

Chapter 11

Vision and Possibilities in Ecosystem Services of a Cultural Landscape: A Case Study in the Yanhe Watershed

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Abstract With increasing anthropogenic influences in the biosphere, the nature is gradually being encroached by human activities, which affect its capacity of providing ecosystem services. In this study, we took the Yanhe Watershed of China as a study area to evaluate ecosystem services and their human driving mechanisms. Net primary production (NPP), carbon sequestration & oxygen production (CSOP), water conservation, soil conservation, and grain production were selected for ecosystem services. A quantitative human activity index (HAI) was formulated based on human population, farmland ratio, road networks, and residential areas. Landscape metrics were also used to quantify the land use change.

The results showed that, except the grain production, the regulating and supporting ecosystem services increased from 2000 to 2008, which demonstrated a conflict of tradeoffs. Spatially, ecosystem services showed conspicuous spatial patterns. Correlation analysis showed that soil conservation and water conservation are closely linked. HAI decreased from 2000 to 2008 with the center area decreased more than the peripheral area. Correlations analysis showed that the decreasing HAI significantly improved the soil and water conservation.

The landscape metrics analysis showed that watershed had a fragmentation tendency, simplification in shape, and enhanced patch connectiveness. For individual land use types, cropland had a strong tendency of fragmentation; grassland had an anti-fragmentation tendency; while forest didn't vary greatly.

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11.1 Introduction

Cultural landscape was first broadly defined as “landscape modified by human activity” by German geographer Ratzel (Jones 2003). American Geographer Sauer (1925) noted that ‘the cultural landscape is fashioned from natural landscape by a cultural group. Culture is the agent, the natural are the medium, the cultural landscape is the result’. The World Heritage Committee stressed the role of interaction between man and nature in shaping the cultural landscape. In 1992, the World Heritage Convention categorized three types of ‘cultural landscape’s according to their ‘tangibility’: (1) “clearly defined landscapes designed and created intentionally by humans”, (2) “organically evolved landscapes” resulting from successive interactions between people and natural environment, and (3) “associative cultural landscape” that have religious, artistic or cultural associations (UNESCO 1996). Outwardly, human-nature interactions of cultural landscape have apparent endemic characteristics, e.g., rice-fish agriculture (China), Maeul (Korea), Satoyama (Japan), Dehesa (Spain), Terroir (France) etc.

Since 1960, the concepts of ‘cultural landscape’ surged in the fields of human geography, anthropology, and environment management, which partially due to the fast pace human influence the ecosystem services. Nowadays, humans appropriate about 24 % of the Earth’s terrestrial net primary productivity (Haberl et al. 2007), and almost all ecosystems and landscapes around the world have been influenced or even “domesticated” by humans (Kareiva et al. 2007). The general ecosystem demonstrated a tendency of structural damage and functional disorder.

As “cultural landscape” embraces a diversity of interactions between human and the environment, the fast pace of human’s alteration on landscape advance the research in cultural landscape. The mere qualitative depiction of cultural landscape (e.g., the categorization by World Heritage Convention) retards a deep understanding of its origin, causing missed opportunities to tighten the connections between human beings and the physical environment. How to quantify the mechanism underlying cultural landscape remains a tough challenge. Forman and Godron (1986) advanced a landscape modification gradient pattern of natural – managed – cultivated – suburban – urban to analyze the human influences on the structure and function of landscapes. Based on the principle of ‘disturbing intensity’ and ‘regenerative capacity’, Naveh (1998) classified landscapes according to their energy inputs, self-organizing, and regenerative capacities on photosynthetic conversion of solar energy as: (1) “solar-powered” semi-natural and managed landscapes; (2) “intensive agro-industrial” landscapes; and (3) “technosphere” landscapes. Such analysis methods play key role in testing the relations between human society and nature, yet they fail to go any further than a qualitative portrait of cultural landscape.

At large scale, human affects the ecosystem by altering the land use pattern, which further impairs its functions in providing ecosystem services. Ecosystem service, human activities, and land use forms the core ‘actors’ of cultural landscape. Ecosystem services were widely defined as the conditions and processes through

which natural ecosystems, and the species that make them up, sustain and fulfill human life (Daily 1997). The Millennium Ecosystem Assessment (MA 2005) popularized the term of ‘ecosystem services’ and divided it into provisioning, regulating, supporting, and cultural services. In a regional scale, human activity affected ecosystems by altering land use pattern, biogeochemical and hydrological cycles. Fast social and economic development, characterized by industrialization, urbanization, population growth exacerbates the conflicts between high requirements for natural resources and the sustainable social and economic development in the long run. We intend to take Yanhe watershed of the Loess Plateau of China as a study area, to explore the mechanism of cultural landscape by tapping the interrelations between ecosystem services, human activities, and land use. The major aims are as:

1. Quantify ecosystem services, probe the interrelation, and analyze their anthropogenic driving forces;
2. Quantify the land use change through landscape metrics analysis;
3. Ecological management suggestion based on ecosystem service and human activity.

