Int. J. Environ. Res., 6(2):499-508, Spring 2012
ISSN: 1735-6865

Dynamics of Ecosystem Service Value Caused by Land use Changes in Manas River of Xinjiang, China

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Received 4 Feb. 2011; Revised 19 Oct. 2011; Accepted 2 Dec. 2011

ABSTRACT: This study aims to quantify the impacts of land use changes on ecosystem service value during large scale land development, and to provide key information for both economic development and policy makers for eco-environmental protection. The study area locates in Manas river watershed which is a typical land development region in northwest China. Landsat MSS/TM/ETM+ images in 1976, 1989, 1999 and 2008 were applied to estimate ecosystem service value based on land use, and subsequently ecosystem service value dynamics were analyzed in response to land use changes. It is found that the built-up area and cultivated land increased significantly from 1976 to 2008. The decreasing ecosystem service value (from 17362.2 million Yuan in 1976 to 16975.0 million Yuan in 2008) is mainly caused by the reduced grassland. The combined ecosystem service value of water body and grassland is over 60% of the total value. Functions of water supply, waste treatment, soil formation and retention and biodiversity protection contributed to over 70% of the total service value. The results suggest that a reasonable land use plan should emphasize protection of water body, woodland and grassland as they have the highest ecosystem service value.

Key words: Ecosystem service value, Land use changes, Manas River, Remote sensing, Arid area, Northwestern China

INTRODUCTION

Ecosystem service can be defined as the conditions and processes through which natural ecosystems and the species that comprise them, sustain and fulfill human life, or the goods and service provided by ecosystem which contribute to human welfare, both directly or indirectly (Costanza *et al*., 1997a,b; Daily, 1997), and the valuation of which play an indispensable role in both sustainable ecology and ecological economic research (Li *et al*., 2010b; Wang *et al.*, 2010). In the process of rapid economic development, the changes in ecosystem service value caused by human activities become a focus of public (Zhao *et al*., 2004; Metzger *et al*., 2006; Li *et al*., 2010a), especially because the land use change can alter the structure and functions of the ecosystem (Turner *et al*., 2007), which plays a key role in the maintenance of service function for ecosystem. Thus, it is imperative to evaluate the impacts of land use change on regional ecosystem service. At the micro level, studies on ecosystem service value can offer information on both the structure and functioning of ecosystems, and even the varied and complex roles of the ecosystems played in supporting human welfare; at the macro level, ecosystem valuation contributes to the construction of the human welfare and sustainability indicators (Hewarth ÿ Farber, 2002). Although many researches had been performed on ecosystem service valuation (Sutton & Costanza, 2002; Curtis, 2004; Hein *et al.*, 2006; Chen *et al.*, 2009; Zang *et al.*, 2010), most of them are at the global or country level and little attention have been paid on the important watershed and nature reserves at medium scale, even fewer valuations have been conducted on the vulnerable arid ecosystems (Zhao *et al*., 2004; Grêt-regamey *et al.*, 2008).

Manas River watershed, a typical inland river watershed in the northwest of China, experienced significant land exploitation and may significantly affect ecosystem service in the past 30 years. These effects, however, are difficult to quantify and seldom taken into account in the policy making. The objectives

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of this study are: (1) to retrieve land use changes in Manas River watershed; (2) to assign specific coefficients of ecosystem service value for Manas River watershed, and determine whether they can be used to evaluate the changes in ecosystem service in the local area; (3) to estimate variations of ecosystem service value in response to land use changes during the past 32 years.

MATERIALS & METHODS

Manas River watershed locates in the northern slope of Tianshan Mountains and also the southern margin of Junggar Basin (Fig. 1), with a total area of 2.1×10^6 ha. It consists of three main physiographical units: mountain, piedmont plain and dessert. The watershed locates in the arid area where the climate is featured as hot-dry in summer and cold-windy in winter. The mean annual temperature is 6.8! and yearly precipitation is 110-200 mm. Manas River watershed has a long grazing history. After 1949, largest artificial oasis of China was developed in Xinjiang and Manas River watershed became the fourth large irrigation agricultural zone of China. The large-scale land exploitation promoted economy significantly, but it also resulted in some ecological problems. This region could be a desirable location for the valuation of ecosystem service value in response to land use changes in the process of land exploitation. Data collected for this study includes Landsat MSS in 1976, TM in 1989 and 1999, and ETM+ in 2008. ERDAS imagine software and a 1:100000 topographic map were applied for mosaiking and geometric correcting images of the four periods (Table 1). The images were classified into six land use types: cultivated land, woodland, grassland, water body, built-up and unused land. The kappa coefficient was used to evaluate the accuracy of interpretation because it illustrates changes in quantity, space, and comprehensive information during landscape change, especially for missing spatial information. Hence, it reveals spatial changes that cannot be detected by conventional methods (Poff & Hart, 2002). The kappa coefficient I_k is expressed as:

