CHINESE GEOGRAPHICAL SCIENCE
Volume 15, Number 4, pp. 315–324, 2005
Science Press, Beijing, China

LAND USE CHANGE AND ITS SOCIO-ECONOMIC DRIVING FORCES UNDER STRESS OF PROJECT IN OLD RESERVOIR AREA
—Case Study of Linshui Reservoir Area of Dahonghe Reservoir in Sichuan Province

SHAO Jing-an[1, 2], HUANG Xue-qin[1], QU Ming[1, 2], WEI Chao-fu[1, 2], XIE De-ti[1, 2]
(*1. College of Resource and Environment, Southwest University, Chongqing 400716, P. R. China;*
2. Chongqing Key Laboratory of Digital Agriculture, Chongqing 400716, P. R. China)

ABSTRACT: The old reservoir areas built in 1950s–1970s left behind many socio-economic problems, because of the administrative backward migration and little migration fund, and all these problems would be tied to land. Based on interviewing with peasant households, combining land use survey and socio-economic statistical index, this paper analyzed land use change and its corresponding driving forces in Linshui reservoir area of Dahonghe Reservoir. Results showed that land use change in the reservoir area was mainly embodied on low-lying land submergence and migration requisition land. The former changed the land use patterns, and the latter mainly reconstructed original land property and made land over-fragmented. Cultivated land per capita was 0.041ha in this area, below the cordon of cultivated land per capita enacted by FAO. Currently, there were still 30.25% of peasant households being short of grain in trimester of one year, and there were 35.27% of people living under the poverty line. The conditions of eco-environment in Linshui Reservoir Area were worse, and healthy and sub-healthy eco-environment accounted for less proportion, composed of green belt around the reservoir area and paddy field ecosystem, and economic forest and orchard ecosystem, respectively. The stress of the reservoir project was macroscopic background to analyze the driving factors of land use change, and real underlying diving factor of the land use change in the area was the change of cultural landscape under the stress of reservoir project. The rapid increase of population was the key factor to induce the change of man-land relationship in the reservoir area, the low level of rural economy was the crucial factor to decide how migrants input for production, and the belief of migrants, influencing the land use patterns in a certain extent, was the inducing factor to keep land use stable. The low-lying submergence and infrastructure construction accompanied the reservoir project were leading factors driving land use change in the area, while changes in land use patterns, after the reservoir being built, were the responses of peasant households' behaviors to land use change.
KEY WORDS: land use change; socio-economic driving factor; project stress; old reservoir area

CLC number: F301.24 Document code: A Article ID: 1002-0063(2005)04-0315-10

1 INTRODUCTION

As old as humanity itself, land use change has run through the whole history of human existence and evolution. This change has not only objectively recorded the space patterns of the earth surface changed by humankind, but also redisplayed the spatio-temporal dynamic processes of earth surface landscape patterns (HALL *et al*., 2002; MCCUSKER, 2004; JORDAN *et al*., 2005). But only in the last two centuries has land use change become truly global in scale and now occurs at unprecedented speed (HALL *et al*., 2002; RUDELA *et al*., 2005). Even though this change has been undertaken at the local or regional level, it has been repeated frequently and by patchwork addition reaches global dimensions. Whilst, a few years ago, land use change researches have been focused mostly on "why", i.e., why land use change takes place, and on "what", i.e., what

Received date: 2005-06-28
Foundation item: Under the auspices of the National Natural Science Foundation of China (No. 49771073) and Key Project of Chinese Academy of Sciences (No. K2952-J1-203)
Biography: SHAO Jing-an (1976–), male, a native of Bozhou of Anhui Province, Ph.D., specialized in land use and eco-environmental evolution. E-mail: shaojinganswau@yahoo.com.cn
Correspondent: QU Ming. E-mail: qmsw@163.com

are affected by land use change (SHAO *et al*., 2005a). However, there have been different land cover types, various actors and diverse land use patterns in different regions (LIU and ANDERSSON, 2004; DEZSO *et al*., 2005). Providing a scientific understanding of the processes of land use change in different spatial-temporal scales, the researches on land use change in global scale have been necessary, but they could not truly disclose underlying mechanisms of land use change, due to the integration and brief of global researches themselves (LESPEZ, 2003; ZHAO and ZHAO, 2003). In fact, to better explain land use change, we should carry out case studies through selecting typical regions, and further contrast different regional natural, social, economic, traditional and technical conditions, in order to obtain possibly the characteristics of land use change for representative different regions (NAGENDRA *et al*., 2004; ZHAO Bin *et al*., 2004; SHAO *et al*., 2005b).

