

## 〈 Review 〉

## Landscape Ecological Changes of Large Dams and Reservoir in China

Lu, Jianbo\*, Lizhong Ding and Xingzheng Zhao

*Agro-Ecology Institute, Huajiachi Campus, Zhejiang University, Hangzhou, 310029, P.R. China*

**ABSTRACT** : Dams are distributed widely in all over the world. China is one of the countries which have the most dams in the world. The construction of dams promotes consumedly to the development of economy and society, at the same time, brings many ecological and social problems. In China, the landscape ecological changes are caused by the construction of dams. These changes are long term or short term, and some of these changes are positive, others are negative. Solving these issues need do a lot of circumspect work in location choosing, planning and designing, practicing and protection of the up reservoir basin and the whole basin and so on. The construction of dams should be implemented by reasonable landscape planning, ecological environment protection in order to realize sustainable development.

**Key words** : Ecological impacts, Landscape changes, Large dam

## INTRODUCTION

Dam is one of the outcomes that human conquers nature. Dams exert huge function in the aspects of preventing or controlling flood, irrigating, generating electricity, water supply and shipping. At present, there are only 1/7 of hydropower resources which can be employed technically and economically have been developed. So the development of hydropower is still continuing. Extensive social and environmental issues are arisen by dam construction. The construction of dams changes landscape and causes resettlement population, especially in the third world. The vehement debate about advantages and disadvantages of the construction of huge dams is still continuing. The secretary-general of International Committee of Large Dams (ICOLD) considers that in one century multi-objective project is characteristic of potamic development. Hydropower is still the best way to solve the problem of electric utilization. In all over the world, the speed of potamic development is slower. Large dams are not built any more at the most profitable place. But, in many countries, large dams and hydropower which account for 20% of world electricity power (account for 94% of the whole reproducible energy sources) is still important to agriculture (Lils 2001). In Egypt, Aswan Dam prevents this country from drought.

Though encountered objection, the speed of dam construction almost does not slacken in some areas. The data from ICOLD shows that up to date 1997, there are about eight hundred thousand various dams in the world, in which there are about 3600 large dams (> 15 m high). From 1952 to 1986 the increasing rate is 688%

(Vorosmarty *et al.* 1997). In addition, now there are 1600 dams that are being built in 40 countries, and output power doubles every ten years (Zhu 1999). The World Bank is the greatest single sources of fund for large dam construction, having provided more than US\$50 billion (1992 dollars) for the construction of more than 500 large dams in 92 countries. The achievement is very prominence. The number of dams in china is the top in the world. The construction of dams achieves great success and acquires tremendous economic benefit. At the same time it brings a series of environmental and social problems. In this paper, as case studies of Xinan River large dams and Three Gorges large dams, their landscape ecological changes are analyzed in order to discuss the landscape changes and ecological environment impacts on the construction of dams in China.

## LANDSCAPE ECOLOGICAL CHANGES AND ENVIRONMENTAL IMPACTS

The construction of dams brings the landscape changes of up reaches and down reaches of the dams, also brings many environmental problems. For example, land reclamation and excessive hag in upriver basin and so on make forest landscape and marsh landscape destroyed; because dams construction destroyed habitats or obstructed migration route, the quantity of fishes is reduced or the breeds of fishes are disappeared; the habitats of threatened and endangered species are destroyed and living space for these species is reduced to lead species depopulation; the scope of waterborne diseases largely extend because dams construction come into being

† This article was presented at the INTECOL meeting (Seoul, August 2002).

\* Corresponding author; e-mail: jianbo.lu@zjuem.zju.edu.cn

extensive water surface, these diseases influence health at not only the reservoir site but also upstream, downstream, and at national or even regional levels (Lerer and Scudder 1999); reservoir reserving water submerges towns and countries, makes a great deal of local dwellers resettled; the quantity of patches and corridors of landscape are increased, proportions are diminished, shape is complication, so that dam construction leads to landscape fragmentation; upstream bedload deposited in reservoir that makes soil corroded and soil erosion increased; natural season flux and bedload sedimentation fashion changed, water temperature and chemical components altered; water pollution severity, entrophication and micro-climate changes can also be caused.