$$I_k = (P_o - P_c)/(P_p - P_c)$$

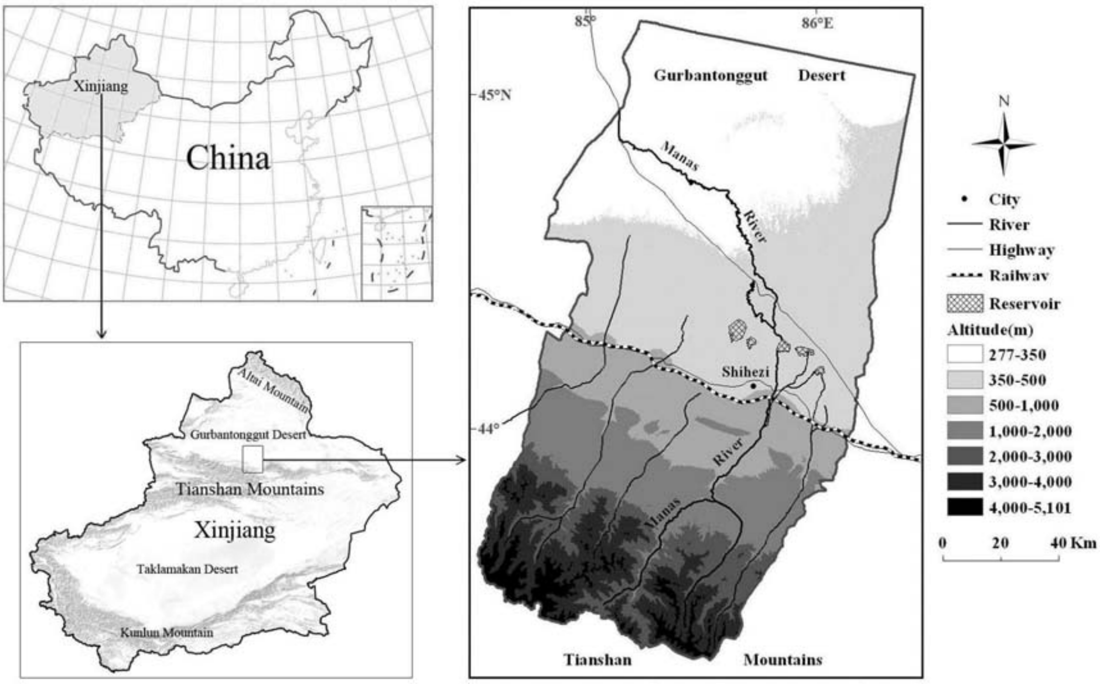

Fig. 1. Geographic and administrative location of the Manas River watershed

Table 1. Data sources

Year	Data types	Remote sensing images (column/row, collection time)
1976	Landsat MSS	155/29, 1976.7.15
1989	Landsat TM	144/29, 1989.09.10; 143/29, 1988.01.26; 144/28, 1989.08.09; 144/30, 1989.09.10.
1999	Landsat ETM	144/29, 1999.07.04; 144/28, 1999.07.04; 144/30, 1999.10.17; 144/29, 2001.08.10.
2008	Landsat ETM+	143/29, 2008.08.06; 144/29, 2008.08.29; 144/30, 2008.08.29.

where P_o is the percentage of correct simulations, P_c is the corresponding percentage of correct simulations under stochastic conditions, and P_p is the percentage of correct simulations under conditions with ideal classification (i.e. 100%). Using the kappa coefficient as an indicator of the degree of similarity, if data for two periods are identical, I_k =1; 0.75≥ I_k <1 indicates relatively significant similarity between data for the two periods; 0.4 ≤ I_k ≤0.75 implies less significant similarity between data for the two periods; and I_k ≤0.4 indicates no significant similarity between data for the two periods.

Interpreting 1976 remote sensing images was carried out in the ARCGIS9.2 using the aerial photograph in 1970s (1:47000) as the reference, and the overall kappa is 71.88%. Data from 1989 were assessed using 1:47 000 colorized aerial photographs taken in the 1980s, revealing an accuracy of 81.88% (Cheng *et al*. 2005). Accuracy assessments of the image classification in 1999 and 2008 were implemented using data derived from field investigation in these periods, and the accuracy is 85.54% and 87.56%, respectively. Supposing that land type *A* has changed from U_a to U_b in area over a time period *T*, the rate of its change *R* can be defined as,

$$R = (\sqrt[T]{\frac{U_b}{U_a}} - 1) \times 100\% \quad (1)$$

Costanza et al. (1997a) classified the global biosphere into 16 ecosystem types and 17 service functions and then estimated their ecosystem service value. The significance for ecosystem service and functions was in Table 2. Based on Costanza et al. 2 s (1997a) parameters, Xie et al. (2003) extracted the equivalent weight factor of ecosystem service per hectare of terrestrial ecosystems in China and modified the value coefficient of Chinese ecosystem (Table 3). The equivalent weight factor listed in Table 3 was obtained by surveying 200 Chinese ecologists and can be applied to different regions across China by localizing the average natural food production (Xie *et al*. 2003). One factor is equal to the economic value of average natural food production of cropland per hectare per year. Generally, the natural food production is proposed to be 1/7 of the actual food production. With Manas River watershed, the average actual food production of cropland was 4393.77 kg/ha^2 from 1976-2008 and the average price for grain was 1.69 Yuan/kg in 2008 (Zhu, 2009). Therefore, the ecosystem service value of one equivalent weight factor for Manas River watershed is 1060.78 Yuan.