The reservoir project, as the huge activity of human bestowing regional natural environment at modern-day (BRADBURY and VAN METRE, 1997; HE *et al*., 2003; CAI *et al*., 2005), has not only created largely socio-economic and ecological effects, but also inevitably changed the states of regional land use, and reconstructed the framework of regional landscape patterns (RAUTELA *et al*., 2002; GUO *et al*., 2003). Accumulating evidence suggested that some of the most important consequences of land use change under the stress of the reservoir project could be identified, e.g., both of low-lying submergence and infrastructure construction accompanied the reservoir project drove land use change in reservoir area (WU *et al*., 2003; SUN *et al*., 2003; VANNI *et al*., 2005), though we have yet known so very little about these important topics and there has been an even poorer understanding of the degree of this change and its effects on peasant households' behaviors in reservoir area. In practices, low-lying submergence and infrastructure construction accompanied the reservoir project were leading factors driving land use change in reservoir area, while changes in land use patterns, after the reservoir being built, were the responses of peasant households' behaviors to land use change induced by low-lying submergence and infrastructure construction. The huge reservoirs, founded by national direct administrative appropriate fund in the 1950s–1970s (now called the old reservoir area), contributed enormously to national macroeconomic resume and regional people's livelihood self-support at that time. However, due to special historic term, old reservoir area not only possessed the commonness of the reservoir construction, e.g., low-lying land submergence, original natural habits over-fragmented, loss of regional biodiversity, but also had some features itself, e.g., administrative backward migration, little migration fund, no systemic planning and even no longer-term planning in migration area, Therefore, the old reservoir areas have been taken as the representative of the zones of global land use change studies. Based on the interviewing with peasant households, combining land use survey and socio-economic statistical index, this paper analyzed land use change and its corresponding driving forces in Linshui reservoir area of Dahonghe Reservoir. The results could serve two purposes, i.e., to explain land use change and its corresponding driving forces under the stress of the reservoir project, and to promote strong decision-making for the present and future reservoir construction.

2 MATERIAL AND METHODS

Linshui County (30°31′–30°33′N, 106°41′–107°18′E) is located in the east of Sichuan Province, China. The Dahonghe Reservoir was one of the huge reservoirs built by Chinese government in the 1950s–1970s. The submergence boundary of Linshui reservoir area of Dahonghe Reservoir involved seven townships with 45 villages, covering an area of 2763.55ha (Fig. 1), with a population of 21 164. The topography is characterized by a low mountainous and hilly landscape. The climate is subtropical monsoon climate, with a relative humidity over 90% in whole year. The natural conditions are suit-

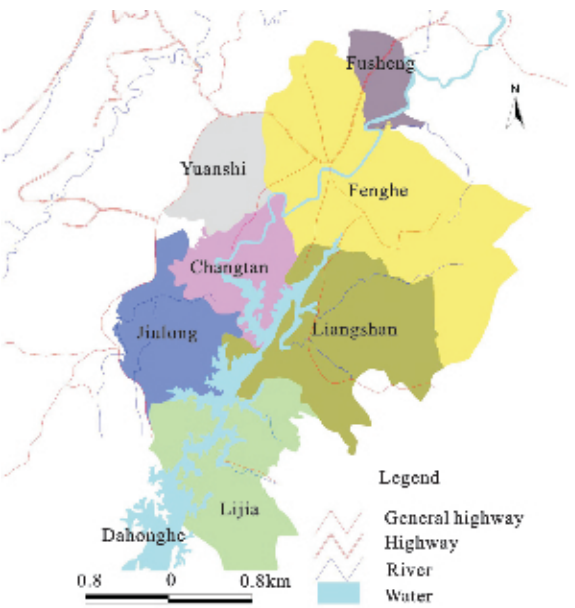

Fig. 1 Submerged villages in Linshui reservoir area

able and landscape resources are abundant in this area. The dominant crops are paddy, maize, wheat, oil plants, etc. Before Dahonghe Reservoir being founded, this area is one of important grain zones in Linshui County. After the reservoir being built, administrative backward migration was the main resettlement means because fertile river valley and flatland were submerged. Thus, the migrants of the Linshui reservoir area were only engaged in agricultural activities in barren hillside. In addition, population has been excessively increased since the 1950s. Hence, although the central government has been taken Linshui reservoir area as the key support region of old reservoir area all along since 1987, there have been still 30.25% of peasant households being incapable of self-support before the end of 2004, and the infrastructure with innate arrear has not been recovered up to now because natural resources were limited.

Land use change in Linshui reservoir area was studied by using historic information available for several periods of the 20th and 21st centuries. Land survey plans of individual farms were available, although at different scales and to different degrees of accuracy. The present land use structures were mapped from existing features in the field. The factors affecting land use change were studied using statistics of the Linshui reservoir area. The analysis of land use was based on statistical data obtained from agricultural surveys conducted in 1958, statistical data of the national economy prepared in the 1986 and 2004, agricultural yearbooks for several periods, as well as unpublished statistical data from the State Archives. To analyze the living standard of migrants in Linshui reservoir area, this paper used materials provided by the Linshui local authorities, opinion polls carried out from April 2003 to November 2004, and interviews with local people and the development plan of Linshui County.

The interviews were carried out using quantitative and qualitative methods of interviewing. All the families of Linshui reservoir area were interviewed. The questions covered the following issues. Firstly, a number of basic statistics were collected. These included the number of people in each household, their age, educational achievement, current employment, family budget, the standard of their habitation and the land use on their property. Secondly, qualitative information on the attitudes of the people was collected, especially their views about their current situation, living in the Linshui reservoir area, and their aspirations for the future. Since the survey was related to people living in identifiable locations, it was possible to carry out a spatial analysis of much of the data. This could be used to infer some aspects about the social factors likely to influence the future directions of land use change compared with the environmental or political influences of the past. Spatial data processing and analysis of the transformation of land use were carried out using ArcView GIS (ESRI GIS software), while statistical analysis of demographic and other data was carried out using Excel and ArcView GIS. All the mapped information was transferred into the GIS and the different original scales resolved to allow overlaying of the data for each period. The social data relating to the different peasants or landowners were also spatially referenced to individual peasants so that the presentation of spatial patterns of attitudinal data was possible.

