Assessment of Ecosystem Water Conservation Value In The Beijing Four Seasons Flower Valley

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Abstract. Based on the data of field investigation and multi-source data analysis, Beijing Four Seasons Flower Valley declared in 2008 towards valley economy water conservation function and value was estimated by means of rainfall storage capacity as well as ecological economy. The results showed that: Landscape structure of FSFV was forest land-cultivated land-grassland. FSFV had the highest water conservation function in Beijing valleys, with the capacity of $1101.13 \text{ m}^3/\text{hm}^2$. Annual total amount of water conservation was $31.20 \times 10^6 \text{ m}^3$, accounting for 10.07% of Beijing valleys, and the total value of water conservation was 3.61×10^8 Yuan. High water conservation capacity areas were mainly located in the eastern mountainous region with broadleaf forest centralized distribution. Low water conservation function areas were mainly occurred in the regions effected by human activities. Forest ecosystem had the highest capacity of water conservation of $1116 \text{ m}^3/\text{hm}^2$, while construction ecosystem had the lowest. Higher degree of human activities, lower capacity of water conservation. Shrub forest and broadleaf forest had the largest contribution on valley water conservation, with contribution rate of 36.35% and 35.62%. Ranking of water conservation capacity, broadleaf forest had the highest value of $1135 \text{ m}^3/\text{hm}^2$, followed by coniferous forest, shrub forest and mixed forest.

1 Introduction

With climate change and rapid socio-economic development, water demand is raising gradually and water environment is deteriorating sharply. Water shortage has become the focus of common concern, presented increasingly serious trend, especially in northern China. Beijing, as the national capital, has become one of metropolises facing the worst water scarcity in the world, with water resources less than 200 m^3 per capita, approximately 1/10 and 1/38 of the national and world per per capita level according to the newest Beijing water resources bulletin published in 2014. As ecological conservation area of the national capital, Beijing's mountainous area is the natural ecological barrier, water conservation region and bearing capacity of biodiversity. Restricted by tough geographical and natural conditions, it is also the region with economic underdevelopment. With the strength of human activities increasing, such as urbanization, industrialization and agricultural intensification, ecological environment and natural resources are faced with tremendous development pressure in those mountainous areas, such as mining, soil erosion, and destruction of vegetation. The contradiction between socio-economic development and ecological environment protection becomes relative prominent and acute, which prompting the gap between urban and rural significantly [1-2].

How to achieve supply equalization and benefits maximum of ecosystem services by means of combination of ecological protection and poverty alleviation on the basis of ecological construction and environmental protection? Ecological economization and economic ecologization is the hot issue currently [3]. With ecological protection as premise, aiming to drive local development, valley economy which was proposed officially in 2008 is industrial economic belt by unified development which takes natural valley of mountain as unit, and an important and effective way to break the bottleneck of the comprehensive arrangement and improvement rural and urban development in Beijing's mountainous areas [4-5]. Beijing has 179 valleys along with area more than 5 km^2 covering total area of 10418 km^2 with the percentage of 62% of total capital area. Beijing mountainous valley has a pivotal role in the capital water conservation, water environment security and socio-economic sustainable development. Ecosystem function in this region showed a decline trend for superimposed effects of human activities and its fragile ecological environment since implementation of valley economy in 2008, especially the function of water conservation in mountainous area. Water conservation function was influenced by many factors such as climate change, physical and chemical properties of soil, and topography [6]. Currently, the research of water conservation function was mainly focused on watershed

and the large scale context, rarely on small-scale territorial unit like valley. Meanwhile, the relevant research was mainly for forest ecosystem, weakly for grass, shrub, and other ecosystems. Differences of water conservation function among varied ecosystems were rarely mentioned, especially in small scale [7].