11.2 Methods

11.2.1 Study Sites

As a ‘cradle’ of Chinese civilization, the Loess Plateau is plagued notoriously by serious soil erosion. The Yanhe Watershed is located in the central Loess Plateau, with a geographic coordinate of 36°21′–37°19′N, 108°38′–110°29′E (Fig. 11.1). Thick mantle of loess, dry climate, and complex topography causes droughts, floods, and soil erosion. Fast population growth, clearance of natural forests, urban sprawling, farmland expansion, over exploitation of oil further degraded the ecological conditions. The area has a warm temperate continental monsoonal climate, with multi-year mean temperature ranging from 8.8 to 10.2 °C. Within the meager annual precipitation of 495 mm, over 65 % falls from June to September. Such uneven rainfall is likely to cause high erosive storm-lit. The Yanhe Watershed is mantled by thick loess, an erosion-prone fine silt soil. As a rugged area, over 90 % of the Yanhe Watershed was composed by gullies and ridges. For long history, farming is the pivotal means of livelihood (embodied by the high ratio of agricultural population of 82 %). In total there are 35 towns in this region under the administration of Yan’an City.

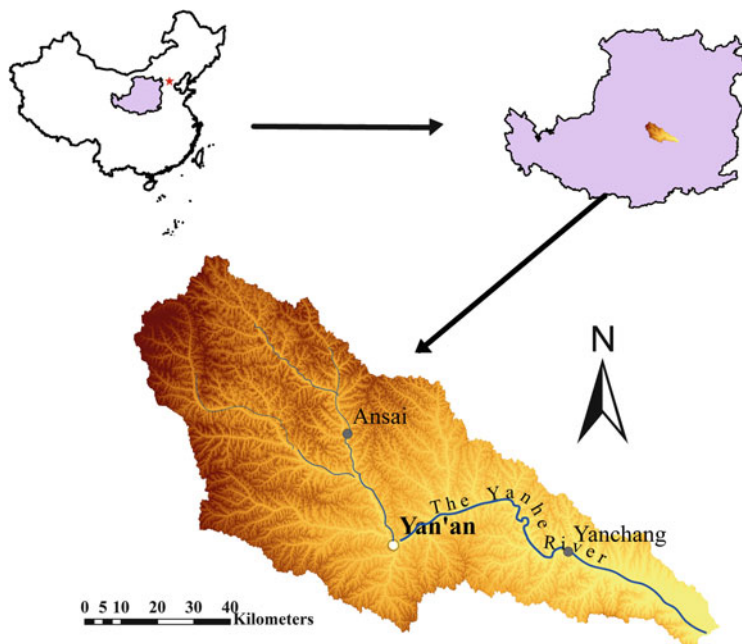


Fig. 11.1 Location of study area

11.2.2 Indicators Selection

The major ecological problems facing Yanhe Watershed are vegetation degradation, water loss, and soil erosion. Moreover, the practice of Grain for Green (GfG) project strongly affected the agricultural production. In such context, we selected net primary production (NPP), carbon sequestration & oxygen production (CSOP), water conservation, soil conservation, and grain production as indices for ecosystem services.

As a major driving force for social and economic development, population is a must for human activity assessment. In Yanhe Watershed, the increasing population leads to expanding demand for farm produce and natural resources. Rapid economic development drives urban sprawling rapidly. Under such context, we selected human population, farmland ratio, influence of residential settlement, and influence of road network as indices for human activity assessment.

Landscape metrics was applied to quantify the land use change. Although relevant software makes it possible to calculate large number of landscape metric indices, high correlations existing within some indices imply that selection too much index is not necessary. In this study, we selected 12 landscape metrics index of three groups: (1) area/density/edge metrics: class area (CA), number of patches (NP), patch density (PD), edge density (ED), landscape shape index (LSI), and largest patch index (LPI); (2) shape metrics: perimeter-area ratio (PARA), shape

index (SHAPE), continuity index (CONTIG), and fractal dimension index (FRAC); (3) contagion/interspersion metrics: aggregation index (AI) and splitting index (SPLIT).

11.2.3 Quantification of Ecosystem Services

NPP was calculated by the process-based Carnegie-Ames-Stanford Approach (CASA) model based on the principle that plant productivity is correlated with the amount of photosynthetically active radiation absorbed or intercepted by green foliage (Monteith and Moss 1977; Potter et al. 1993). According to the photosynthetic equation, the ratio of organic matter produced, and carbon sequestered, and oxygen released by the photosynthesis process is 1:1.47:1.07. The volume of CSOP was calculated from NPP based on this ratio. Vegetation conserves water through the process of rainfall interception, evapotranspiration, sorption and storage (Li et al. 2006). Water conservation was calculated by summation of rainfall intercepted by the processes of canopy retention, litter absorption, and soil storage. Soil conservation is calculated by the empirical model of RUSLE (Revised Universal Soil Loss Equation). Grain production was obtained from the statistical data, in which, grain yield was divided by the township area, and then input to the attribute table of vectorized township administrative map for spatialization.

11.2.4 Quantification of Human Activities

We formulated an integrative human activity index (HAI) based on human population, farmland ratio, road network influence, and residential influence. The weights of these four factors were assigned by Analytic Hierarchy Process (AHP) as: human population 0.3, farmland 0.3, road influence 0.2, and residential influence 0.2. The equation is as follows:

$$\text{HAI} = P \times 0.3 + C \times 0.3 + R \times 0.2 + S \times 0.2$$

Where: P, C, R, and S stand for the standardized human population, farmland ratio, road network influence, and the residential influence respectively. By reference to the State Basic Geographical Data Coding System, we assigned the values of influences to residential site and road network (Su et al. 2012).