#### The main dams and reservoirs in China (>10km<sup>3</sup>)

In China, many dams were set up in the past, especially after the foundation of the Peoples Republic of China, the construction of dams made even more rapid progress. Up to 1996, there were 118 large and medium hydropower dams across China's seven major rivers and their tributaries (Jackson and Sleight 2000). Dams and along with formed reservoirs landscape produce crucial functions in many aspects such as generating electricity, defending disaster, irrigation, shipping, accelerating the development of economy and giving benefit to inhabitant in a wide broad. But at the same time it brings many social and ecological problems that cannot be neglected or cry for be resolved. There are five large dams in China which cubage of reservoirs exceeds 10 km<sup>3</sup>. These dams are separately Longyang Gorge Dam located in the Yellow River, Xinan River Dam located in Xinan River, Danjiangkou Dam located in Han

Table 1. Basic information of five large dams in China

Name	River	Volume(km <sup>3</sup> )	Year
Longyang Gorge	The Yellow River	24.7	1988
Xinan River	Xinan River	22.0	1959
Danjiangkou	Han River	20.9	1973
Shuifeng	Yalu River	14.7	1941
Three Gorge	Yangtse River	39.3	Now

Table 2. The main landscape changes in Xinan reservoir basin

	Cultivated land (km <sup>2</sup> )	Percent of up basin (%)	Water surface (km <sup>2</sup> )	Percent of up basin (%)	Mountain and hilly land (km <sup>2</sup> )	Percent of up basin (%)
Before the project	412.98	9.33	33.4	0.75	3980.63	89.92
After the project	146.40	3.3	595.93	13.46	3684.67	83.24
Change	-266.58	-6.03	562.53	12.71	-295.96	-6.68

River, Shuifeng Dam located in Yalu River and Three Gorge Dam located in the Changjiang River. Their main information is listed in the Table 1 below:

#### Ecological Changes of the Xinan Dam and Reservoir

##### General Situation of Xinan Dam and Reservoir

Xinan dam locats in the Xinan River which is the upriver of Qiantang River lied in Zhejiang province of China. The dam that is 108 meter high was set up in 1959. The reservoir surface is 600 km<sup>2</sup> and the maximum reservoir water volume is 22 km<sup>3</sup>. After the construction of dam, 562.5 km<sup>2</sup> land has been submerged, of which cultivated land is 204.7 km<sup>2</sup>. The total population of resettlement was 233 thousand people.

##### Landscape Change in River Basin

After the establishment of the large dam, landscape was intensively changed in the up reservoir basin. The main changes are: water surface increased, cultivated land decreased, landscape fragmentation increased. Moreover, mountain and hilly land changed little. The changes can be illuminated by the Table 2 below:

##### Submerged Land and Resettlement

After the construction of dam, the total area of submerged land is 562.5 km<sup>2</sup> in which cultivated land is 204.7 km<sup>2</sup>, garden plot is 133.3 km<sup>2</sup>. There are 49 townships and 1377 villages submerged. The total population of resettlement is 233 thousand people. Most of the submerged land is cultivated land of high and steady yield which are formed by long term cultivation in valley and plain. In addition, there is a large number of migration need to be allocated so that the contradiction between population and land became more aculeate. The resettlement of population and the reclamation of new cultivated land destroyed the forest and wetland landscape more heavily and caused soil erosion at the same time.

##### Climate Changes in Xinan River Basin

Large water body causes local climate changed. The climate is changed more pleasant in the mass, but there are some bad impacts. Compared to no dam, after the project, the highest air temperature

is declined 3.2°C, the lowest air temperature is increased 4.4°C, the annual average temperature increased 1°C, no frost period is increased 25 days, the first frost date is postponed 20 days and the latest frost date advanced about 10 days (Yu and Yang 1991). It is obvious that after dam construction, the new formative landscape brought considerable effect to reservoir basin environment.