3 RESULTS AND DISCUSSION

3.1 Land Use Change

Land use change in the old reservoir area resulted from the coupling actions among low-lying submergence, emigrants moving, and townships and buildings relocating, infrastructure construction accompanied the reservoir project and other factors. That is, changes in land use were the consequences of integrative function among land use subsystem, socio-economic subsystem and eco-environmental subsystem. Great changes have taken place in land use patterns of Linshui reservoir area after the reservoir was built in 1966. Peasant household and field survey indicated that these changes were not only embodied on low-lying land submergence and migration requisition land of the reservoir built, but also on infrastructure construction of the reservoir built in migration region, and land exploitation that the migrants undertook to meet their basis living demand, e.g., steep slope land cultivated, unused land exploited, etc.

3.1.1 Land use subsystem

Land use was the core of regional land use pattern dynamics (SEMWAL *et al*., 2004; DEZSO *et al*., 2005; POSCHLOD *et al*., 2005). To analyze favorably, this paper divided land use subsystem into low-lying land submergence and migration requisition land. The former, which was mostly submerged in the reservoir area, was land cover conversion, i.e., the complete replacements of one cover type by another. The latter, as requisition land for settling migrants, was land cover modification, i.e., more subtle changes that affected the character of the land cover without changing its overall classification, but reconstructed original land property and made land over-fragmented.

It was inevitable to submerge and requisition land for the reservoir construction and infrastructure construc-

tion accompanied the reservoir project. In Linshui reservoir area 2763.55ha of land were submerged, including paddy field of 1329.61ha, dry land of 836.66ha, economic forestland of 197.01ha, firewood forestland of 400.27ha, and land use classification was according to the standard before submerged (Table 1). The submerged area was the granary in Linshui County. It was the dependence and groundwork of people here. The submergence of these land types influenced significantly regional land use patterns through affecting people living level of the reservoir area. On the quantity of submerged land, there are seven townships being involved in Linshui reservoir area, where the largest occupied area was in Lijia (1107.66ha), the second in Changtan (659.74ha), and the least in Yuanshi (28.40ha). So, the main submerged area of Linshui reservoir area was in Lijia, Changtan and Liangshan. On the types of submerged land, the largest area of paddy field was in Lijia (505.53 ha), the second in Changtan (318.40ha), and the least in Yuanshi (12.47ha); the largest area of dry land was in Changtan (305.07ha), the second in Lijia (298.13ha); economic forest land was mainly distributed in Lijia (107.00ha), and firewood forest land was mainly distributed in Lijia (197.00ha) and in Liangshan (197.67ha). On the spatial distribution of submerged land types, the most was located in shallow hilly and flatland region, because of the main land types submerged being paddy field and dry land, even the more paddy field than dry land. Generally, paddy field was distributed in relatively even topography and nearer to water head, but dry land in the area with worse conditions, such as unmatching condition of water and soil, inconvenience of cultivation, etc. Forestland was commonly distributed in the place with steeper slope and higher altitude. But, parts of forestland in the submerged area were also occupied, due to the stone that needed by reservoir construction and cofferdam being mined locally. There were close relationships between submerged area of the reservoir and relatively height of land use patterns.

The type of migrant settlement was mainly backward migration in Linshui reservoir area, and total 21 164 migrators were settled down during the years of 1958 – 1960. To solve the livelihood of migrants, the central government adopted the way to average the land area of the backward settlement villages, that is, confiscated land was used to settle down the migrants. Accumulating data showed that before the end of 1986, 1737.67ha of land was confiscated from seven townships, including 789.07ha of paddy field, 687.33ha of dry land, 175.53ha of firewood forestland (Table 2).

The number of migrants was related greatly to the confiscated land area, because of the way to average the land area of the backward settlement villages. Totally, the more migrators were, the more land were confiscated, for instance, Fenghe confiscated land of 342.13ha, but Yuanshi only confiscated land of 34.33ha. Simultaneously, firewood forestland was confiscated mainly in

Table 1 Submerged land area of Linshui reservoir area of Dahonghe Reservoir from 1958 to 1960 (ha)

Site	Submerged land area	Paddy field	Dry land	Economic forest land	Firewood forest land
Lijia	1107.66	505.53	298.13	107.00	197.00
Liangshan	514.94	184.27	124.33	8.67	197.67
Jiulong	147.01	84.47	49.20	10.27	3.07
Fenghe	222.86	178.20	26.33	16.00	2.33
Changtan	659.74	318.40	305.07	36.27	0.00
Fusheng	82.94	46.27	31.00	5.67	0.00
Yuanshi	28.40	12.47	2.60	13.13	0.20
Total	2763.55	1329.61	836.66	197.01	400.27

Table 2 Confiscated land area for migratior resettlement of Linshui reservoir area of Dahonghe Reservoir from 1958 to 1960

Site	Settled migrant	Paddy field (ha)	Dry land (ha)	Firewood forestland (ha)
Lijia	4483	188.41	125.60	169.33
Liangshan	3465	122.40	122.47	6.53
Jiulong	2375	100.73	67.14	0.00
Fenghe	5114	198.80	143.33	0.00
Changtan	3509	100.33	150.46	0.00
Fusheng	1732	61.20	61.20	0.00
Yuanshi	486	17.20	17.13	0.00
Total	21164	789.07	687.33	175.86

Lijia of 169.33ha. On the type of occupied land, paddy field was the most in Fenghe (198.80ha), and the least in Yuanshi (17.20ha); dry land was the most in Changtan (150.46ha), and the least in Yuanshi (17.13ha). On the land area per capita, it was primarily equal after immigration in the seven towns (about 0.07ha). But different from the area of dry land per capita, the paddy field per capita was the most in Lijia and Jiulong (0.042ha), and the least in Changtan (0.029ha). The dry land per capita was the most in Changtan (0.043ha), and the least in Lijia, Jiulong and Fenghe (0.028ha). It was illuminated that the idea of household responsibility system was carried out when originally resettling migrants.