11.2.5 Quantification of Landscape Metrics Index

Three sets of satellite images (Landsat TM for 1995 and 2000, and one Cbers-2B for 2008) were interpolated and calibrated with field survey. The data were classified in six domains: (1) cropland, including dry cropland of various slope and irrigated cropland; (2) woodland, including evergreen coniferous woodland, deciduous broad-leaf woodland and mixed broadleaf-conifer woodland; (3) grassland, including typical grassland and shrub land; (4) construction land, including urban construction land, rural settlement, and transportation facility areas; (5) water body, including swamp, lake, river, and wetland; and (6) wasteland, including naked rocks, bare land, and sand land. These vectorized images were converted into grid format of 30 m resolution to calculate landscape metrics by the software of FRASTAT 3.3.

11.2.6 Data Sources

MODIS images of 1-km resolution of 2000 and 2008 (for NPP, CSOP) were downloaded from internet (<http://labsweb.nascom.nasa.gov/data/search.html>). Land use data (for soil/water conservation, land metrics) were extracted from Landsat TM image (2000) and Cbers-2B image (2008). Topographical data (for soil conservation) was obtained from 1:50,000 digital elevation map (DEM). Soil types (for soil conservation) were obtained from the 1:50,000 soil map. Precipitation (for soil/water conservation) and temperature (for NPP and CSOP) were obtained from the Meteorological Bureau of Yan'an City. Grain production, human population, and cropland ratio (for HAI) were obtained from statistical data. Township administrative maps (for ecosystem services allotting) and residential sites (for HAI) were obtained from local civil affairs department. Road network map (for HAI) were extracted from atlases of Shaanxi Province.

11.3 Results

11.3.1 Spatiotemporal Patterns of Ecosystem Services and HAI

11.3.1.1 NPP and CSOP

In 2000, NPP/CSOP demonstrated a gradient increasing tendency from northwest and southeast to the southwest. 2008 saw a big increase of NPP/CSOP across the whole area. The spatial pattern of NPP/CSOP showed a difference from that of

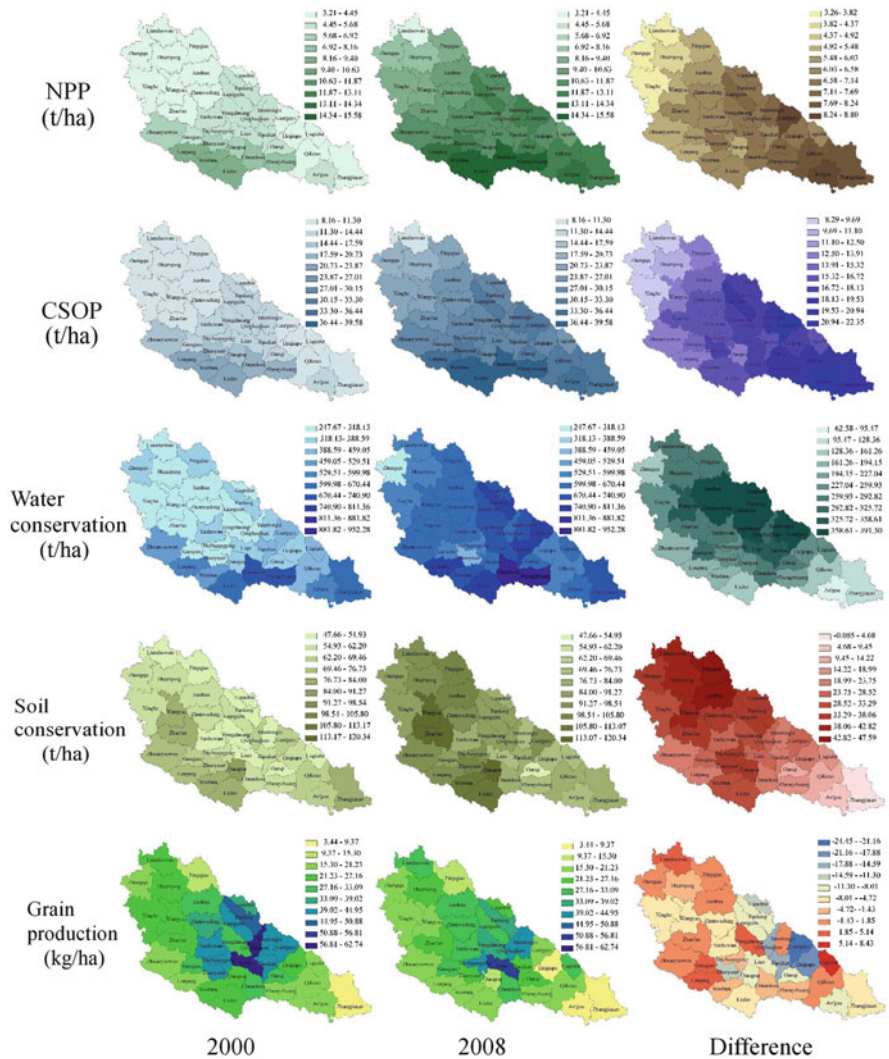


Fig. 11.2 Spatial variation of ecosystem services. Grain production was calculated through dividing the grain yield by the territory area of the township. The variation of ecosystem services was obtained through subtraction of ecosystem service images of 2008 by those of 2000. *NPP* net primary production, *CSOP* carbon sequestration and oxygen production

2000, with high *NPP*/*CSOP* townships distributed more eastward. The increment of *NPP*/*CSOP* assumed a spatial pattern of gradual increasing from the northwest to the southeastern (Fig. 11.2).