Ecosystem service value of one unit area of each land use category in Manas River watershed was then assigned based on the nearest equivalent ecosystems (Table 4). For example, cultivated land equates to cropland, woodland equates to forest, and unused land

Table 2.The significance for ecosystem service and functions (Costanza *et al.*, 1997a)

Ecosystem service and functions	Significance
Gas regulation	Regulation of atmospheric chemical composition.
Climate regulation	Regulation of global temperature, precipitation, and other biologically mediated climatic processes at global or local levels. Capacitance, damping and integrity of ecosystem response to environmental fluctuations.
Water supply	Regulation of hydrological flows. Storage and retention of water.
Soil formation and retention	Soil formation processes. Storage, internal cycling, processing and acquisition of nutrients. Retention of soil within an ecosystem.
Waste treatment	Recovery of mobile nutrients and removal or breakdown of excess or xenic nutrients and compounds.
Biodiversity protection	Movement of floral gametes. Trophic-dynamic regulations of populations. Sources of unique biological materials and products. Habitat for resident and transient populations.
Food	That portion of gross primary production extractable as food.
Raw material	That portion of gross primary production extractable as raw materials.
Recreation and culture	Providing opportunities for recreational activities. Providing opportunities for non-commercial uses.

Table 3. Equivalent weight factor of ecosystem service per hectare of terrestrial ecosystems in China (Xie et al, 2003)

	Forest	Grassland	Cropland	Water body	Barren land
Gas regulation	3.50	0.80	0.50	0.00	0.00
Climate regulation	2.70	0.90	0.89	0.46	0.00
Water supply	3.20	0.80	0.60	20.40	0.03
Soil formation and retention	3.90	1.95	1.46	0.01	0.02
Waste treatment	1.31	1.31	1.64	18.20	0.01
Biodiversity protection	3.26	1.09	0.71	2.49	0.34
Food	0.10	0.30	1.00	0.10	0.01
Raw material	2.60	0.05	0.10	0.01	0.00
Recreation and culture	1.28	0.04	0.01	4.34	0.01
Total	21.85	7.24	6.91	46.01	0.42

Table 4. Ecosystem service value of unit area of different land use categories in Manas River watershed (Yuan·ha^{-1}·a^{-1})

	Forest	Grassland	Cropland	Water body	Barren land
Gas regulation	3712.7	848.6	530.4	0.0	0.0
Climate regulation	2864.1	954.7	944.1	488.0	0.0
Water supply	3394.5	848.6	636.5	21639.9	31.8
Soil formation and retention	4137.0	2068.5	1548.7	10.6	21.2
Waste treatment	1389.6	1389.6	1739.7	19306.2	10.6
Biodiversity protection	3458.1	1156.3	753.2	2641.3	360.7
Food	106.1	318.2	1060.8	106.1	10.6
Raw material	2758.0	53.0	106.1	10.6	0.0
Recreation and culture	1357.8	42.4	10.6	4603.8	10.6
Total	23178.1	7680.1	7330.0	48806.6	445.5

equates to barren land. The service values for built-up are zero. Although the biomass used as proxies for the land use categories are clearly not perfect matches in every case (Kreuter *et al*. 2001), they are closely related. Estimation of the ecosystem service value based on land use data has been applied and has been proven to be feasible in other case studies (Li *et al*. 2010b).

Once the ecosystem service value of one unit area for each land use category has been extracted, the service value for each land use category, and service function are given in Eqs. (2)-(4).

$$ESV_k = \sum_f A_k \times VC_{kf} \quad (2)$$

$$ESV_f = \sum_k A_k \times VC_{kf} \quad (3)$$

$$ESV = \sum_k \sum_f A_k \times VC_{kf} \quad (4)$$

ESV_k, ESV_f and ESV are referred to the ecosystem service value of land use category "*k*", value of ecosystem service function type "*f*" and the total ecosystem service value respectively. "A_k" is the area (ha) for land use category "*k*" and VC_{kf} the value coefficient (Yuan·ha-1·a-1) for land use category "*k*", ecosystem service function type "*f*".

Since the biomes used as proxies for the land use categories are clearly not perfect matches as mentioned above, and there are uncertainties of the value coefficients, additional sensitivity analysis is needed in order to test the percentage change in the ecosystem service value for a given percentage change in a value coefficient. In each analysis, the coefficient of sensitivity (*CS*) was calculated using the standard economic concept of elasticity as follows (Kreuter *et al.* 2001).

$$CS = \frac{(ESV_j - ESV_i) / ESV_i}{(VC_{jk} - VC_{ik}) / VC_{ik}} \quad (5)$$

Where *ESV* is the estimated ecosystem service value, *VC* is the value coefficient, "*i*" and "*j*" represent the initial and adjusted values, respectively, and '*k*' represents the land use category. If *CS* is greater than unity, then the estimated ecosystem value is elastic with respect to that coefficient, but if *CS* is less than one, then the estimated ecosystem value is considered to be inelastic.

