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Spatial Analysis of Land Use and Land Cover Changes in Recent 30 Years in Manas River Basin

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Abstract

Manas River Basin, best represent the mountain-basin system in arid area, is the major part of the economic belt on the northern slope of the Tianshan Mountains. Based on the 3S technology and four periods of remote sensing image data of MSS image in 1976, TM image from USA Landsat in 1987 and 1998, and CBERS image in 2006, combining GIS and quantitative analysis of landscape ecology, this paper analyzed the spatial changes of land use and land cover in Manas River Basin among 1976-2006 by using ARCGIS and FRAGSTATS. Analysis on four periods of remote sensing image showed that there was a wide change in land use and land cover of Manas River Basin in recent 30 years. Natural grassland decreased with a rate of 91.426km^2/a and cultivated land increase with a rate of 121.383km^2/a. The rapid expansion of cultivated land converted mainly by reclamations of wasteland and natural grassland. And there were little changes of other land use types. From the relationship of transformation between various types of land use and land cover, it could be found that unused land is relatively stable land-use types, the areas of residential land and industrial land increased gradually and the cultivated land and natural grassland were the main source, a larger proportion of natural grassland mainly changed into cultivated land, forest land and residential land and industrial land, land changed into cultivated land was larger than cultivated land changed into the other land and the increased land main converted by natural grassland, and the forest land converted to other land increased gradually and the they mainly converted to salt and kaline land. However, land use and land cover change was resulted from the interaction of human activity (social and economic factors) and natural environmental changes (natural factors). So, it is necessary to consistently improve the natural environment of Manas River Valley which can provided stable basis of the theory and practice for sustainable development of Manas River Valley.

Keywords:Manas River Basin; land use; land cover changes.

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1. Introduction

Manas River Basin is located in extreme arid area of Central Asia. Owning to the geomorphic conditions of high altitude, river basin has abundant precipitation and deep snow, which become the precious water resources of Tianshan Mountains and support the local agriculture. Water resource is source of life in arid area, the coexistence of mountain, oasis and desert ecosystems is the characteristic of arid area [1]. Manas River Basin is the most typical mountain-basin system in arid area, and representative in Xinjiang with the characteristic oasis environment and social development [2]. Because of long-term economic growth, rapid population growth, and unreasonable water resources utilization, the occupation and scramble of ecological water are aggravated, which result in the lack of ecological water in the fringe of the oasis or oasis-desert transitional zone. And the ecological deterioration and landscape fragmentation will be more serious. Additionally, excessive human activities such as overgrazing aggravate the degeneration of natural ecosystem, and endanger the sustainable development of social economy. By means of analyzing the change of land use and land cover types in Manas River Basin, especially the expansion of farmland and reduction of natural grassland, as well as thus appeared ecological problems, this paper presented the significance of natural grassland resources conservation and reasonable control on oasis scale for resources exploitation and oasis sustainable development in Manas River Basin.

2. Study area

Manas River Basin, located between northern Tianshan Mountains and southern Junggar basin (84°42′～86°33′, 43°5′～45°58′) with the total area of $3.35\times10^4 km^2$, includes Jingou River, Ningjia River, Bayinggou river, Taxi river, and Manas River (Fig.1). The total runoff is $22.8\times10^8 m^3$[3], Manas river is the largest with an average runoff of $12.8\times10^8 m^3/a$[4]. Manas River Basin originates from Eren Habirga, enter the oasis zone of piedmont plain by Hongshanzui, and passes through Gurbantunggut Desert and northward into Manas River Basin from Xiaoguai and Daguai. The total length of Manas River is 324km. Manas River Basin oasis has been the biggest farming area of oasis in Xinjiang, the first four irrigation farming area in China, and one of agricultural bases in Xinjiang. As the result of excessive human disturbance and intensive exploitation of land and water resources, artificial oases landscape replace desert landscape, and bring about profound influence to agricultural production and city construction.