11.3.1.2 Water Conservation

Water conservation in 2000 assumes a rough increasing tendency from the northwest to the southern fringe. In 2008, the spatial pattern is somewhat obscure with some high water conservation townships in the north. Water conservation is greatly increased from 2000 to 2008 with a spatial pattern of fanning-out decreasing from the northeast to the surrounding area (Fig. 11.2).

11.3.1.3 Soil Conservation

Soil conservation in both 2000 and 2008 shows somewhat obscure spatial pattern. In 2000, soil conservation shows a spatial pattern high in the south and low in the north, which changed greatly in 2008 as high in the west and low in the east. Temporally, soil conservation is greatly increased from 2000 to 2008, with a conspicuous spatial pattern of gradual increase from southeastern to the northwestern (Fig. 11.2).

11.3.1.4 Grain Production

Grain production in both 2000 and 2008 demonstrated a centrifugally decreasing tendency fanning out from the center to the peripheral area. Temporally, grain production decreases for the bulk of the area (26 out of 35 townships). The remaining 9 townships shows a marginal increasing ranging from 0.17 kg/ha to 8.43 kg/ha. Overall, grain production decreased by 17.25 % from 27.59 kg/ha in 2000 to 22.83 kg/ha in 2008 (Fig. 11.2).

11.3.1.5 HAI

HAI of both 2000 and 2008 demonstrated a gradient decreasing tendency from the urban area through the surrounding area to the remote area. The total area underwent a sharp decrease from 2000 to 2008 in HAI with a distinct spatial pattern of converging from the peripheral area to the northwest (Fig. 11.3).

11.3.2 Correlations and Tradeoff Analysis

Using SPSS 11.5, we analyzed the correlations of the differences of each individual ecosystem service and that of HAI between 2000 and 2008 on basis of township. Two pairs of significantly negative correlations (at 0.01 levels) were observed between soil conservation and HAI and between water conservation and HAI,

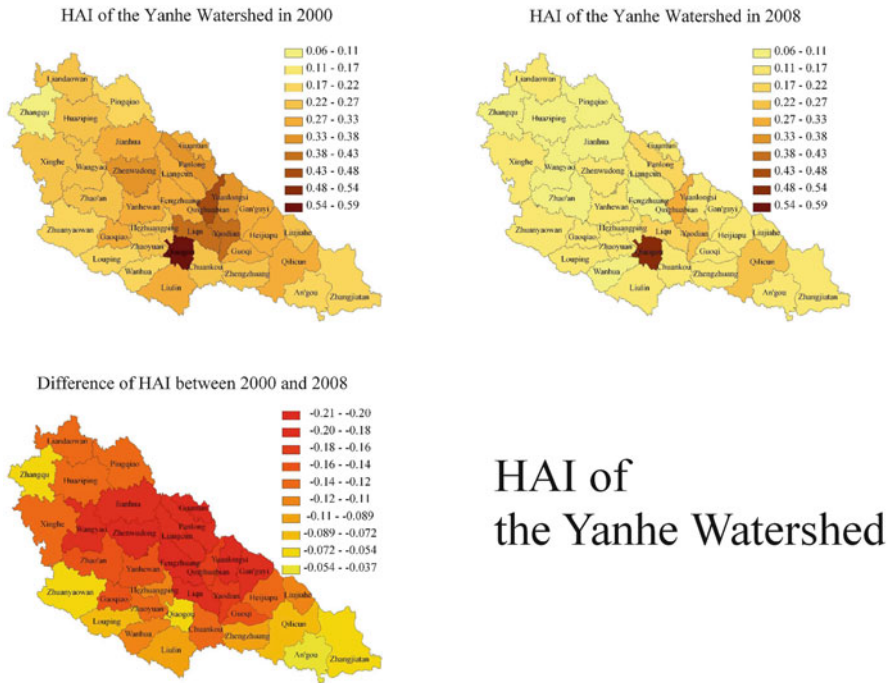


Fig. 11.3 Spatial variation of HAI. HAI is dimensionless

which demonstrated that the decreasing HAI significantly enhance soil and water conservation (Table 11.1). Within the ecosystem services, soil conservation and water conservation are significantly positive correlated (at 0.01 levels). Grain production is negatively correlated with NPP/CSOP (Table 11.1). As CSOP is deducted from NPP, the two is naturally highly positive correlated. ‘Spider diagram’ is a simple yet powerful approach in portraying tradeoffs between ecosystem services. We divided each individual ecosystem services of 2008 by that of 2000 to show their temporal variations. A quotients-based spider diagram shows tradeoff existing between provisioning services vs. regulating and supporting services (Fig. 11.4).

11.3.3 Landscape Metrics Index

Due to the inception of GfG project from 1998, the Yanhe Watershed underwent a conversion from cropland to woodland and grassland from 2000 to 2008, e.g., 165,800 ha and 8,477 ha cropland were converted to grassland and woodland respectively.