#### Changes in Fishery Production

The construction of dam brought the changes of ecological environment, altered intrinsic season flux mode of the river and obstructed continuity of river biological web. Components and chemical characters of water in the river also have been changed. The habitats of fishes were destroyed, or migration routes of fishes were obstructed that made some kinds of fishes can not natural reproduction (Zhu 1999). These reasons leads to the number of fishes decreased or species deracinated and the yield declined continuous in the down reaches. For example, the fishery yield in Fuyang count decreased year by year. But in up reaches of the dam, the fishery production are made rapid progress and the fish yield enhanced continuous because the water flood a large region, nutrimental material and the types of environment increased. Close to 600 thousand ha. water surface offers ascendant condition to breed aquatics in the reservoir. The fishery production is largely enhanced and the yield of other aquatic product is also increased durative (Yu and Yang 1991).

#### Change of Agricultural Production

After the construction of the dam, more upland was increased to produce more food, much large grade land was reclaimed and cultured, needy area felled fuelwood that caused vegetation destroyed, addition to local landform considerable complex caused soil erosion more severe. Saving water in the reservoir submerged a great deal of fertile land which was cultivated by people in a long time. More leanness land with high hypsography and large grade was used to plant crops and the production of foodstuff largely decreased. A great deal of fertile land was submerged lead to personal average arable land reduced. And soil fertility was decreased. All of the above reasons caused the shortage of food of inhabitant in the area of reservoir. On the other side, the changes of landscape in reservoir area brought the changes of climate so that some kinds of crop and fruit trees are changed from unsuitable for growth to suitable. For example, citriculture became from unsuitable region to suitable region (Yu and Yang 1991). After the construction of the dam, new increaser water surface made the quantity of farmland reduced, reclamation of new cultivated land caused more farmland and woodland combined together, accordingly formed more agroforestry system in quantity and types. These systems advanced agriculture

product and at the same time created many new agroforestry models.

#### Rapid Development of Tourism

After construction of the dam, Qiandao Lake beauty spot was formed in up basin region of the dam. The main types of landscape changed from farmland and forest to forest and lake. There are warm climate and enough rainfall in the reservoir basin. The multi-year average temperature is 17°C and the annual average rainfall is 1430 mm. The vegetation in the beauty spot is good, the forest covering rate is 93% and green visual field rate is near 100%. In reservoir basin there are more than one hundred pieces of river afflux into the lake. The multi-year average water volume entered the lake is 9.45 billion m<sup>3</sup> and the annual effluent water volume by Xinan River Dam is 9.17 billion m<sup>3</sup>. The seeing resources in Qian-dao Lake beauty spot are also very abundance. The number of view spots is 95 and landscape sceneries 297. The water quality of the lake is the first degree. The environmental quality of sound of the beauty spot is better and the environmental quality of sound of each function section answers basically for concerned demand. The environment and air quality in the beauty spot reached the first degree (Xiang *et al.* 1999).

After construction of the dam, especially after opening to the oversea, the tour industry of the region got rapid development. In 1980, there are only 5 rest houses including 600-700 beds in the beauty spot. Up to now, the total quantity of hotels, restaurants and rest houses have reached more than 80 including 13000 beds (Su 1992). There are 27 tourism hotel and 3782 beds in them. The tour vehicle in beauty spot gives priority to yacht. There are all kinds of yachts 71 pieces and total amount of seats is 5969. The amount of motorboat is 140 provided with 1200 seats. From 1982 in this year the beauty spot opening to the world to the end of 1998, there are 18227.3 thousand people accumulated total came from national and international visited the beauty spot and the total revenue of tour economy is 1.017 billion (Xiang *et al.* 1999).