3. Data sources and study Methods

3.1. Remote sensing data sources

The remote sensing data was from MSS image in 1976 (free image from University of Maryland), TM image from USA Landsat in 1987 and 1998, and CBERS image in 2006. False color composite in bands 421 was applied to MSS image in 1976, and false color composite in bands 432 was applied to the remote sensing images in 1987, 1998, and 2006. Referring to TM image in 2000 and the topographic map of 1:100000 in the 1950s and 1970s, geometry correction was carried out by

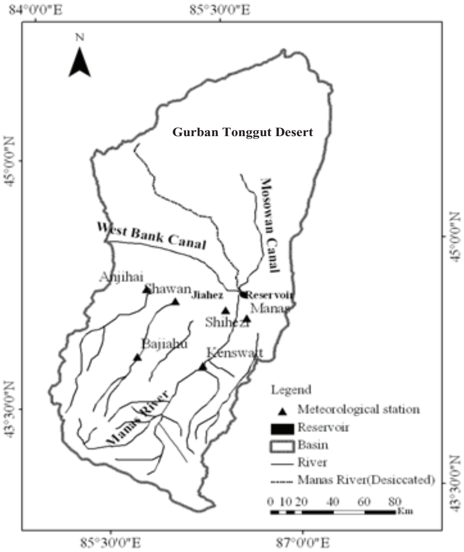

Fig.1 The sketch map of Manas River Basin

polynomial transfer equation in ERDAS9.0, and the resample was realized through bilinear interpolation method under the condition that the number of image element is less than 0.5. The resample of MSS image was 57m, the resample of TM image was 28.5m, and the resample of CBERS image was 19.5m. In addition, the topographic map was also registered for the accuracy and vacuolization. The volume of the corrected image data was large, so that the image was spliced by using the command of ERDAS9.0MOSIC after correction. For the spliced images of four periods, the administrative boundaries of river basin were masked as the base map of remote sensing images interpretation. The field survey and indoor interpretation were combined in image processing.

3.2. Remote sensing data processing

According to the secondary classification system of China's land resources classification system, and considering the practical conditions, saline land and sand land were separated from unutilized land as the separate type in remote sensing images interpretation. The land use and cover types were mainly divided into eight types: farmland, forest land, grassland, water area, residential area and industrial land, unutilized land, sand land and saline land. Supported by ARCGIS and FRAGSTATS softwares, this paper carried out visual interpretion on remote sensing images according to the classification system, digitalized the image data, built topological relation, and corrected the results based on the field data. As a result, the graphic data and attribute data of land use and cover were attained (Fig.2), and a series of indexes such as area and number of patches in different periods were calculated.

3.3. Study methods

The dynamic degree of land use describe the change rate of regional land use quantitatively, (Wan, et al.,2005), it is available to compare the regional difference of land use changes and predict change trend of land use in the future, which include single land use change dynamic degree (K) and synthetical land use dynamic degree (LC). The former

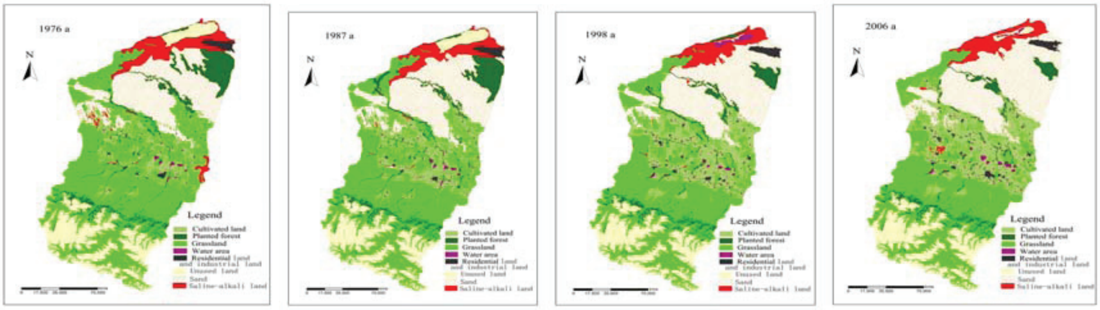

Fig.2 Interpretation map of land use and over
in Manas River Basin (1976a, 1987a, 1998a, 2006a)

primarily describe the change rate of number of some type of land use in a special time, and the latter represent the change rate of the whole study area. The relative equations are as follows (Wang, et al., 1999).