According to the investigation of Beijing Municipal Commission of Rural Affairs, Yanqing District as the host site of 2022 the winter Olympics has 17 valleys with development potential [5]. Ecological environment protection and ecological civilization construction becomes urgent and irreplaceable for regional sustainable development [8]. Four Seasons Flower Valley (FSFV), which is located in eastern mountainous region of Yanqing District, was listed as one of ten strategic growth pole construction of 'Demonstration Area of Green Beijing' in the 12th Five-Year Plan of Yanqing County. Meanwhile, it has also been listed as one of seven key valleys in Beijing mountainous area in 2011. Based on the land use and land cover classification maps in 2013 extracted by SPOT5 images, forest ecosystem was major natural type with proportion of 81.27% in FSFV, followed by farmland and grassland ecosystem. Therefore, water conservation function of ecosystem in FSFV is the significant role. Effective assessment of water conservation function and its value is the basis for the establishment of long-term ecological compensation mechanism, for providing further natural vegetation protection and ecological construction, which meeting the construction of ecological civilization and ecological economy development in Beijing mountainous areas [9]. The value of water conservation function was assessed using method of ecological economics in FSFV in 2013, for the purpose of providing basic data for reasonable protection and exploration local natural resources, and serving in the ecological, economic and social sustainable development in Beijing mountainous areas.

2 Materials and methods

2.1 Study area

Four Seasons Flower Valley (FSFV) is located in the eastern part of Yanqing District in Beijing mountainous areas, including Liubinpū Town, Sihai Town and Zhenzhuquan Town (Figure 1).

Figure 1. The Location of Study Area

The complex topography with altitude ranging from 385 m to 1482 m formed the typical vertical climate change, which brings out the significant vertical distribution of plant communities with warm temperate deciduous broad-leaved forest dominating. This region has a temperate continental monsoon climate, with annual mean temperature 8 °C and annual average precipitation ranged from 550 mm to 700 mm. The region cover 284.12 km² accounting for 14.25% of the total area of Yanqing District (2.73% of Beijing mountain areas) with ditch length of 47 km and a population of 16540 that has 45.88% of urbanization rate.

FSFV located in the middle mountainous area of Yanqing District has obvious artificial ecosystem features. Regional structure of land use and land cover in study area was forest land-cultivated land-grassland, while woodland was the major land cover type with proportion beyond 44% based on the land use and land cover classification maps in 2013 extracted by SPOT5 images (Figure 2). Farmland ecosystem was the dominant artificial type with proportion 12.23% mainly located in the relative low altitude areas and along the road regions, while forest ecosystem was major natural type with proportion of 81.27%. Orchard land was mainly occurred in the scope surrounding farmland and construction land. The primary forest types in FSFV are broadleaf forest, coniferous forest, mixed forest and shrub forest, the proportion respectively was 34.58%, 6.20%, 4.02% and 36.47% in 2013.

Figure 2. Land Cover Map of Fsfv In 2013

2.2 Methodology

Ecosystem water conservation function is consisted of water regulation and water purification. According to the similar essence between water regulation and reservoir storage, this study adopted the method of alternative cost of reservoir storage project to calculate the water regulation value. Meanwhile, the value of water purification was evaluated through shadow project method with reference to the average price of residential water for the same principle of water purification. Currently, methods of regional water balance and rainfall storage are the common methods to evaluate water conservation function at home and abroad [10]. This study considered the water conservation as the increment of forest, grassland, waterbody, farmland, and desert ecosystem compared with bare land, that is the reduction of surface runoff. Quantization of water conservation function was used the method of rainfall storage. Formula is as follows:

$$Q_w = J \times R \times A = 0.55 \times J \times A \times VC \quad (1)$$

$$J = J_0 \times K \quad (2)$$

$$R = R_0 - R_g \quad (3)$$

$$VC = (NDVI - NDVI_s) / (NDVI_v - NDVI_s) \quad (4)$$

$$NDVI = \frac{R_{nir} - R_{red}}{R_{nir} + R_{red}} \quad (5)$$

where Q_w is the annual rainfall storage of ecosystem, m^3/a ; J is runoff from rainfall, mm; J_0 is the total rainfall, mm; K is the proportion rainfall runoff accounted for the total rainfall; R is efficiency coefficient of ecosystem runoff reduction, as ompared with bare land; R_0 is the rainfall runoff rate of bare land; R_g is the rainfall runoff rate of ecosystem; VC is the vegetation coverage, %; A is the acreage of region, m^2 ; $NDVI$ is normalized difference vegetation index; $NDVI_v$ is the maximum of $NDVI$; $NDVI_s$ is the minimum of $NDVI$; R_{nir} is the infrared spectral reflectance; R_{red} is the red spectral reflectance. K value is calculated based on daily rainfall data, this study used 0.4 based on the existing research results [11].