RESULTS & DISCUSSION

The area of grassland, unused land and cultivated land accounts for more than 80% of total area. Table 5 showed that the unused land experienced the largest change during the period from 1976 to 1989, and the area of unused land decreased by 51029.1ha, while the water body changed at the fastest speed of 2.7%, followed by unused land with a -0.6% reduction. From 1989 to 1999, the unused land remained most significant change and it increased from 578767.2 ha in 1989 to 655495.5 ha in 1999; however, the water body still decreased most at the speed of -3.3% followed by built-up of 1.2%. The area of cultivated land changed most in 1999-2008 (a 77007.5ha increase at the rate of 1.7%), followed by grassland of a 57358.5 ha decrease. Meanwhile (1999-2008), the built-up area increased at a relatively fast speed of 1.5%. Taking 1976 to 2008 into account, the area of grassland (a 122548.3ha decrease) and cultivated land (a 122548.3ha increase) changed the most, and the built-up area changed at the fastest rate (1.0%) followed by cultivated land (0.8%). Overall, the built-up and cultivated land increased the most from 1976 to 2008, while woodland and grassland decreased gradually, and the water body together with unused land changed slightly. The interchange between different land use types inevitably influences the structures and functions of ecosystems and further the variations of ecosystem service value. It is of necessity to estimate variations in ecosystem service value in response to land use changes.

With Equations (2) and (4), the ecosystem service value of each land use category of Manas River watershed during 1976 to 2008 could be obtained respectively (Table 6). The total ecosystem service value experienced a decline in Manas River watershed, it reduced from 17362.2 $\times 10^6$ Yuan in 1976 to 16975.0$\times 10^6$ Yuan in 2008 with the average annual decreasing rate of 0.1% per year, although the maximum value (19643.9$\times 10^6$ Yuan) appeared in 1989. The decreased ecosystem service value was mainly caused by the decrease of grassland which covers most land in the study area. Water body changed most in ecosystem service value during 1976 to 1999, while cultivated land and grassland changed most significantly during 1999-2008. From 1976 to 2008, the cultivated land increased 846.5$\times 10^6$ Yuan as ecosystem service value, with an annual increasing rate of 0.9%, followed by unused land of a slight increase, all the other land types were in decline, especially for the grassland which decreased 15.2%. Because of the large coefficient of ecosystem service value for water body and the large area of grassland, the ecosystem service value produced by these two were the highest, about 60% of the total value, followed by cultivated land and woodland. Although the area of wood land was small, it generated enormous service value, indicating that this land use category plays important roles in ecosystem service, which should be paid special attention in the future ecological management and protection.

Table 5. Land use change in Manas River watershed

Land use type		Cultivated land	Forest	Grassland	Water body	Built-up	Unused land
1976	Area (ha)	418640.7	96024.9	806803.9	114554.7	26944.9	629796.4
1989	Area (ha)	443245.2	95932.3	784893.8	161567.0	28360.0	578767.2
1999	Area (ha)	457114.6	90434.9	741614.1	116054.1	32052.3	655495.5
2008	Area (ha)	534122.1	85381.1	684255.6	113535.1	36744.7	638726.8
1976-1989	Area change (ha)	24604.5	-92.5	-21910.1	47012.3	1415.1	-51029.1
	Change speed(%)	0.4	0.0	-0.2	2.7	0.4	-0.6
1989-1999	Area change (ha)	13869.4	-5497.5	-43279.6	-45512.9	3692.3	76728.3
	Change speed(%)	0.3	-0.6	-0.6	-3.3	1.2	1.3
1999-2008	Area change (ha)	77007.5	-5053.7	-57358.5	-2519.0	4692.4	-16768.7
	Change speed(%)	1.7	-0.6	-0.9	-0.2	1.5	-0.3
1976-2008	Area change (ha)	115481.4	-10643.7	-122548.3	-1019.6	9799.7	8930.5
	Change speed(%)	0.8	-0.4	-0.5	0.0	1.0	0.0

Table 6. Ecosystem service value of Manas River watershed from 1976 to 2008

		Cultivated land	Forest	Grassland	Water body	Built-up	Unused land	Total
Ecosystem service value 10^6yuan/yr	1976	3068.6	2225.7	6196.3	5591.0	0.0	280.6	17362.2
	1989	3249.0	2223.5	6028.0	7885.5	0.0	257.9	19643.9
	1999	3350.7	2096.1	5695.6	5664.2	0.0	292.0	17098.6
	2008	3915.1	1979.0	5255.1	5541.3	0.0	284.6	16975.0
1976-1989	10^6yuan/yr	180.4	-2.1	-168.3	2294.5	0.0	-22.7	2281.7
	%	5.9	-0.1	-2.7	41.0	—	-8.1	13.1
	%/yr	0.5	0.0	-0.2	3.2	—	-0.6	1.0
1989-1999	10^6yuan/yr	101.7	-127.4	-332.4	-2221.3	0.0	34.2	-2545.3
	%	3.1	-5.7	-5.5	-28.2	—	13.3	-13.0
	%/yr	0.3	-0.6	-0.6	-2.8	—	1.3	-1.3
1999-2008	10^6yuan/yr	564.5	-117.1	-440.5	-122.9	0.0	-7.5	-123.6
	%	16.8	-5.6	-7.7	-2.2	—	-2.6	-0.7
	%/yr	1.9	-0.6	-0.9	-0.2	—	-0.3	-0.1
1976-2008	10^6yuan/yr	846.5	-246.7	-941.2	-49.8	0.0	4.0	-387.2
	%	27.6	-11.1	-15.2	-0.9	—	1.4	-2.2
	%/yr	0.9	-0.3	-0.5	0.0	—	0.0	-0.1