Though confiscated land for resettling migrants did not change the land cover types, the relationship between human and land has been changed with the increase of population on the same area of land. The backward migration would come down to corresponding inhabitants and other infrastructure construction, accompanied the reservoir project having been built. The labor forces of resettling migrants also need some land. Simultaneously, the problem, caused by the change of relationship between human and land, would be tied to land of the reservoir area. For instance, to meet demands for migrant livelihood, using excessively fertilization and pesticide have greatly harmed water and healthiness of human and livestock. The improvement of multiple crop index, induced by the increase of population, was go against of maintaining the cropland biodiversity. In addition, the idea of household responsibility system was adopted for back-off migration resettlement, thus the average land area of per household was little, yet it was divided into several plots. Therefore, the plot in the migration area was over-fragmented, and the farmland boundary was more diversity. These all could change local land use patterns.

3.1.2 Socio-economic subsystem

Socio-economic subsystem was the embodiment of regional land use in the process of economic development (WOOD *et al*., 2004; SHAO *et al*., 2005b; HODGSON *et al*., 2005). Land use, especially cultivated land per capita, was the basis of regional economic development, while the conditions of regional economic development laid out whether regional land resources allocation was optimized or not (MÜNIER *et al*., 2004; STOLTE *et al*., 2005). The analysis of reservoir socio-economic subsystem in this paper comprised of three parts of cultivated land area per capita, grain per capita, income per capita (Table 3). In fact, these three indexes were highly related with each other in the relatively backward region. Because income per capita customarily depended on cultivated land per capita, and grain per capita was rooted in cultivated land area and its fertile condition. To variously reflect the changes of socio-economic condition in the old reservoir areas, this paper still chose these three indexes to make out the evolvement of socio-economic condition in Linshui reservoir area.

Table 3 Migrants' income in Linshui reservoir area of the Dahonghe Reservoir in 2004

Site	Migrant household (family)	Migrant (person)	Cultivated land per capita (ha)	Agricultural value ($\times 10^6$ yuan)	Income per capita (yuan)	Migrant without basic living security			Grain per capita (kg)
						Household	Person	Labor force	
Lijia	2614	10410	0.023	15.61	878	1350	5414	2166	256
Liangshan	1937	6910	0.037	10.36	805	1342	4424	1770	241
Jiulong	2618	9454	0.057	14.18	1003	452	1702	681	293
Fenghe	6994	24122	0.042	36.18	1073	892	3632	1453	271
Changtan	3185	10800	0.037	16.20	935	1500	5833	2560	209
Fusheng	1898	6145	0.043	9.22	862	978	3938	1575	243
Yuanshi	899	3229	0.047	4.84	1034	38	121	48	280
Total	20145	71070	0.041	106.59	969	6548	25066	10026	256

Up to the present, cultivated land was the security of basic necessities of life, and the change of cultivated land area per capita reflected the living level in a certain extent. Before Dahonghe Reservoir was founded in 1966, Linshui reservoir area, with 21 164 migrants and total cultivated land of 2166.27ha, was one of important grain zones of paddy, maize, wheat, oil plants, etc., in Linshui County. Cultivated land per capita was 0.102ha in this area. After the reservoir was constructed in 1966, there was cultivated land of 1476.40ha and the same population. Cultivated land per capita was decreased to 0.07ha, deduced by 0.032ha compared to that before the reservoir was constructed. The population increased greatly from 1966 to 1986, especially the former ten years of this term. In 1986, the number of migrants burst to 63 110, cultivated land per capita was only 0.051ha. Although cultivated land increased during the last 20 years, the ratio of population growth was more

rapid than that of the area of cultivated land. In 2004, cultivated land per capita decreased further to 0.041ha, and this number was greatly below the cordon of cultivated land per capita enacted by FAO of 0.053ha. At the same time, the yield per unit area in migration region was very low, because of cultivated land located on the area with steeper slope and higher altitude, with barren soil layer, worse fertility and unmatched cultivating facility.

Food security was the footstone of regional harmonious development. Providing that there was not certain food security coefficient, regional economy could not develop harmoniously, because of being short of favorable development environment. Food supplies per capita, in a certain extent, determined socio-economic development status and present and future economic development circumstance in the old reservoir areas. With the sight of the food supplies per capita during 1986–2004, we could not be optimistic with the circumstance basis of regional economic development. In 1966, food supplies per capita in Linshui reservoir area was just 240kg, and in 1986 the number reduced by 24kg, because of the population growth. Though food supplies per capita increased to 256kg in 2001, it was less than the average level of Linshui County of 72kg. The interviews indicated that there were 56.78% of migration families in Linshui reservoir area being short of grain in half of one year, despite in 2001 with more food supplies per capita. Before the end of 2004, there were still 30.25% of families in the area being short of grain in trimester of one year.