$$K = \left(U_b - U_a\right)/U_a/T \times 100\% \qquad (3.2)$$

$$LC = \left\{ \frac{\sum_{i=1}^{n} \Delta U_{i-j}}{2\sum_{i=1}^{n} U_i} \right\} \times \frac{1}{T} \times 100\% \qquad (3.3)$$

Where K is the dynamic degree of the single land use and cover change in the study period, LC the dynamic degree of the synthetical land use and cover change in the study period, U_a and U_b the area of some land use and cover type at the beginning and end of the study period, ΔU_{i-j} the area of the land use type non-i (type j, j=1…… n) transferred by land use type i in the study period, U_i the area of land use type i at the beginning of the study period, T the study period. When T is given as the year, LC the annual change of some land use type in the study period.

4. results

4.1. General characteristics of land use and cover changes in different periods

The area change of land use and cover types is the major part of LUCC in river basin, and the area change is reflected firstly in the total quantity change of different land types. On the basis of the interpretation of LUCC in Manas River Basin in four periods (Fig.3) and attribute database, the histogram of land use and cover changes in different periods was drawed (Fig.4). Fig.3 and Fig.4 demonstrated the total quantity change of land use and cover types. The area percentages of land use types in 1976-2006 was represented as grassland＞sand land＞farmland＞unutilized land＞forest land＞saline land＞water area＞residential area. The area of grassland, sand land, farmland and unutilized land accounted for 92% above of the total land area. There has a wide change in land use and cover in Manas River Basin in recent 30 years (Fig.3), which is mainly reflected in grassland, farmland and sand land.