According to Equation (3), the ecosystem service value provided by individual ecosystem service functions (ESV_f) were also estimated (Table 7). The contributions of each ecosystem function to the total ecosystem service value in each year were ranked based on their estimated ESV_f from 1976 to 2008. The trends of variations were presented in Table 7 by an upward arrow (↑) for increasing contribution, downward arrow (↓) for decrease in contribution, and a horizontal line (—) for no change. Generally, the changes in the contribution of each ecosystem function to the total service value were small and the rank order remained nearly same. Contributions of water supply, waste treatment, soil formation and retention, biodiversity protection take up to over 70% of the total ecosystem service value. During 1976-2008, only the food supply and waste treatment increased, and the food supply increased faster mainly due to the dramatic increase in cultivated land. The spatial distribution of ecosystem service value of Manas River watershed in 1976-2008 was shown in Fig.2. Areas with ecosystem service values over 40,000 Yuan·ha^{-1}·year^{-1} were mainly located in the south mountainous glaciers and middle plain reservoirs, while those with the ecosystem service values of 20,000–40,000 Yuan·ha^{-1}·year^{-1} were in the south mid-mountain forests, and those between 5, 000 and 20,000 Yuan·ha^{-1}·year^{-1} mainly distribute in the south hilly land and mid-plain. Areas with ecosystem service values less than 5000 Yuan·ha^{-1}·year^{-1} mainly covered desert in the northern area.

As shown in Table 8, the percentage change in estimated total ecosystem service value and the coefficient of sensitivity resulting from a 50% adjustment in the value of the coefficient was calculated using Equation (5). In all cases, *CS* was far less than unity and often close to zero, indicating that the total ecosystem service value estimated in this study area was relatively inelastic with respect to the value coefficients. *CS* for grassland and water body was relatively bigger, because the ecosystem service value provided by the two land use categories takes up to more than 60% of total ecosystem service value. The sensitivity analysis indicated that the estimation in this study was robust in spite of uncertainties on the value coefficients.

Costanza *et al*. (1997a,b) proposed a method to estimate ecosystem service value from ecosystem service coefficient, however, this method was mostly applied at global scale, and will not well estimated the per unit area ecosystem service value in some ecosystems. Basing on this method, Xie *et al*. (2003) made an equivalent factor table about terrestrial ecosystem service value of China. According to Xie *et al*. (2003), ecosystem service value per unit area for Manas River watershed was adjusted by utilizing grain productivity and average grain price, and then the value were estimated for different land use categories and ecosystems. The results indicate that this method is capable of estimating the variations of ecosystem service value in response to land use changes.

Table 7. Values of ecosystem service functions in 1996 and 2004

	1976			1989			1999			2008			
	ESV_f 10^6yuan /yr	%	Rank	ESV_f 10^6yuan /yr	%	Rank	ESV_f 10^6yuan /yr	%	Rank	ESV_f 10^6yuan /yr	%	Rank	Tendency
Gas regulation	1263.2	7.3	6	1257.3	6.4	6	1207.6	7.1	6	1181.0	7.0	6	↓
Climate regulation	1496.4	8.6	5	1521.4	7.7	5	1455.2	8.5	5	1457.5	8.6	5	—
Water supply	3776.1	21.7	2	4788.6	24.4	2	3759.5	22.0	2	3687.7	21.7	2	—
Soil formation and retention	2729.1	15.7	3	2720.9	13.9	3	2631.3	15.4	3	2610.6	15.4	3	↓
Waste treatment	4201.2	24.2	1	5120.5	26.1	1	4199.0	24.6	1	4197.4	24.7	1	↑
Biodiversity protection	2110.0	12.2	4	2208.6	11.2	4	2057.5	12.0	4	2019.0	11.9	4	↓
Food	729.9	4.2	7	753.4	3.8	8	749.8	4.4	7	812.2	4.8	7	↑
Raw material	353.3	2.0	9	354.9	1.8	9	338.5	2.0	9	329.6	1.9	9	↓
Recreation and culture	703.1	4.0	8	918.2	4.7	7	700.4	4.1	8	680.1	4.0	8	—
Total	17362.2	100.0	—	19643.9	100.0	—	17098.6	100.0	—	16975.0	100.0	—	—

Table 8. Percentage change in estimated total ecosystem service value and coefficient of sensitivity resulting from adjustment of ecosystem valuation coefficients (VC)

Change of value coefficient	1976		1989		1999		2008	
	%	CS	%	CS	%	CS	%	CS
cultivated land VC±50%	8.84	0.18	8.27	0.17	9.80	0.20	11.53	0.23
forest VC±50%	6.41	0.13	5.66	0.11	6.13	0.12	5.83	0.12
Grassland VC±50%	17.84	0.36	15.34	0.31	16.66	0.33	15.48	0.31
water body VC±50%	16.10	0.32	20.07	0.40	16.56	0.33	16.32	0.33
Built up VC±50%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unused land VC±50%	0.81	0.02	0.66	0.01	0.85	0.02	0.84	0.02

However, the results using this method have some deviations and uncertainties due to the complex, dynamic and nonlinear ecosystems (Turner *et al.*, 2003), limitations of economic valuation (Costanza *et al.*, 1997b), and problems of double counting (Turner *et al.*, 2003) and scales. Land use is a proxy measure of ecosystem service, however, the biomes used as proxies for the land use categories are clearly not perfect matches in every case (Kreuter *et al.*, 2001). In addition, the accuracy of the average value coefficient is in doubt because of ecosystem heterogeneity (Li *et al.*, 2010b). For instance, built up is proposed to be zero, neglecting negative effectiveness of pollution (e.g. air pollution, water pollution, waste pollution) which may produce a negative value. Multiplying "*A*" (area of land use category) and "*VC*" (ecosystem value coefficient) with uncertainties will thus lead to a coarse "*ESV*" (ecosystem service values) with more uncertainties.