Table 11.1 Correlations of ecosystem services and HAI

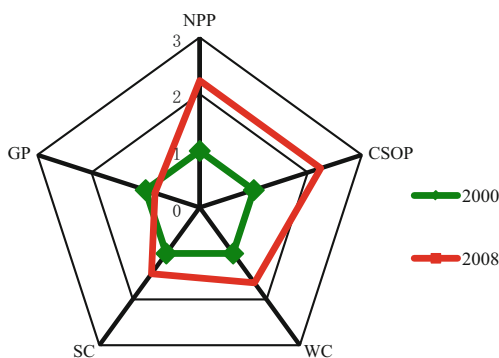
	NPP	CSOP	SOIL	WATER	GRAIN	HAI
NPP	1	1**	-0.600*	-0.004	-0.423*	-0.070
CSOP	1**	1	-0.600*	-0.004	-0.423*	-0.070
SOIL	-0.600**	-0.600**	1	0.561**	0.106	-0.489**
WATER	-0.004	-0.004	0.561**	1	-0.212	-0.957**
GRAIN	-0.423*	-0.423*	0.106	-0.212	1	0.185
HAI	-0.070	-0.070	-0.489**	-0.957**	0.185	1

NPP net primary production, *CSOP* carbon sequestration & oxygen production, *SOIL* soil conservation, *WATER* water conservation, *GRAIN* grain production, *HAI* human activity index

**Correlation is significant at the 0.01 level (two-tailed)

*Correlation is significant at the 0.05 level (two-tailed)

Fig. 11.4 Diagram illustrating the trade and synergy between ecosystem services. Individual ecosystem service of 2008 was divided by that of 2000 to show their temporal variation



11.3.3.1 For the Total Landscape

NP and PD increased from 1995 to 2008, indicating a fragmentation tendency (Fig. 11.5). ED slightly increased from 1995 to 2000 and then decreased sharply after 2000, indicating a simplification in shape (Fig. 11.5). LSI and PARA remained relatively stable from 1995 to 2000 and then decreased after 2000, well echoing the ED. CONTIG decreased slightly between 1995 and 2000 and then increased drastically after 2000, indicating an enhanced contiguity. AI showed a decrease-and-increase curve from 1995 to 2008, which is in sharp contrast to SPLIT, indicating more aggregated patches (Fig. 11.5). Both SHDI and SHEI increased slightly between 1995 and 2000 and decreased sharply after 2000, implying a diversification and even-distribution tendency (Fig. 11.5). FRAC decreased linearly from the whole period from 1995 to 2008, while LPI decreased slightly before 2000 and increased after 2000, indicating more frequency of large patches (Fig. 11.5). In conclusion, land use in the Yanhe Watershed assumed a fragmentation tendency, with a simplification and uniformity in patch shape.

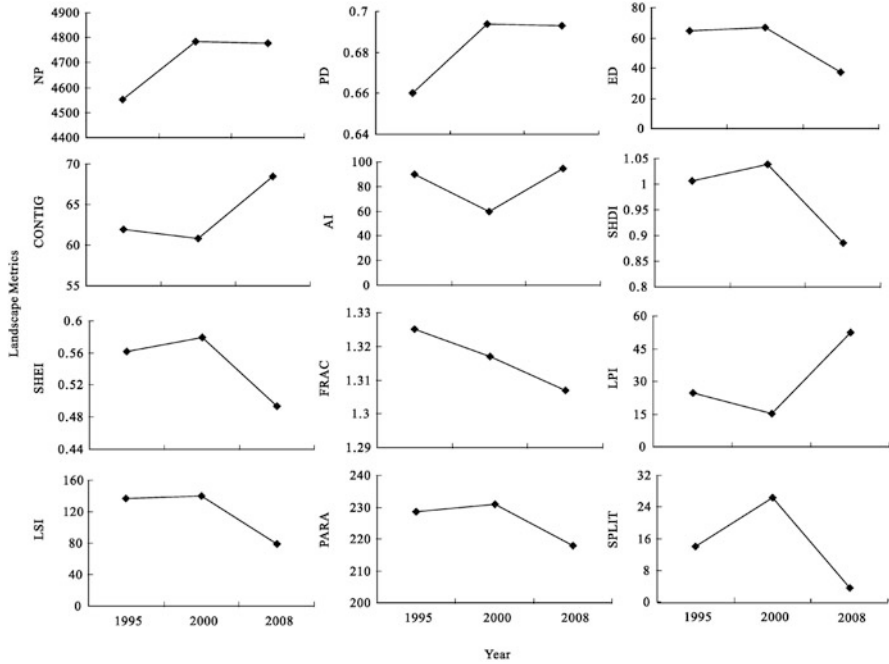


Fig. 11.5 Changes of landscape metrics at landscape level. *NP* number of patches, *PD* patch density, *ED* edge density, *CONTIG* continuity index, *AI* aggregation index, *SHDI* Shannon’s diversity index, *SHEI* Shannon’s evenness index, *FRAC* fractal dimension index, *LPI* largest patch index, *LSI* landscape shape index, *PARA* perimeter-area ratio, *SPLIT* splitting index