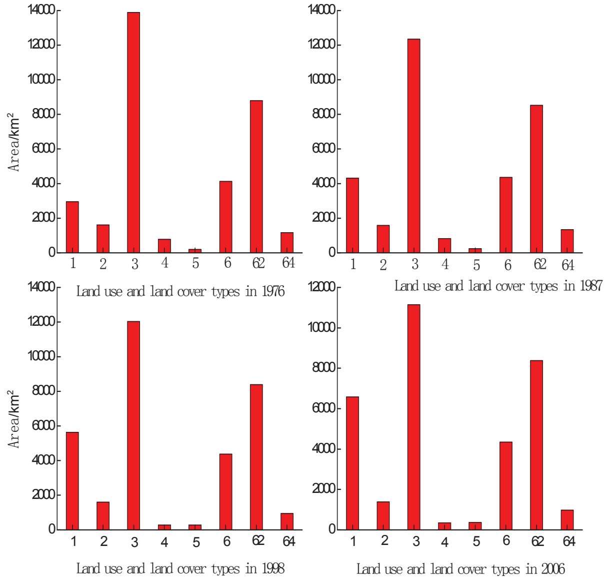

Fig.3 Area change of land use and land cover types in different periods

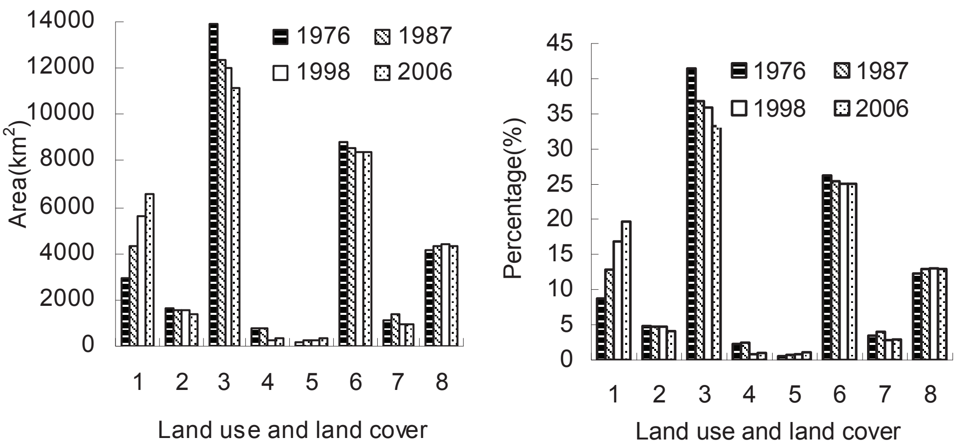

Fig.4 Area histogram of land use and cover in different periods

Tab.1 Average change area of land use and cover types in different periods

	average change area/km^2			
	1976-1987	1987-1996	1996-2006	1976-2006
farmland	123.50	120.61	119.53	121.38
forest land	-2.63	1.81	-27.09	-7.52
grassland	-140.51	-28.06	-111.06	-91.43
water area	4.04	-50.01	9.85	-14.23
residential area and industrial area	4.45	2.62	10.15	5.30
unutilized land	36.16	-34.81	0.15	0.53
sand land	-25.00	-12.22	-1.52	-14.05
saline land	16.12	-37.53	4.01	-6.78

From the area and relative ratio of land use and cover types (Fig.4), the area and relative ratio of grassland and sand land was the largest in Manas River Basin. The area of grassland and sand land were 13885.08km^2 and 8798.07km^2 in 1976, accounted for 41.5% and 26.3% of the total area. In 2006, the proportion of grassland declined to 33.3%, and the proportion of sand land was down to 25.0%. As with the average change area (change rate) of land use and cover types in different periods (Fig.3), the area of grassland was on the decrease with the rate of 91.426km^2 per year, 0.27% of grassland transferred into other types per year. Additionally, the proportion of farmland was also larger, and the change rate was more significant than that of grassland. The area of farmland increased with the rate of 121.383km^2 per year, there was 0.36% of land types transferring into farmland per year in Manas River Basin. The analysis on the rangeability of land use indicated the general development trend of regional land use and change of land use structure. In 30 years among 1976-2006, the dominant cover types (grassland,farmland and sand land) had changed greatly. The area of unutilized land was large ,but the rangeability was small. The proportions of forest land, saline land, water area, residential area and industrial land were smaller relatively. Addition to the area of residential area and industrial land increased slightly, the other three all had the decreasing trends.

4.2. Transformation into farmland from different land use and cover types in different periods

For the further research on the mutual transformation of land use and cover types, the landscape types figures of four periods was analyzed by using the Intersection function of Arcmap, and the transfer matrix of land use was attained. In transfer matrix, the line stand for the area percentage of type *j* transferred from type *i* of land use and cover in three periods

From the transfer matrix of land use types in three periods (Tab.1), unutilized land was relatively stable, and the transfer-in area of which was less than 1%. In addition to the period of 1976-1987 (in which period the contribution rate of unutilized land for water area was up to 78.32%), the transfer-out rate of unutilized land was less than 1% in 1987-2006.