Could the economy in the reservoir area develop well with such food security coefficient? Whether the migration was colored by politics. The reason for this was that the construction of reservoir area was carried out in the political atmosphere with the Great Leap Forward and People's Community. Therefore, the migrants were moved rapidly with little fund, but without the support of planning and infrastructure accompanied the reservoir project. Under such feeble economic development background, the economy of the reservoir area could more easily get into a vicious circle, namely the economic development could not always use the coin for capital. Even in the time of household responsibility system, the living level of inhabitants in reservoir area was still awfully poor. For example, in 1986, annual income per capita was 187 yuan, only 713 yuan in 1996 though it increased in a certain extent. Before the end of 2004, annual income per capita of 969 yuan in reservoir area was just close to 55% of the average level in Linshui County. On the occasion, there were still 35.27% of migrants living under the poverty line.

3.1.3 Eco-environmental subsystem

Terrestrial ecosystem was "sources and sinks" to support the material flow and energy flow of Biosphere and Geosphere (JANSSENS *et al*., 2003; NEMANI *et al*., 2003; MASATAKA *et al*., 2005). Hence, land use change, driven by human socio-economic activities, could greatly influence climate, hydrology, biogeochemical cycle, biodiversity, etc. (SHARMA *et al*., 2004; SHAO *et al*., 2005b; TANG *et al*., 2005; JORDAN *et al*., 2005). Natural conditions in the old reservoir area were relatively poor, e.g., undulate terrain, coupling contradiction between water and soil resources, etc. Because of the backward resettlement in Linshui reservoir area of Dahonghe Reservoir, the emigrants mostly dwelled in barren mountains and steep slopes. For survival, the migrants inevitably paid more attention to utilization than protection, even reclaimed land at the expense of deforestation. These human activities caused the decline of land quality, serious soil erosion, vulnerable eco-environment and even the instable reservoir banks.

Field survey of seven towns in Linshui reservoir area of Dahonghe Reservoir (Fig. 2), suggested that health ecosystem was mainly the green belt around the reservoir and paddy field ecosystem. This system was not easily damaged, with slight erosion degree, high biodiversity, complex structure, high and stable productivity, strong anti-jamming capability and sound sustainability. Sub-health ecosystem was mostly economic forest and orchard land around the reservoir area and shrub land.

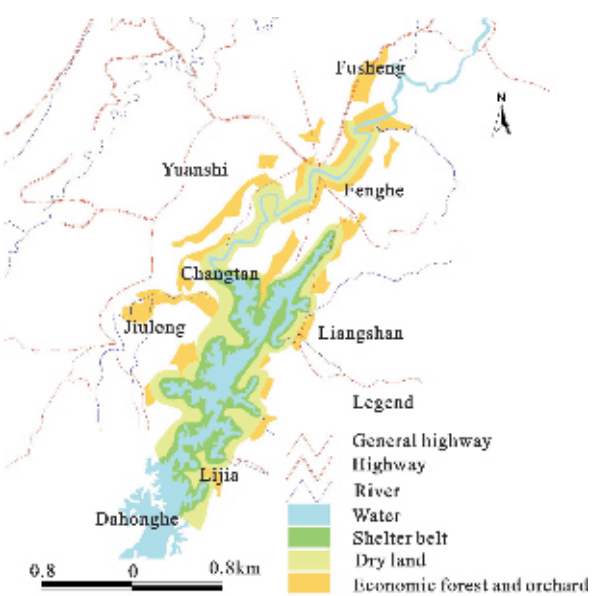

Fig. 2 Land use patterns around Linshui reservoir area

This system had lower biodiversity than health ecosystem, and showed inadequate circulation of mass and energy among each element inside and outside ecosystem, because of unmatched proportion of water and soil and slight disturbance of humankind. This system would be damaged when humankind activities exceeded the threshold of ecosystem, but humankind easily reconstructed it. Less health ecosystem was mainly dry land. This system had single structure, lower productivity and worse stability. It would be easily damaged by the disturbances of human and nature, and harder to be reconstructed, due to worse sustainability. Unhealth ecosystem was mainly bare land and bare rock sporadically scattering in the reservoir area, and steep cultivated land. This system was in lower stage of ecological succession with hard natural habitats, such as steeper slope and bare rock where only pioneer species grew, and degenerative forestland and bare land under the serious disturbances of human, with low productivity level.

3.2 Socio-economic Driving Force

The stress of reservoir project was macroscopic background to analyze the driving factors of land use change, and real underlying diving factors of the land use change in Linshui reservoir area were the changes in emigrant cultural landscape patterns under the stress of the project, including population growth, traditions, belief, mentality and economic development anticipation after migration moving. Although this paper analyzed emphatically changes in land use caused by low-lying land submergence and migration requisition land, socio-economic driving forces should be the changes of the cultural environment under the background of project stress. Thus, it was helpful to analyze the long-term effects of land use change under the stress of reservoir project.

3.2.1 Population

Population was the leading factor of regional man-land relationship, and any land management practices was induced by human behaviors (URAMA, 2005). The increase of population undoubtedly resulted in that the number of other land use patterns (e.g., forest land, unused land, etc.) were used for harvesting wood or converted to cropland (VEERLE *et al*., 2003; HUNTER *et al*., 2003; SEMWAL *et al*., 2004; EWERT *et al*., 2005). Changes in diet patterns of the population also induced agricultural restructure (SHAO *et al*., 2005b). For example, agricultural land has currently been transformed to the economic crop production and the aquatic farming. But in Linshui reservoir area, land use patterns were driven strongly more by population growth than changes in diet patterns of the population. After Dahonghe Reservoir was finished, the number of migrators in Linshui reservoir area increased from 21 164 in 1958 to 63 110 in 1986, and to 71 070 in 2004 (Table 4). It was obvious that population growth was very rapid. But, the population growth in Linshui reservoir area made land per capita over-fragmented. Facing food problems, migrants usually reclaimed slope land, but attached more importance to using than to fattening. Thus, in Linshui reservoir area, soil erosion was serious, and economic development has got into a vicious circle together. At the same time, more field ridges also make against land scale management and biodiversity protection. Hence, population was the most direct driving factors of land use change in the reservoir area. Adopting reasonable measures to control population growth was the best strategy to harmonize the man-land relationship from headstreams and to further turn land use patterns to fine evolvement in the reservoir area.