Currently, land use change rate is often calculated with mean-value methods (Song *et al.*, 2008; Liu *et al.*, 2010) in which the hypothesis is the land changes in different period are independent. However, land change is an accumulated process which increases in geometrically multiplied annual change rate. As a result, mean-value method is not able to reflect the real land change. According to Equation (1), the estimated land use change rate is reasonable and reliable.

In the study area, the primary driving forces of the land change in this study are closely related to population growth. The population of the study area was 59,000 in 1949, 897,000 in 1975 and 1,107,000 in 2004 according to the statistical information (Li *et al.*, 2008). The increasing population triggered the increase in the area of cultivated land and built-up while a decline of wood land and grassland. Otherwise, the large tracts of unused land especially in the pluvial–

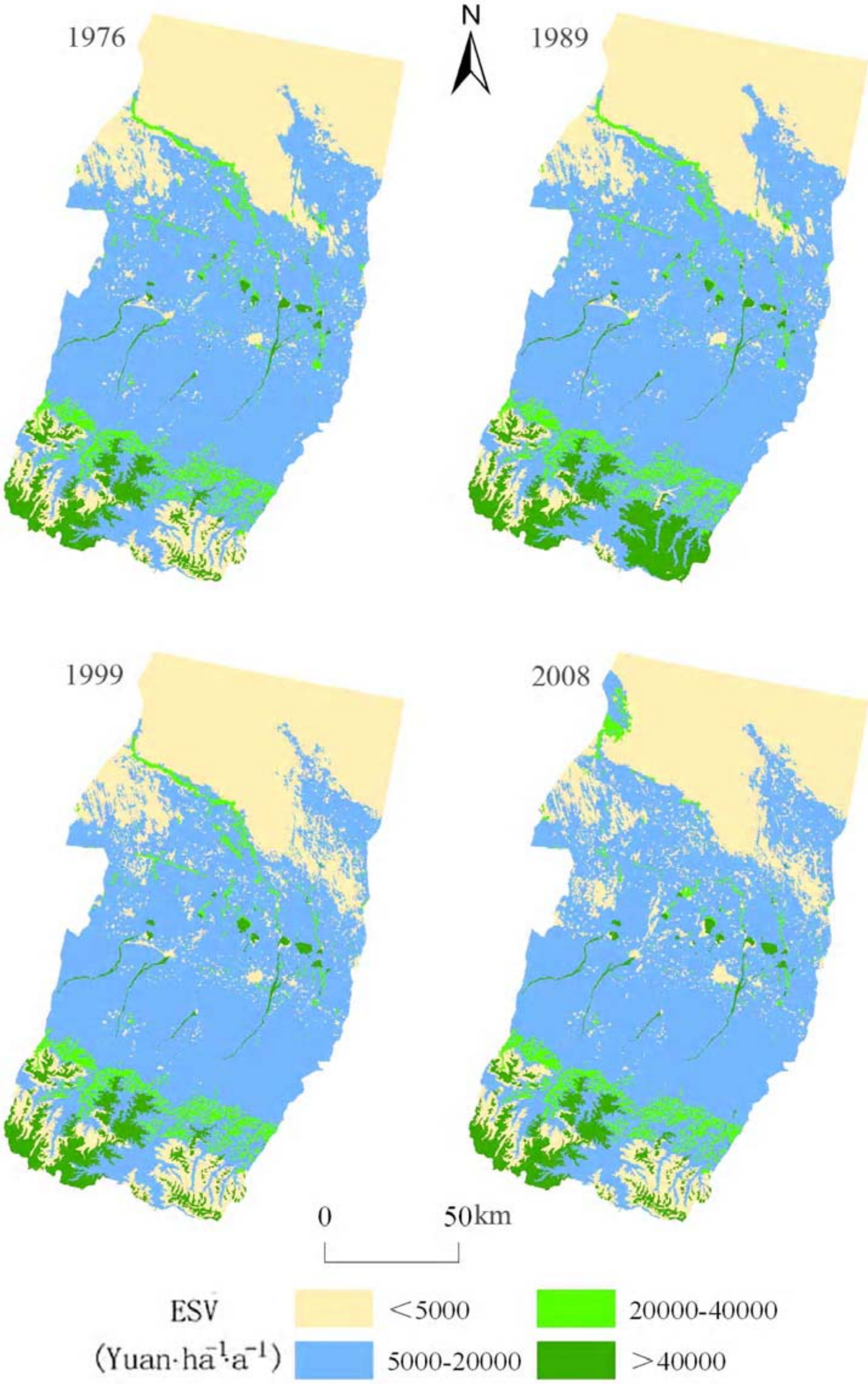

Fig. 2. Distribution of the ecosystem services value in Manas River watershed in 1976-2008

alluvial plain that had relatively shallow groundwater and ease of transport were reclaimed by the Production and Construction Group of Xinjiang since 1950s, leading to a rapid increase in cultivation and construction land, along with an overall increase in land use (Yao & li, 2010; Dai *et al.*, 2011). In addition, technological innovations and advances in irrigation, fertilizing application and the managing system have been applied since the late 1970s, which also contributed to a large extent to the rapid change in land types. Using proxies for the land use categories, the results indicated a decline of total ecosystem service value. Sensitivity analysis showed that total ecosystem service value estimated in this study area was relatively inelastic with respect to the value coefficients, and the results were reliable with a certain value coefficient uncertainties. From 1976 to 2008, GDP (gross domestic product) increased 213.7% indicating that economy increased more significantly than ecosystem value. In order to maintain a balance between economic development and ecosystem health in the future, it is suggested that a reasonable land use planing should be made with emphasis on protecting water body, woodland and grassland which have high ecosystem service value.