Grassland belongs to the land use type with the greater changes. The transfer-out rate of grassland was larger in three periods, and grassland mainly transferred into farmland, forest land and residential area and industrial land, the proportions of grassland transferring into farmland in three periods were 39.11%, 23.31% and 15.39% separately, which were declining but still the highest in three periods. It showed that the expansion of farmland was attributed to the reclamation of grassland. Secondly, grassland mainly transferred into forest land, residential area and industrial land. In two periods of 1976-1987 and 1987-1998, the contribution rates of grassland for forest land were 16.46% and 11.07%, and for residential area and industrial land were 15.82% and 10.08%. During 1998-2006, the transfer-in rate of forest land, residential area and industrial land declined, while the percentage of grassland into saline land and water area rose, up to 16.28% and 10.70%. The transfer-in area of grassland took a small proportion, the area of other land use types into grassland accounted for less than 5% in three periods, the transfer-out area was larger than transfer-in area, the area of grassland had a declining trend.

The transfer-in area of farmland was 1858.40 km^2 during 1976-1987, larger than that in 1987-1998 (1684.107 km^2) and 1998-2006 (1246.563km^2). Farmland was generally transferred from grassland, and the increment of farmland was still from grassland reclamation basically. The transfer-out area of farmland has the decreaisng trend in three periods (499.85km^2, 357.24km^2 and 290.30 km^2). However, due to population growth, the area of residential area transferred from farmland was larger, and the area of farmland has been increasing in the study period (the transfer-in area was larger than transfer-out area).

In three periods, the proportion of residential area and industrial land was increasing, and farmland and grassland were the primary sources of its new area, but the two will decrease with the larger proportion in future, and the transfer-in distribution of sand land for residential area and industrial land was reflected merely in 1976-1987.

The transfer-out area of forest land increased gradually in three periods with the area of 377.73km^2, 382.99km^2 and 463.00km^2, and forest land mainly transferred into saline land in 1976-1987 and 1998-2006. Whereas the transfer-out area was larger than transfer-in area, which indicated that parts of the forest were destroyed in this period, and the felling quantity was larger than the growth, forest land has expanded to deep desert with the length of 40～50km. However, there has the forest land transferred from not only grassland and farmland, but also sand land and saline land in three periods, the area of artificial forest had been increasing. Farming eight division adopte the exclusion measures and constructions simultaneously, build sand protecting plantation, delimit the protection zone of desert vegetation as well as promote the water-saving technology in restoring *Haloxylon ammodendron* forest. The number of *Haloxylon ammodendron* added up to 9.5 million by 1995 (600 hectare), and there forms a protection zone connecting 11 regiments with the total area of 96,000 hectare. However, forest land is still on the decrease because of excessive desert vegetation destruction. Western ecological environment construction and policy of returning cultivated land into forest and grass make parts of the farmland transfer into the forest land in three periods with the rate of 3.29%, 2.20% and 3.85%.

Fig.5 Area of farmland transferred by different land use types in Manas River Basin in three periods

4.3. Analysis of the driving forces of land use and land cover change

From the overall characteristics of land use change and mutual conversion of land use and cover types, it can be drawn that the spatial patterns of land use and cover types have taken place great changes. Due to the Manas River Valley is a typical arid inland basin and mountainous - Oasis - Desert pattern, and it also is a typical composite system of the natural - economic - society. Therefore, land use and land cover change is resulted from the interaction of human activity (social and economic factors) and natural environmental changes (natural factors).

Tab.2 Transfer matrix of land use types in Manas River Basin in three periods (%)