Table 4 Increase of population in Linshui reservoir area of Dahonghe Reservoir

Site	1958	1986	2004
Lijia	4443	8925	10410
Liangshan	3465	6165	6910
Jiulong	2375	8001	9454
Fenghe	5114	21103	24122
Changtan	3549	9781	10800
Fusheng	1732	6019	6145
Yuanshi	486	3116	3229
Total	21164	63110	71070

3.2.2 Rural economy

Economic behavior was an integrated result of many factors, e.g., biophysical, institutional, and technological factors, etc. (POLASKY *et al*., 2004; LAU *et al*., 2005). In Linshui reservoir area, economic factor driving changes in land use patterns lays on regional economic development level and migrant consumption ways more than supply and demand. Because of less cultivated land per capita in the reservoir area, in a longer term, land use dynamics was to solve migrant demand for food and fiber, and the commodity rate of products was low. At the same time, consumption of meat and milk was less, while grain consumption was much in the reservoir area. Therefore, supply and demand did not effect directly on land use patterns in the reservoir area. Regional economic level generally determined the input for improving productivity conditions (DUBROEUCQ and LIVENAIS, 2004; NAGENDRA *et al*., 2004). As we known, there was little installing fund and lack of planning in the backward emigrating

adopted by government. After emigrating, many infrastructures lagged and economic basis was weaker. Though, to solve the productivity and living problems, Linshui reservoir area has been ranked as the key supported area since 1987, the net income per year of migrants was increased from 187 yuan in 1986 to 969 yuan in 2004. But, the migrants have been still living hardly, because of the worse infrastructure and being serious lack of supporting fund. Hence, peasant households stressed generally utilization but neglected protection under the lower level of economy in the reservoir area. In addition, water and soil resources were not matched enough, and there was short of irrigation in this region. Thus, the migrants here dare not to input too much, even though they would like to input, due to relying upon the weather for their food and being short of dependable income. At the same time, land per capita was averaged in migration resettlement area, which had not been sound habitats, over-fragmented. There went against the normal running of productivity facilities, such as field pathways and irrigation and drainage facilities. Without the supports of economic basis, land use patterns of worse habitats could only get into a vicious circle in the reservoir area.

3.2.3 Migrants' belief

The belief was the destinations of one-person aspirations for the society and other thoughts (JEBKINS, 2002; LASANTA-MARTÍNEZ *et al*., 2005). The processes of land use change also included tradition and belief evolution. But tradition and belief, from a lot of respects, were such a force that helps to keep land use stable, and yields positive impacts on controlling overexploitation, uncontrollable cutting, and protecting biodiversity. At the same time, this force and others forces, e. g., policy, technological progress and population growth, decide the orientation of land use change together (DE MENOCAL, 2001; ZHAO Lin *et al*., 2004). Interviews showed that the migrants were long for belongings by using the patterns of nostalgia in the reservoir area of the Dahonghe Reservoir. However, the resettlement areas of migrants inevitably broke down the original cultivation modes, living habit and habitats, e. g., crop structure, production input, diet structure, personal relationship, etc. These changes in microhabitat and microenvironment would be embodied on present and future land use patterns. For instance, after the Dahonghe Reservoir was finished in 1966, many migrants went back to their original dwelling places in Linshui reservoir area because of not getting rid of poverty and seriously being lack of government supporting fund. Even though these migrants stayed in the resettlement area, they could not intensively cultivate their own contract farmland for the strange feelings. Thus, the rich nostalgia of migrants not only went against the input of agricultural production (e.g., infrastructure construction, chemical fertilizer, pesticide, seed, etc.), but also harmed greatly the eco-environment of the reservoir area. Extensive cultivation but less harvesting and straight plowing were not favorable for water and soil conservation. Thus, it could be concluded that land use changes in Linshui reservoir area of the Dahonghe Reservoir, to some extent, was the result of evolution of migrants' belief driven by external culture and technological progress. Therefore, the analysis of land use change in the reservoir area should not be solely occupied with changes in economic development, but had to include migrants' belief factor as well.

4 CONCLUSIONS

Land use change is one of the hot topics of global environmental change. Its researches have dealt with different spatio-temporal scales. Currently, these studies have been increasingly turning from global dimension towards regional dimension. The huge reservoirs were built by direct national administrative appropriate fund in the 1950s–1970s (now called old reservoir area). Because the administrative backward migration was the main way of resettlement, and migration fund was little at that time, the infrastructure of the reservoir area was not recovered in time. Up to now, the producing and living of migrants here have still been very hard as well. Liushui reservoir area has been the representative region for the study on land use change at regional scale. Based on the interviewing with peasant households, combining land use survey and socio-economic statistical index, this paper analyzed land use change and its corresponding driving forces in Linshui reservoir area of Dahonghe Reservoir. Land use change in the old reservoir area was driven by land use subsystem, socio-economic subsystem and eco-environmental subsystem.