11.3.3.2 For Different Land Use Types

The landscape metrics of different land use types varied greatly. (1) For cropland, the decreasing CA versus increasing NP & PD indicate fragmentation tendency of cropland, which was well echoed by the gradual decrease of LPI (Fig. 11.6). LSI, SHAPE, and ED of cropland decreased, implying a simplifying tendency of shape. The increase of SPLIT of cropland implied the patches are more separated (Fig. 11.6). (2) For grassland, the increasing CA versus decreasing NP & PD demonstrates an anti-fragmentation tendency. The ascending LPI demonstrated that large and continuous patches appeared in grassland (Fig. 11.6). Similar to cropland, the grassland also demonstrated a simplification in shape implied by the decrease of LSI, SHPAE (Fig. 11.6). The increase of AI indicated that grassland patches are more aggregated. (3) For woodland, Landscape metrics varied very slightly possibly due to the woodland’s strong resilience to environmental change and the difficulties of woodland’s regenerating with high requirements for site condition. As the other three land use types of construction land, water body, and wasteland occupied very small area, the landscape metric index of which are likely diluted by even small systematic error and can not reflect much spatial pattern.

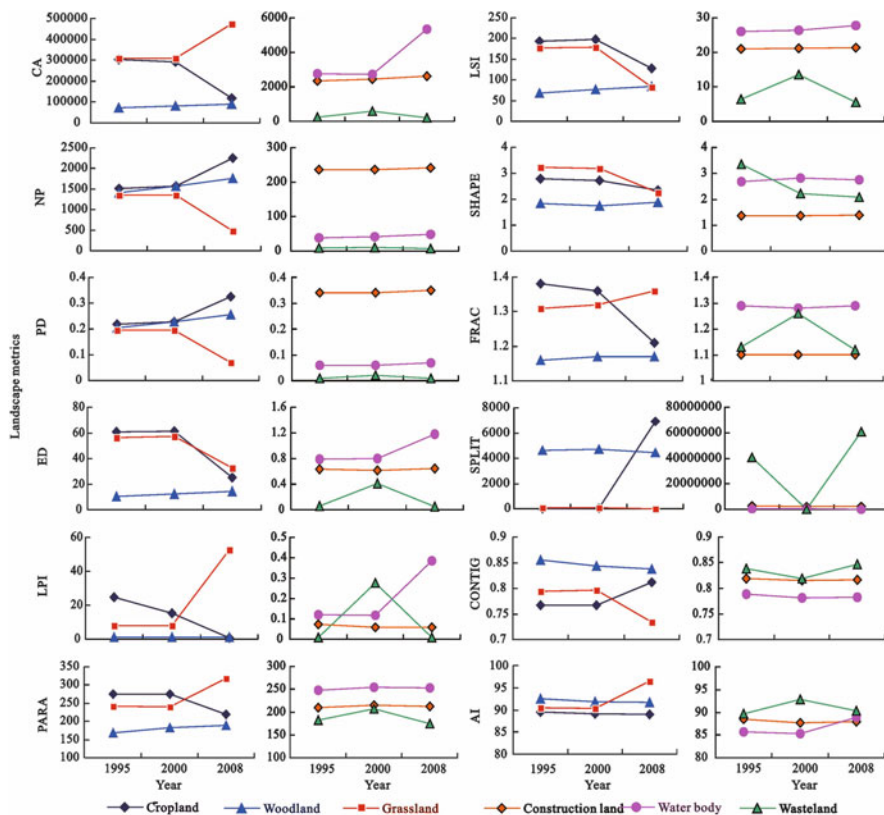


Fig. 11.6 Changes in landscape metrics at class level. *CA* class area, *NP* number of patches, *PD* patch density, *ED* edge density, *LPI* largest patch index, *PARA* perimeter-area ratio, *LSI* landscape shape index, *SHAPE* shape index, *FRAC* fractal dimension index, *SPLIT* splitting index, *CONTIG* continuity index, *AI* aggregation index. Every two neighboring subplots in one row share the same y-axis

11.4 Discussion

The interaction between man and nature brings about cultural landscapes which constitute a testimony of the past and present relationships between society and its environment. Ratzel’s concise definition of cultural landscape as ‘landscape modified by human activity’ provided a basic direction, yet failed to provide an operable methodology on quantifying the mechanism underlying cultural landscape. Recognition and categorization by World Heritage Convention as cultural landscape were strongly biased by ‘culture’, without touching the ‘scientific’ essence. Big challenges in cultural landscape research lie in distilling the ‘plausible’ indicators and seeking the suitable quantifying methods, either by empirical analysis or by models. Here we selected five ecosystem services endeavoring to depict the general

ecological situation of the study area. We also attempt to grasp the basic human activity underlying the ecosystem services by formulating an integrative HAI. As the most explicit manifestation human exert on ecosystem is land use, we quantified the land use through analyzing a series of landscape metrics index. The possible vision/ possibility of cultural landscape lie in:

11.4.1 The Tradeoff Between Ecosystem Services

Ecosystem services offer an operable concept for quantifying the capability cultural landscapes provide the natural assets for humans. Ecosystem services are diverse, including ‘intangible’ supporting and regulating services that underpin life on Earth, as well as ‘tangible’ goods which are directly or indirectly involved in the social, ecological, economical, and cultural sectors (MA 2005). Potential interlinks exist within different ecosystem services due to the common drivers therein. Ecosystem services are strongly scale-dependent. Interlinks of ecosystem services are also contingent to the scales. Such relations boil down to tradeoff and synergy, with the former being more significant for enacting a prudent ecological policy. Ignoring tradeoff is prone to cause double counting in economic valuation of ecosystem services (Fu et al. 2011). In our research, the increase of grain production and other supporting and regulating services forms conspicuous tradeoff, which constitute the core of the GfG project, i.e., balancing agricultural production and ecological renovation.