1976 / 1987	farmland	forest land	Grass land	Water area	residential area and industrial land	unutilized land	sand land	saline land
farmland	56.81	0.88	39.11	0.03	1.53	0.00	0.65	0.99
forest land	3.29	77.87	16.46	0.10	0.16	0.01	1.73	0.37
grassland	2.95	0.22	95.05	0.05	0.05	0.00	0.42	1.26
water area	1.18	0.23	3.35	16.77	0.12	78.32	0.01	0.02
residential area and industrial land	10.34	0.30	15.82	0.00	26.09	0.00	47.26	0.19
unutilized land	0.00	0.00	0.00	0.00	0.00	99.62	0.04	0.34
sand land	0.29	0.59	0.97	0.00	0.01	0.00	98.11	0.03
saline land	0.07	19.32	2.22	0.00	0.03	0.00	8.05	70.31
1987 / 1998	farmland	forest land	grass land	water area	residential area and industrial land	unutilized land	sand land	saline land
farmland	70.08	2.31	23.31	0.28	2.21	0.04	1.55	0.21
forest land	2.20	74.76	11.07	2.91	0.10	0.00	4.01	4.96
grassland	1.66	1.72	88.39	0.58	0.13	0.11	3.32	4.09
water area	0.92	0.22	0.41	98.34	0.11	0.00	0.00	0.00
residential area and industrial land	20.53	1.39	10.08	0.35	61.45	0.04	6.10	0.07
unutilized land	0.01	0.00	0.23	0.01	0.00	99.75	0.00	0.00
sand land	0.16	0.41	1.53	0.00	0.10	0.00	93.90	3.91
saline land	0.05	0.44	2.67	45.09	0.00	0.00	5.31	46.44
1998 / 2006	farmland	forest land	grass land	water area	residential area and industrial land	unutilized land	sand land	saline land
farmland	81.07	2.74	15.39	0.04	0.10	0.00	0.56	0.10
forest land	3.85	82.14	8.17	0.01	0.20	0.00	5.62	0.00
grassland	1.39	1.21	92.79	0.06	0.00	0.00	2.99	1.56
Water area	2.12	0.36	10.70	74.39	0.00	0.00	0.00	12.43
residential area and industrial land	10.50	0.24	3.30	0.00	84.30	1.65	0.00	0.00
unutilized land	0.00	0.06	0.00	0.00	0.00	99.94	0.00	0.00
sand land	0.18	0.60	4.21	0.00	0.29	0.00	94.70	0.03
saline land	0.00	9.54	16.28	0.10	0.00	0.00	0.86	73.22

(1) The growth of population Documents and statistical results showed that the population of the entire watershed was just 5.9051×10^4 people in 1949, 89.73×10^4 in 1975, and 110.69×104 in 2004. With the continuous growth of population, a large area of wasteland or natural grassland is reclaimed for cultivated land. The population growth is the main driving force of land use and land cover change and landscape fragmentation. Firstly, the growth of population increased the demand for agricultural products and the per capita land in general, which resulted in the continuous expansion of the scale and intensity of land resources development and utilization. From the analysis of land use and land cover change, it can be drawn that the cultivated land increased continuously (Fig. 3 and Fig.4). Secondly, population growth has also increased the demand for residential land, which leads some cultivated land into residential land. Thirdly, the increment of population in the desert-oasis ecotone resulted in the cut of firewood, such as region's forests and shrubs, and the increment of sand. In resent 30 years, the residence of the population increased by about 14 million (only Manas County) in southern margin of the desert. And plenty of the natural forests were cutting for firewood and forest land decreased by 20～30km, which resulted in degradation and fragmentation of the desert. Most of the reclaimed cultivated lands are concentrated on the fringe of the alluvial and diluvia fan within the catchment of Bayingou River, Jingou River, Manas River and et al., and slope natural grassland of the up reaches of the Jingou River and Ningjia River. After the blind reclamation, many cultivated land were abandoned because of the fertility of soil. In addition, the increment in total number of livestock (Fig. 5) brought about a severely damage of pastures, and overload of the mountain pastures resulted in serious fragmentation and degradation.