Despite some methodological shortcomings, ecosystem service valuation is still helpful in decision-making by highlighting the benefits of sustainable ecosystem management. Comparisons with findings obtained in other watersheds may also help us to understand the reliability of ecosystem service valuation. Zhang *et al*. (2001) applied the coefficients proposed by Costanza et al. to estimate the ecosystem service value in Heihe River Basin (37°412 N-42°422 N, 96°422 E-102°002 E); The total ecosystem service value of Heihe River Basin decreased from 1.79 billion Yuan in 1987 to 1.46 billion Yuan in 2000, while GDP increased 23 times. Su *et al*. (2006) used a set of modified coefficients of woodland and grassland derived from different ecosystem categories features and by consulting experts to estimate the ecosystem service value in Shiyanghe River watershed (36°292 N-39°272 N, 101°412 E-104°162 E), the estimated result showed that the total ecosystem value of Shiyanghe River watershed decreased from 3.7 billion Yuan in 1995 to 3.5 billion Yuan in 2000, while GDP increased from 6.2 billion Yuan to 9.5 billion Yuan. Although the ecological and economical characteristics and the techniques of evaluation varied, their estimated results consistently showed that ecosystem service and functions tend to decline under current patterns of economic development. Future planning should therefore put more emphasis on environmental protection and nature conservation.

This research provided a case study of ecosystem service valuation in continental river basin in arid zone. Compared with humid natural ecosystems, ecosystems in arid areas are much more complicated because of the nature of drought, water shortage, low vegetarian coverage, and wide-spread desert. Future studies on ecosystem service valuation should pay more attention to ecosystems in arid areas where with intensive interactions between human and ecosystems, and this will make the techniques of valuation more useful to guide future human activity.

CONCLUSION

By studying the changes in ecosystem service value based on land use in Manas River watershed from 1976 to 2008, it can be concluded as follows: (1) land use change is significant in the study area. Built-up and cultivated land were the top two increasing land use categories and their areas changed 1.0% and 0.8% respectively, while the area of woodland and grassland decreased slowly, and the other land use categories changed slightly. (2) The total ecosystem service value of the study area declined from about 17362.2 million Yuan in 1976 to 16975.0 million Yuan in 2008 with an average annual decreasing rate of 0.1%, which was mainly caused by the decreasing areas of grassland which account for the majority of the study area. (3) Water supply, waste treatment, soil formation and retention, biodiversity protection were the top four ecological functions with high service value, contributing about 70% of the total service value. (4) Areas with high service level were mainly located in the southern mountainous area, while those with low service level were at the northern desert.

Ecosystem service value is the benefits that human derive from ecosystem (Millennium, 2005). To evaluate ecosystem service value in an economical way, on one hand, it can draw sufficient public attention. On the other hand, it is a premise of building a green GDP accounting system and ecological compensation mechanism. Land development changed the biogeochemical cycling, ecosystem structure, and ecosystem service value. The consequences have become the main difficulty of global sustainable development and the vital focus of public attention. Thus, evaluating its variations due to the land change is of profound significance.

ACKNOWLEDGEMENT

This study was funded by the National Natural Science Foundation of China (No. 41101179), the National Basic Research Program of China (No. 2009CB825105), and a Chinese Academy of Sciences Special Grant for Postgraduate Research, Innovation and Practice. We thank Doctor Longhui Li for the assistance of the article language.

REFERENCES

Chen, N. W., Li, H. C. and Wang, L. H. (2009). A GIS-based approach for mapping direct use value of ecosystem services at a county scale: management implications. Ecological Economics, **68**, 2768-2776.

Cheng, W. M., Zhou, C. H., Liu, H. J., Zhang, Y., Jiang, Y., Zhang, Y. C. and Yao, Y. H. (2005). Oasis expansion and eco-environment change of the Manas watershed in the last 50 years. Science in China Ser D:Earth Sci, **35 (11)**,1074-1086.

Costanza, R., Cumberland, J., Daly, H., Goodland, R. and Norgaard, R. (1997b). An Introduction to ecological economics. St Lucie Press, FL, USA.

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R. V., Paruelo, J., Raskin, R. G., Sutton, P. and van den Belt, M. (1997a). The value of the world's ecosystem services and natural capital. Nature, **387**, 253-260.

Curtis, I. A. (2004). Valuing ecosystem goods and services: a new approach using a surrogate market and the combination of a multiple criteria analysis and a Delphi panel to assign weights to the attributes. Ecological Economics, **50**, 163-194.

Dai, S. P., Zhang, B., Wang, H. J., Wang, Y. M., Guo, L. X., Wang X. M. and Li, D. (2011). Vegetation cover change and the driving factors over northwest China. J. Arid Land, **3 (1)**, 25-33.