11.4.2 The Challenge in Human Activity Quantification

As integral players or agents of the cultural landscape, humans play significant roles in shaping the landscape and influencing the relations between biotic species and abiotic environment. Quantifying the human activity remains a tough challenge as there is various uncertainties and bias, especially for the most unquantifiable factor – policy. Selection of the right indicators is a challenge as human activity is endemic and there is no ubiquitous rule across different localities. The rationale of our selection of HAI composing factors is based on series factors closely related to the GfG projects, i.e., farming shrinkage, population transfer, countryside upgrading movement, and urban development. Of cause the weights we assign for each indicators is not without biasness, which calls for further improvement.

11.4.3 Lack of Ecological Implication of Landscape Metrics

The ultimate purpose of landscape metrics analysis is quantifying the interrelations between landscape pattern and ecological process. Unfortunately, current landscape metrics index were established at the early stage of landscape ecology, which stress the mathematical statistics, geometry characteristics, and spatial relations, yet neglect the potential ecological meaning. Consequently, the landscape metrics is sensitive to the classifying system of the data sources, and the sampling scale, but not sensitive to the landscape function. In our study, we tried but failed to build a quantitative links between ecosystem services and the land use metrics. Even so, we settle for a links between the variation of ecosystem services and the variation of finer land use types (Table 11.2). The result shows that the increase of grassland facilitates soil & water conservation; the increase of forest helps to enhance water conservation; shrinkage of slope farmland of 10–25° plays significant roles in improving soil & water conservation.

11.4.4 Human-Nature Research and Its Implication in Ecosystem Management

Human nature relation constitutes the core of cultural landscape, which has high potentials in ecosystem management. The IUCN Commission for ecosystem management (IUCN-CEM) defined that ‘ecosystem management is a process integrating ecological, social-economic, and institutional factors into a comprehensive analysis and action in order to sustain and enhance the quality of the ecosystem to meet current and future needs’ (Pirot et al. 2001). This definition necessitates the imbedding of Coupling Human and Nature System (CHANS) in the ecosystem management process. Unfortunately, due to the influence of ‘Ecological Determinism’ (Paine 1984), the traditional ecosystem management excessively stressed physical conditions, and neglected human factors. Based on ecosystem services and HAI of 2008, we used SPSS 11.5 software, clustering the Yanhe Watershed townships into four groups (Fig. 11.7). Suggestions for ecosystem management were also provided catering to each group as: (1) group 1 (urban area): As the economic and political center, this area should be given full use of secondary and tertiary industries to create more job opportunities to absorb the influx of population from ecologically vulnerable areas. Forest parks, city greenbelt, wetland park, and urban river system should be established. Tourism should be developed as various revolutionary historic relics are scattered through the area. (2) Group 2 (suburban area) is the most productive both in agriculture and industry. The farming system should be enhanced by increasing high value-added sideline productions, such as animal husbandry and cash crops. Intensified farming should be practiced, e.g., advanced irrigation techniques, agricultural mechanization, and high-yield varieties. Conservation farming practices, such as straw mulching, and reduced or eliminated tillage, should be encouraged to curb

Table 11.2 Correlation between ecosystem services and land use change

	Slope cropland									
	Forest	Shrub	Grassland	<5°	5–10°	10–15°	15–20°	20–25°	>25°	
NPP	0.032	-0.143	0.084	0.177	0.371*	-0.007	-0.251	0.206	0.620**	
CSOP	0.032	-0.143	0.084	0.177	0.371*	-0.007	-0.251	0.206	0.620**	
SOIL	0.306	-0.046	0.512**	-0.099	-0.313	-0.525**	-0.340*	-0.654**	-0.550**	
WATER	0.435**	0.021	0.946**	-0.159	-0.232	-0.937**	-0.915**	-0.729**	-0.121	
GRAIN	-0.075	0.221	-0.314	-0.162	-0.07	0.254	0.367*	-0.015	-0.206	

NPP net primary production, *CSOP* carbon sequestration and oxygen production, *SOIL* soil conservation, *WATER* water conservation, *GRAIN* grain production, *HAI* human activity index

**Correlation is significant at the 0.01 level (two-tailed)

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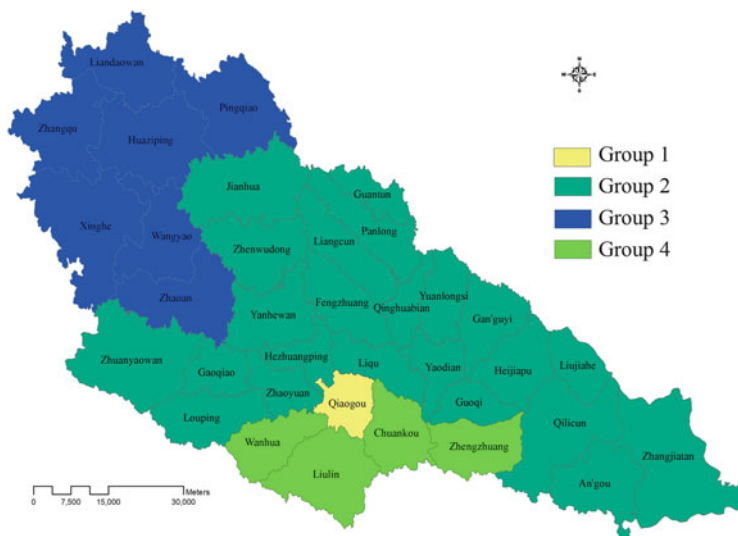