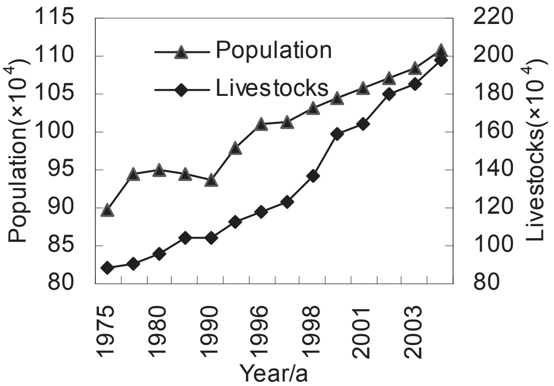

Fig.5 Changes in population and livestock amount of Manasi River Valley in last 30 years

(2) Utilization of water resource The reclaimed land were mainly irrigated by river water. Since the 1970s, many reservoirs were built in the fringe of the alluvial and diluvia fan of Manas River. Plenty of the river water was intercepted and the lower reaches of river dried. Salinity concentrated in the middle reaches of river region, which lead to the deterioration of the secondary salinization, and many farmlands were abandoned. So the fragmentation of cultivated land increased, the tail lake of Manas River dried up and the riparian woodland dead.

(3) Environmental policy changes The implementation of reform and opening up policy in 1978 and household contract land system of the river basin in 1984 and the gradual development of market economy after 1990's brought about many changes of policies and socio-economic. Especially the implementation of western development has a profound impact on land use and land cover changes. For the farmers in the river basin, land is the only source of dependence of survival and benefits. So, they can gain maximize profits by expanding the oasis, and plant crops such as cotton and breed livestock to expand the market. However, over-reclamation of cultivated land and dramatical increment of livestock accelerated the degradation and fragmentation of cultivated land and natural grassland, especially in the ecologically sensitive and fragile areas such as in the fringe of oasis, forest land, low mountain regions and the edge of desert.

(4) Long-term effects of natural conditions (include climate, topography, soil and et al.) is the dominant factor in land-use change Climatic conditions have a restraining effect on utilization of land, which mainly shown in the distribution and composition of crops, pasture and forest, the selection of crops species, farming system and yield. For the study area, drought is the main limited factor in the natural aspect. Such as there was a severe drought in 1989 occurred in the last 30 years of the Shihezi City. The Manas River, Bayingou River, Jingou River and other major rivers dry severely for a long time. Along with low output of agricultural production and the hot flush of land reclamation, all the reservoirs emptied in July and Channel of the West Bank dried up, which resulted in landscape change. On the other hand, wind and soil erosion not only reduced the cultivated land, but also decreased soil fertility, and lead to farmers' poverty and restrain of agricultural development further. Consequently, farmers had to stabilize grain production levels by expanding the cultivated land and taking turn of wasteland and arable land, which resulted in land use changes of the river basin.

Therefore, land use and land cover change was resulted from the interaction of human activity (social and economic factors) and natural environmental changes (natural factors). So, it is necessary to consistently improve the natural environment of Manas River Valley, such as determination of the appropriate scale according to water resources carrying capacity of the oasis, prohibition of drilling wells in the edge of the desert, adjustment of the planting structure properly, development of product processing, and promotion of the gradual restoration of natural vegetation by strict enclosure. And it can provided stable basis of the theory and practice for sustainable development of Manas River Valley.

5. Conclusions

There was a wide change in land use and land cover of Manas River Basin in recent 30 years. Natural grassland decreased with a rate of 91.426km^2/a and cultivated land increase with a rate of 121.383km^2/a. The rapid expansion of cultivated land converted mainly by reclamations of wasteland and natural grassland. And there were little changes of other land use types. From the relationship of transformation between various types of land use and land cover, it could be found that unused land is relatively stable land-use types, the areas of residential land and industrial land increased gradually and the cultivated land and natural grassland were the main source, a larger proportion of natural grassland mainly changed into cultivated land, forest land and residential land and industrial land, land changed into cultivated land was larger than cultivated land changed into the other land and the increased land main converted by natural grassland, and the forest land converted to other land increased gradually and the they mainly converted to salt and kaline land. However, land use and land cover change was resulted from the interaction of human activity (social and economic factors) and natural environmental changes (natural factors). So, it is necessary to consistently improve the natural environment of Manas River Valley which can provided stable basis of the theory and practice for sustainable development of Manas River Valley.

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