700	1.925
Herbaceous	Selaji Mountain	4500	2.796
Herbaceous	Selaji Mountain	4700	3.001

Table 2 Estimation of biodiversity conservation value of forest ecosystem in Nyingchi Prefecture of Tibet

Dominant species	Area//ha	Biodiversity conservation value//10^4 yuan/a
Abies fabri (Mast.) Craib	961632	96.1632
Tsuga chinensis pritz	9437	0.9437
Picea asperata	136456	13.6456
Cupressus funebris Endl.	41801	4.1801
Larix spp.	31164	3.1164
Pinus armandii Franch.	26801	2.6801
Pinus densata	283076	28.3076
Pinus yunnanensis	330608	33.0608
Pinus wallichiana A. B. Jackson	4237	0.4237
Oak	110702	11.0702
Betula	70412	7.0412
Sclerophyllous broad-leaved	126445	12.6445
Poplar	9882	0.9882
Deciduous broad-leaved	213	0.0213
Total	2142866	214.2866

4 Value estimation of biodiversity

Although the species of Nyingchi is extremely rich, there is still no estimation method for the value of biodiversity conservation in the forest ecosystem of Nyingchi Prefecture. Therefore, in this study, we adopted the evaluation method specified in the Evaluation Procedure for Forest Ecosystem Service Functions published by the State Forestry Administration in 2008.

Biodiversity conservation value: $U_{biology} = S_{biology} \times A$.

From Table 1, the Shannon-Wiener index of forest in Nyingchi Prefecture was 2 – 3, $S_{biology}$ = 10000 yuan/ha/a. Through calculation, the biodiversity conservation value of forest in Nyingchi Prefecture $U_{biology}$ = 214.29 (10^8 yuan/a).

5 Result analysis

Forest ecosystems not only provide habitat for all kinds of organisms, but also provide conditions for biological evolution and the formation of biological diversity. A variety of organisms is the most valuable asset of the earth with 4 billion years of biological evolution. It is the basis for maintaining ecological balance, and also the material base for human survival and development. According to the study, the annual economic benefit generated by global biodiversity is about 3 trillion USD, accounting for 11% of the total value of products and services provided by global ecosystems (33 trillion USD). The annual economic benefit of biodiversity in Nyingchi Prefecture is about 21.4 billion yuan, which shows that the ecological value of forest ecosystem service is very large in Nyingchi Prefecture, indicating that Nyingchi Prefecture has extremely important ecological value. Therefore, in the decision-making process, it is necessary to strengthen the protection of forest ecosystem, with particular emphasis on the restoration of damaged ecosystem.

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development of the Pingle economy and the opening of Jingziling scenic spot, there will be more and more frequent exchanges with outside world, more serious human interference, and higher spread of alien species. Nevertheless, due to weak public awareness of the harm caused by invasive alien plants, various economic activities have intentionally and unintentionally led to the introduction and spread of many alien plant species. Without proper control and prevention, invasive plants will further worsen the exclusion and kill local plants of Jinziling scenic spot. The survey results showed that a total of 23 species of alien invasive plants was found in Jinziling scenic spot. With the further development of tourism, the number of tourists will increase, which will introduce new species of alien invasive plants and increase the risk of invasion of alien plants. Therefore, it is necessary to establish a proper evaluation system and database for alien plants and formulate economic and effective control measures on the basis of field survey with reference to related research results and in combination with the local existing conditions.

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