(1) Land use change in Linshui reservoir area was mainly embodied on low-lying land submergence and migration requisition land. The former changed the land use patterns, and the latter mainly reconstructed original land property and made land over-fragmented.

(2) Cultivated land per capita was 0.041ha in Linshui reservoir area at present, below the cordon of cultivated land per capita enacted by FAO. Currently, there were still 30.25% of peasant households being short of grain in trimester of one year, and there were 35.27%

of people living under the poverty line.

(3) The conditions of eco-environment in Linshui reservoir area were worse, and healthy and sub-healthy eco-environment accounted for less proportion, composed of green belt around the reservoir area and paddy field ecosystem, and economic forest and orchard ecosystem, respectively.

(4) The stress of reservoir project was the macroscopic background to analyze the driving factors of land use change, and real underlying diving factors of the land use change in Linshui reservoir area were the changes of migrants cultural landscape under the stress of project, e.g., population growth, tradition, belief, mentality and economic development anticipation after migration moving.

(5) The rapid increase of population was the key factor to induce the change of man-land relationship in old reservoir area, the low level of rural economy was the crucial factor to determine how emigrants inputt for production, and the belief of emigrants, influencing the land use patterns in a certain extent, was the inducing factor to keep land use stable.

(6) The low-lying submergence and infrastructure construction accompanied the reservoir project were leading factors driving land use change in the reservoir area, while changes in land use patterns, after the reservoir was built, were the responses of peasant households' behaviors to land use change induced by low-lying submergence and infrastructure construction accompanied the reservoir project.

ACKNOWLEDGMENT

All persons and institutes who kindly made their data available for this analysis are acknowledged. The authors thank David Corriveau for comments on earlier versions of this paper.

REFERENCES

BRADBURY J P, VAN METRE P C, 1997. A land-use and water-quality history of White Rock Lake reservoir, Dallas, Texas, based on paleolimnological analyses [J]. *Journal of Paleolimnology* 17: 227–237.

CAI Q G, WANG H, CURTIN D, 2005. Evaluation of the EUROSEM model with single event data on Steeplands in the Three Gorges Reservoir Areas, China [J]. *Catena*, 59(1): 19–33.

DE MENOCAL P B, 2001. Cultural responses to climate change during the Late Holocene [J]. *Science*, 292: 667–673.

DEZSO Z, BARTHOLY J, PONGRACZ R *et al*., 2005. Analysis of land-use/land-cover change in the Carpathian region based on remote sensing techniques [J]. *Physics and Chemistry of the Earth*, 30(1–3): 109–115.

DUBROEUCQ D, LIVENAIS P, 2004. Land cover and land use changes in relation to social evolution—a case study from Northern Chile [J]. *Journal of Arid Environments*, 56(2): 193–211.

EWERT F, ROUNSEVELL M D A, REGINSTER I, 2005. Future scenarios of European agricultural land use I. Estimating changes in crop productivity [J]. *Agriculture, Ecosystems and Environment*, 107(2–3): 101–116.

GUO Zhong-wei, XIAO Xiang-ming, GAN Ya-ling, 2003. Landscape planning for a rural ecosystem: case study of a resettlement area for residents from land submerged by the Three Gorges Reservoir, China [J]. *Landscape Ecology*, 18: 503–512.

HALL B, MOTZKIN G, DAVID R, 2002. Three hundred years of forest and land-use change in Massachusetts, USA [J]. *Journal of Biogeography*, 29: 1319–1335.

HE Long-hua, LORENZ K, TONG Jiang, 2003. On the land use in Three Gorges Reservoir area [J]. *Journal of Geographical Sciences*, 13(4): 416–422.

HODGSON J G, MONTSERRAT-MARTÍ G, CERABOLINI B *et al*., 2005. A functional method for classifying European grasslands for use in joint ecological and economic studies [J]. *Basic and Applied Ecology*, 6(2): 119–131.

HUNTER L M, GONZALEZ M de J G, STEVENSON M *et al*., 2003. Population and land use change in the California Mojave: Natural habitat implications of alternative futures [J]. *Population Research and Policy Review*, 22: 373–397.

JANSSENS I A, FREIBAUER A, CIAIS P *et al*., 2003. Europe's terrestrial biosphere absorbs 7 to 12% of European anthropogenic CO_2 emissions [J]. *Science*, 300: 1538–1542.

JENKINS T N, 2002. Chinese traditional thought and practice: lessons for an ecological economics worldview [J]. *Ecological Economics*, 40(1): 39–52.

JORDAN G, van ROMPAEY A, SZILASSI P *et al*., 2005. Historical land use changes and their impact on sediment fluxes in the Balaton basin (Hungary) [J]. *Agriculture, Ecosystems and Environment*, 108(2): 119–133.

LASANTA-MARTÍNEZ T, VICENTE-SERRANO S M, CUADRAT-PRATS J M, 2005. Mountain Mediterranean landscape evolution caused by the abandonment of traditional primary activities: a study of the Spanish Central Pyrenees [J]. *Applied Geography*, 25(1): 47–65.

LAU S S Y, GIRIDHARAN R, GANESAN S, 2005. Multiple and intensive land use: case studies in Hong Kong [J]. *Habitat International*, 29 (3): 527–546.

LESPEZ L, 2003. Geomorphic responses to long-term land use changes in Eastern Macedonia (Greece) [J]. *Catena*, 51(3–4): 181–208.

LIU X H, ANDERSSON C, 2004. Assessing the impact of temporal dynamics on land-use change modeling [J]. *Computers, Environment and Urban Systems*, 28(1–2): 107–124.