$$V_{cw} = Q_w \times c_r \quad (6)$$

where V_{cw} is the annual water regulation value, Yuan/a; Q_w is the annual rainfall storage of ecosystem, m^3/a ; c_r is the unit capacity cost of reservoir construction, Yuan/ m^3 . According to China Water Conservation Yearbook from 1993 to 1999, the unit capacity cost of reservoir construction is 2.17 Yuan/t. In the light of Beijing's consumer fixed base Fixed price index, the c_r is 7.54 Yuan/t in 2013.

$$V_{pw} = Q_w \times p_w \quad (7)$$

where V_{pw} is the annual water purification value, Yuan/a; Q_w is the annual rainfall storage of ecosystem, m^3/a ; p_w is the water purification cost, replaced with the

average price of residential water in Beijing, that is 4 Yuan/ m^3 in 2013.

$$V_w = V_{cw} + V_{pw} \quad (8)$$

where V_w is the annual water conservation value, Yuan/a; V_{cw} is the annual water regulation value, Yuan/a; V_{pw} is the annual water purification value, Yuan/a.

3 Results and analyses

FSFV has high vegetation coverage over 80%, which means that water conservation function is the vital ecosystem service in this valley. The average annual rainfall in this vally was 518.18 mm, close to the average of overall Beijing mountainous valleys. The water conservation capacity of FSFV in 2013 was 1101.13 m^3/hm^2 , amount to 21.25% of annual average rainfall, higher than the capacity of overall mountainous valleys (1016.66 m^3/hm^2), which pointed that FSFV had the highest water conservation function in Beijing valleys. Annual total amount of water conservation was $31.20 \times 10^6 m^3$, accounting for 10.07% of Beijing mountainous valleys.

Water conservation function within the ditch showed significant spatial differences (Figure 3). High water conservation capacity areas were mainly located in the eastern mountainous region which was centralized distribution of broadleaf forest, followed by the northern and southern regions which mainly had shrub forest distribution. Low water conservation function areas were mainly in the western gently topography parts, regions along the road and the population concentrated areas. Those places was effected by human activities obviously, resulted in severely damaged vegetation and large intensity of land use which the land use types were farmland, orchard land and construction land with poor water conservation capacity. Other water conservation capacity areas had sparse vegetation coverage, low rainfall, with dominant land cover types of shrub forest and grassland.

Figure 3. Spatial Distribution of Water Conservation Function of FSFV in 2013

Different ecosystem types had different water conservation capacity. Forest ecosystem had the highest capacity of water conservation, with the index value of $1116 \text{ m}^3/\text{hm}^2$, while construction ecosystem had the lowest capacity of $955 \text{ m}^3/\text{hm}^2$. The water conservation capacity showed apparent characteristics, that was natural ecosystem types were higher than artificial ecosystem types. Higher degree of human activities, lower capacity of water conservation. Although farmland ecosystem was dominant in FSFV for valley economy, but the capacity of artificial ecosystem types was farmland > orchard > construction.

Toward to the forest ecosystem with highest water conservation capacity, different forest types varied obviously in water conservation function. Shrub forest and broadleaf forest had the largest contribution on valley water conservation, with contribution rate of 36.35% and 35.62% (cumulative contribution rate of 71.97%), while the contribution rate of coniferous forest and mixed forest was 6.33% and 4.04%. In light of water conservation capacity, broadleaf forest had the highest value of $1135 \text{ m}^3/\text{hm}^2$, followed by coniferous forest of $1125 \text{ m}^3/\text{hm}^2$. Shrub forest had the lowest capacity with value of $1098 \text{ m}^3/\text{hm}^2$, but had the largest quantity of water conservation for the largest acreage.

The value of water conservation in FSFV was 3.61×10^8 Yuan in 2013, with 2.36×10^8 Yuan of water regulation value and 1.25×10^8 Yuan of water purification value accounting for 62.34% and 34.66% of the total water conservation value respectively. To the unit area value, the FSFV was 11991 Yuan/ hm^2 of water conservation, 8303 Yuan/ hm^2 of water regulation, and 4405 Yuan/ hm^2 of water purification.