Daily, G. C. (1997). Nature's Services: Societal Dependence on Natural Ecosystems. Island Press, Washington, DC.

Grêt-regamey, A., Bebi, P., Bishop, I. D. and Schmid, W. A. (2008). Linking GIS-based models to value ecosystem services in an Alpine region. J. Environmental Management, **89**, 197-208.

Hein, L., van Koppen, K., de Groot, R. S. and van Ierland, E. C. (2006). Spatial scales, stakeholders and the valuation of ecosystem services. Ecological Economics, **57**, 209-228.

Hewarth, R. B. and Farber, S. (2002). Accounting for the value of ecosystem services. Ecological Economics, **41**, 421-429.

Kreuter, U. P., Harris, H. G. and Matlock, M. D. (2001). Change in ecosystem service values in the San Antonio area, Texas. Ecological Economics, **39**, 333-346.

Li, J. C., Wang, W. L., Hu, G. Y. and Wei, Z. H. (2010a). Changes in ecosystem service values in Zoige Plateau, China. Agriculture, Ecosystems and Environment, **139 (4)**, 766-770.

Li, T. H., Li, W. K. and Qian, Z. H. (2010b). Variations in ecosystem service value in response to land use changes in Shenzhen. Ecological Economics, **69**, 1427-1435.

Li, Y. L., Qao, M., Yang, X. L., Zhou, S. B. and Zeng, Y. J. (2008). Analysis on land use/cover change and landscape fragmentation in typical watershed of arid zone in last 30 years-a case of Manasi river watershed, Xinjiang. J. Desert Research, **28**, 1050-1057.

Liu, J. Y., Zhang, Z. X., Xu, X. L., Kuang, W. H., Zhou, W. C., Zhang, S. W., Li, R. D., Yan, C. Z., Yu, D. S., Wu, S. X. and Jiang, N. (2010). Spatial patterns and driving forces of land use change in China during the early 21st century. J. Geographical Sciences, **20**, 483-494.

Metzger, M. J., Rounsevell, M. D. A., Acosta-Michlik, L., Leemans, R. and Schröter, D. (2006). The vulnerability of ecosystem services to land use change. Agriculture, Ecosystems and Environment, **114**, 69-85.

Millennium, E. A. (2005). Business and Industry Synthesis Report. Island Press, Washington, DC.

Poff, N. L. and Hart, D. D. (2002). How dams vary and why it matters for the emerging science of dam removal . Biosci, **52 (8)**, 659-668.

Song, K. S., Liu, D. W., Wang, Z. M., Zhang, B., Jin, C., Li, F. and Liu, H. J. (2008). Land use change in Sanjiang Plain and its driving forces analysis since 1954. Acta Geographica Sinica, **63**, 93-104.

Su, X. L., Kang, S. Z. and Tong, L. (2006). A dynamic evaluation method and its application for the ecosystem service value of an inland river basin: a case study on the Shiyanghe River Basin in Hexi Corridor of Gansu Province. Acta Ecologica Sinica, **26**, 2011-2019.

Sutton, P. C. and Costanza, R. (2002). Global estimates of market and non-market values derived from nighttime satellite imagery, land Cover, and ecosystem service valuation. Ecological Economies, **41**, 509-527.

Turner II, B. L., Lambin, E. F. and Reenberg, A. (2007). The emergence of land change science for global environmental change and sustainability. PANS, **105**, 20666-20671.

Turner, R. K., Paavola, J., Coopera, P., Farber, S., Jessamya, V. and Georgiou, S. (2003). Valuing nature: lessons learned and future research directions. Ecological Economics, **46**, 493-510.

Wang, X., Chen, W. Q., Zhang, L. P., Jin, D. and Lu, C. Y. (2010) Estimating the ecosystem service losses from proposed land reclamation projects: a case study in Xiamen. Ecological Economics, **69**, 2549-2556.

Xie, G. D., Lu, C. X., Leng, Y. F., Zheng, D. and Li, S. C. (2003). Ecological assets valuation of the Tibetan Plateau. J. Natural Resources, **18**, 189-196.

Yao, Y. H. and Li, H. G. (2010). Tectonic geomorphological characteristics analysis for evolution of the Manas Lake. J. Arid Land, **2 (3)**, 167-173.

Zang, S. Y., Wu, C. S., Liu, H. and Na, X. D. (2010). Impact of urbanization on natural ecosystem service values: a comparative study. Environmental Monitoring and Assessment, DOI 10.1007/s10661-010-1764-1.

Zhang, Z. Q., Xu, Z. M., Wang, J. and Cheng, G. D. (2001). Value of the ecosystem services in the Heihe River Basin. J. Glaciology and Geocryology, **23**, 360-367.

Zhao, B., Kreuter, U., Li, B., Ma, Z. J., Chen, J. K. and Nakagoshi, N. (2004). An ecosystem service value assessment of land-use change on Chongming Island, China. Land Use Policy, **21**, 139-148.

Zhao, B., Kreuter, U., Li, B., Ma, Z. J., Chen, J. K. and Nakagoshi, N. (2004). An ecosystem service value assessment of land-use change on Chongming Island, China. Land Use Policy, **21**, 139-148.

Zhu, X. F. (2009). Analysis on the grain price of China in 2008 and the outlook for 2009. Agricultural Outlook, **5**, 3-4.