Fig. 11.7 Clustering of townships in the Yanhe watershed based on ecosystem services and HAI

soil and water losses. Check-dam is an advisable engineering measure at the lower reaches to control soil losses. (3) Group 3 (remote farming area), located in the upper reaches of the Yan River, is the most ecologically degraded area. The mountains in this area need to be closed completely in order to allow ecological recuperation. Farmland on slopes over 25° and yield less than 750 kg/ha of grain should be converted to forests or grassland (State Council of the People's Republic of China 1998). Within the GfG project area, the ecological forests should overwhelm the commercial forest. The low ecological capacity of this area necessitates resettlement of the vast population to other areas. (4) Group 4 (ecological shelterbelt) has well-established vegetation coverage and play significant roles in safeguarding the whole watershed. As a shelterbelt, this area should be well nourished. Farming should be prohibited and large populations be resettled. Ecotourism should be enhanced to improve the ecological self-reliance of this area.

11.5 Conclusions

Under the concept of cultural landscape concept, this chapter endeavor to quantify the underlying mechanisms of cultural landscape based on ecosystem services, human activity, and landscape metrics of the Yanhe watershed. The conclusions are as follows:

The regulating/supporting services of NPP, CSOP, water/soil conservation increased during the period of 2000–2008. While the provisioning service of grain production decreased. Tradeoff exists between the regulating/supporting

services and the provisioning services, while slight synergies exist within the regulating services. HAI decreased accordingly, which significantly drives the water/ soil conservation services. Both ecosystem services and HAI have diverse and conspicuous spatial patterns.

The landscape metric indexes implied that Yanhe watershed has a fragmentation tendency, simplification in shape, and enhanced patch connectiveness. For specific land use type, cropland has strong tendency of fragmentation; grassland has an anti-fragmentation tendency; landscape metrics of forest varied mildly.

The coupling ecosystem services and human activity provide a useful means for enacting spatial explicit ecosystem management policy.

References

- Daily GC (1997) *Nature's services: societal dependence on natural ecosystems*. Island Press, Washington, DC, pp 1–49
- Forman RTT, Godron M (1986) *Landscape ecology*. Wiley, New York
- Fu BJ, Su CH, Wei YP, Willett IR, Lü YH, Liu GH (2011) Double counting in ecosystem services valuation: causes and countermeasures. *Ecol Res* 26(1):1–14
- Haberl H, Erb KH, Krausmann F, Gaube V, Bondeau A, Plutzer C, Gingrich S, Lucht W, Fischer-Kowalski M (2007) Quantifying and mapping the human appropriation of net primary production in earth's terrestrial ecosystems. *PNAS* 104(31):12942–12947
- Jones M (2003) The concept of cultural landscape: discourse and narratives. In: Palang H, Fry G (eds) *Landscape interfaces*. Kluwer, Dordrecht, pp 21–51
- Kareiva P, Watts S, McDonald R, Boucher T (2007) Domesticated nature: shaping landscapes and ecosystems for human welfare. *Science* 316(5833):1866–1869
- Li J, Ren ZY, Zhou ZX (2006) Ecosystem services and their values: a case study in the Qinba mountains of China. *Ecol Res* 21(4):597–604
- MA (Millennium Ecosystem Assessment) (2005) *Ecosystems and human well-being*. Synthesis Island Press, Washington DC, pp 1–18
- Monteith JL, Moss CJ (1977) Climate and the efficiency of crop production in Britain. *Philos Trans R Soc B* 281(980):277–294
- Naveh Z (1998) Ecological and cultural landscape restoration and the cultural evolution towards a post-industrial symbiosis between human society and nature. *Restor Ecol* 6(2):135–143
- Paine RT (1984) Ecological determinism in the competition for space: the Robert H. MacArthur award lecture. *Ecology* 65(5):1339–1348
- Pirot JY, Meynell PJ, Elder D (2001) *Ecosystem management: lessons from around the world—a guide for development and conservation practitioners*. IUCN, Cambridge/Gland
- Potter CS, Randerson JT, Field CB, Matson PA, Vitousek PM, Mooney HA, Klooster SA (1993) Terrestrial ecosystem production: a process model based on global satellite and surface data. *Glob Biogeochem Cycles* 7(4):811–841
- Sauer CO (1925) The morphology of landscape. *Univ Calif Publ Geogr* 2:19–53
- State Council of the People's Republic of China (1998) Notice of the state council on printing and distributing the construction and planning of nationwide eco-environment. G.F. [1998] No. 36, Beijing, China, pp 1–7 (in Chinese)
- Su CH, Fu BJ, He CS, Lü YH (2012) Variation of ecosystem services and human activities: a case study in the Yanhe Watershed of China. *Acta Oecol* XXX:1–12
- UNESCO (United Nations Educational, Scientific and Cultural Organization) (1996) *Operational guidelines for the implementation of the world heritage convention*. UNESCO, Paris