4 Conclusions

Water conservation function and value of Four Seasons Flower Valley (FSFV) was investigated and assessed by method of remote sensing, GIS integrated technology and ecological economy in 2013 after being listed as of seven key valleys in Beijing mountainous area in 2011 by Beijing Municipal Commission of Rural Affairs. The results showed that:

(1) Regional structure of land use and land cover in FSFV was forest land-cultivated land-grassland based on SPOT5 images in 2013. Farmland ecosystem was the dominant artificial type with proportion more 12%, while forest ecosystem was major natural type with proportion over 80%. The primary forest types in FSFV are broadleaf forest, coniferous forest, mixed forest and shrub forest, the proportion respectively was 34.58%, 6.20%, 4.02% and 36.47%.

(2) FSFV had the highest water conservation function in Beijing valleys, with the water conservation capacity of $1101.13 \text{ m}^3/\text{hm}^2$, higher than the overall valleys ($1016.66 \text{ m}^3/\text{hm}^2$). Annual total amount of water conservation was $31.20 \times 10^6 \text{ m}^3$, accounting for 10.07% of Beijing mountainous valleys. The value of water conservation in FSFV was 3.61×10^8 Yuan, with 2.36×10^8 Yuan of water regulation value and 1.25×10^8 Yuan of water purification value. Water conservation function

showed significant spatial differences. High water conservation capacity areas were mainly located in the eastern mountainous region which was centralized distribution of broadleaf forest. Low water conservation function areas were mainly in the regions effected by human activities obviously, the land use types were farmland, orchard land and construction land.

(3) Different ecosystem types had different water conservation capacity. Forest ecosystem had the highest capacity of water conservation, with the index value of $1116 \text{ m}^3/\text{hm}^2$, while construction ecosystem had the lowest capacity of $955 \text{ m}^3/\text{hm}^2$. Natural ecosystem types were higher than artificial ecosystem types. Higher degree of human activities, lower capacity of water conservation. Different forest types varied obviously in water conservation function. Shrub forest and broadleaf forest had the largest contribution on valley water conservation, with contribution rate of 36.35% and 35.62%. Ranking of water conservation capacity, broadleaf forest had the highest value of $1135 \text{ m}^3/\text{hm}^2$, followed by coniferous forest, shrub forest and mixed forest.

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References

1. K.J. Yu, S.S. Wang, D.H. Li, et al. Ecological baseline for Beijing's urban sprawl: Basic ecosystem services and their security patterns. *City Plann. Rev.* 34(2), 19-24 (2010)
2. X.X. Yu, B. Zhou, X.Z. Lv, et al. Evaluation of water conservation function in mountain forest areas of Beijing based on InVEST model. *Sci. Silvae Sin.* 48(10), 1-5 (2012)
3. G.D. Xie and S.Y. Cao. Ecological economization and economic ecologization in succession progress of development. *Resour. Sci.* 32(4), 782-789 (2010)
4. Y.F. Zhang, D.M. Jia, J. Tan, et al. The spatial structure of valley economy development in the mountainous areas of Beijing. *Acta Geog. Sin.* 64(10), 1231-1242 (2009)
5. J.H. Chen, H. Li, and L.D. Zhou. Gully economy development's exploration and practice in Beijing mountain area. *Ecol. Econ.* (1), 57-62 (2010)
6. Y. Liu, W.B. Zhu, Y. Han, et al. Regionalization of water conservation function of Beijing-Tianjin-Hebei Area based on SOFM neural network. *Res. Environ. Sci.* 28(3), 369-376 (2015)
7. B. Fu, P. Xu, Y.K. Wang, et al. Spatial pattern of water retention in Dujiangyan County. *Acta Ecol. Sin.* 3(3), 789-797 (2013)

8. B.J. Yang, J.X. Gao, and C.X. Zou. The strategic significance of drawing the ecological protection red line. *Chin. Dev.* 14(1), 1-4 (2014)
9. J.M. Qin, W.Q. Yang, and J. Zhang. Assessment of ecosystem water conservation value in the Upper Minjiang River, Sichuan, China. *Chin. J. Appl. Environ. Biol.* 15(4), 453-458 (2009)
10. W.L. Jiang. Theory and method to accounting value of forest water conservative. *J. Soil Water Conserv.* 17(2), 34-36 (2003)
11. T.Q. Zhao, Z.Y. Ouyang, H. Zhen, et al. Forest ecosystem services and their valuation in China. *J. Nat. Resour.* 19(4), 480-491 (2004)