MASATAKA W, WANG Qin-xue, HAYASHI S *et al*., 2005. Monitoring and simulation of water, heat, and CO_2 fluxes in terrestrial ecosystems based on the APEIS-FLUX sysem [J]. *Journal of Geographical Sciences*, 15(2): 131–141.

MCCUSKER B, 2004. Land use and cover change as an indicator of transformation on recently redistributed peasants in

Limpopo Province, South Africa [J]. *Human Ecology*, 32(1): 49–75.

MÜNIER B, BIRR-PEDERSEN K, SCHOU J S, 2004. Combined ecological and economic modelling in agricultural land use scenarios [J]. *Ecological Modelling*, 174(1–2): 5–18.

NAGENDRA H, MUNROE D K, SOUTHWORTH J, 2004. From pattern to process: landscape fragmentation and the analysis of land use/land cover change [J]. *Agriculture, Ecosystems and Environment*, 101(2–3): 111–115.

NEMANI R R, KEELING C D, HASHIMOTO H *et al*., 2003. Climate-driven increases in global terrestrial net primary production from 1982 to 1999 [J]. *Science*, 300: 1560–1563.

POLASKY S, COSTELLO C, MCAUSLAND C, 2004. On trade, land-use, and biodiversity [J]. *Journal of Environmental Economics and Management*, 48(2): 911–925.

POSCHLOD P, BAKKER J P, KAHMEN S, 2005. Changing land use and its impact on biodiversity [J]. *Basic and Applied Ecology*, 6(2): 93–98.

RAUTELA P,RAKSHIT R, JHA V K, 2002. GIS and remote sensing-based study of the reservoir-induced land-use/land-cover changes in the catchment of Tehri dam in Garhwal Himalaya, Uttaranchal (India) [J]. *Current Science*, 83(3): 308–311.

RUDELA T K, COOMES O T, MORAN E *et al*., 2005. Forest transitions: towards a global understanding of land use change [J]. *Global Environmental Change*, 15(1): 23–31.

SEMWAL R L, NAUTIYAL S, SEN K K, 2004. Patterns and ecological implications of agricultural land-use changes: a case study from central Himalaya, India [J]. *Agriculture, Ecosystems and Environment*, 102(1): 81–92.

SHAO Jing-an, HUANG Xue-xia, GAO Ming *et al*., 2005a. Response of CH_4 emission from paddy fields to land management practices at a microcosmic cultivation scale [J]. *Journal of Environmental Sciences*, 17(4): 691–698.

SHAO Jing-an, NI Jiu-pai, WEI Chao-fu *et al*., 2005b. Land use change and its corresponding ecological responses: a review [J]. *Journal of Geographical Sciences*, 15(3): 305–328.

SHARMA P, RAI S C, SHARMA R *et al*., 2004. Effects of land-use change on soil microbial C, N and P in a Himalayan watershed [J]. *Pedobiologia*, 48(1): 83–92.

STOLTE J, RITSEMA C J, BOUMA J, 2005. Developing interactive land use scenarios on the Loess Plateau in China, presenting risk analyses and economic impacts [J]. *Agriculture, Ecosystems and Environment*, 105(1–2): 387–399.

SUN D F, LI H, LIN P, 2003. Monitoring land use and landscape changes caused by migrant resettlement with remote sensing in Region of Three Gorges of Yangtze River [J]. *Transactions of the CSAE*, 19(5): 218–224.

TANG Z, ENGEL B A, PIJANOWSKI B C, 2005. Forecasting land use change and its environmental impact at a watershed scale [J]. *Journal of Environmental Management*, 76(1): 35–45.

URAMA K C, 2005. Land-use intensification and environmental degradation: empirical evidence from irrigated and rain-fed peasants in south eastern Nigeria [J]. *Journal of Environmental Management*, 75(3): 199–217.

VANNI M J V, AREND K K, BREMIGAN M T *et al*., 2005. Linking landscapes and food Webs effects of omnivorous fish and watersheds on reservoir ecosystems [J]. *Bioscience*, 55(2): 155–167.

VEERLE V, GERARD G, SANDRA B *et al*., 2003. The effect of short-term socio-economic and demographic change on landuse dynamics and its corresponding geomorphic response with relation to water erosion in a tropical mountainous catchment, Ecuador [J]. *Landscape Ecology*, 18: 1–15.

WOOD E C, TAPPAN G G, HADJ A, 2004. Understanding the drivers of agricultural land use change in south-central Senegal [J]. *Journal of Arid Environments*, 59(3): 565–582.

WU J G, HUANG J H, HAN X G *et al*., 2003. Three-Gorges Dam—experiment in habitat fragmentation? [J]. *Science*, 300: 1239–1240.

ZHAO Bin, KREUTER U, LI Bo *et al*., 2004. An ecosystem service value assessment of land-use change on Chongming Island, China [J]. *Land Use Policy*, 21(2): 139–148.

ZHAO Jie, ZHAO Shi-dong, 2003. Application of the participatory rural appraisal method in the research of land use change at local dimension—a case study of Yaoledianzi village in Koeqin sand [J]. *Resources Science*, 25(5): 52–57. (in Chinese)

ZHAO Lin, PING C L, YANG Da-qing *et al*., 2004. Changes of climate and seasonally frozen ground over the past 30 years in Qinghai–Xizang (Tibetan) Plateau, China [J]. *Global and Planetary Change*, 43(1–2): 19–31.