#### Ecological Issues of Xinan River Basin

Over 90% of the up reservoir basin is mountain and hilly. After the construction of the dam, the mounts and hills were separated by water so that many new patches and corridors were formed. The acreage of patches diminished, the quantity of patches and corridors increased, it makes landscape fragmentation and the function of landscape descendent. With the development of economy and the promotion of tourism, the industry development and city construction make a rapid progress. The diffusion of industry castoff and city garbage brings many ecological problems and affects the stabilization of species and ecosystem, it also causes many watery environmental problems. The unity and network of shipping traffic

were not considered and ship pass had not been set up, the unity of shipping routes was jammed and the development of large bound traffic was blocked. In addition, the water surface enlarged, the development of shipping inside reservoir region also brings many environment problems. The non-point agricultural pollution increases. Agricultural cultivation around the reservoir, utilization of chemical fertilizer and pesticide along with feedstuff in aquatic production breeding are the main reasons of non-point agricultural pollution. The pollution impacts the subsistence and reproduction in reservoir basin. More soil subsides to the reservoir bed because of water surface enlarged and the velocity of current slower. Agricultural non-point pollution, shipping, nutrition surplus of breed aquatics production and the random casting off of industry garbage all make water pollution and eutrophication severely. Now the issue of water eutrophication becomes more and more serious. The water quality presents a worse trend and nutrition grade is changing from light eutrophication degree to middle eutrophication degree.

### Ecological Changes of the Three Gorges Program

#### General Situation of Three Gorge Program

The Three Gorge located in Chongqing city and Hubei province is a part of Yangtze River basin. The engineering has attracted worldwide attention and this program will result in a dam that is 185m high and has a 175m water-storage level. After completion, the reservoir surface will be over 1,084 km<sup>2</sup>, the maximum reservoir water volume will be  $3.93 \times 10^{10}$  m<sup>3</sup>. 632 km<sup>2</sup> land will be submerged, of which cultivated land is 238 km<sup>2</sup>, orchard is 49.6 km<sup>2</sup>. The program involves the resettlement of 1.13 million people within 21 counties in Hubei Province and Chongqing City, the complete or partial submergence of two cities, 11 county towns, 114 market towns, 1,352 villages and 1,599 manufacturers.

#### Infection to Ecological Environment

The Three Gorges Dam will be produced extensive ecological impacts to the whole reservoir basin including: the ecological capability of resettlement in up reservoir basin; climate impacts; mountains disasters; the impacts on biodiversity in up reservoir basin and whole basin; the influence on soil in down basin and so on.

#### Short Term Impact

The Three Gorge reservoir will inundate a great deal of high quality cultivated land for saving water, migration needs to be allocated and some towns need relocating. Whether allocation in the local area or the construction of new towns, the place with gently landform and the preferably soil conditions is necessary. The situation augments difficulty even more to the Three Gorge Reservoir

area which has much population and little cultivated land. Abundant resettlement and a great deal of cultivated land to be submerged made the conflict between population and food supply very obvious. Moreover, the sloping field which gradient is more than 25° will be returned from cultivated land to forest that makes the contradiction more serious. After the construction of dam, the land which altitude is lower than 200 meters will be submerged. Most of these areas are farmland. The project will flood nearly 34,000 ha of agricultural land. Fifty percent of them is rice paddy fields, 22% garden plots, 1% fishponds and 10% forests (Jackson and Sleigh 2000). The economic cost of submerging farm land is high in China. The submerged farmland in high and steady yield is formed by long term cultivation and new farmland is difficult to be produced with the same quantity. Because the population increases continuously, the status of forest will be destroyed and land reclamation severity lead to the forest cover rate declined. The average forest cover rate of reservoir area is 19% and merely 10% beside the river bank. The soil erosion in this region is very severe and the upland disasters are often occurred. According to the statistical data, the area of soil erosion account for 80% in the total land acreage and it is one of the fragility zones of ecological environment in China. The first time population resettlement in this area is 860 thousand and together with the second time resentment the total population of resettlement will reaches 1160 thousand at last (Xu 1991, 1995). After the resettlement, disturbance will become more frequency. It can be imaged that these disturbances will bring strong concussion to the frail ecological environment and make it more deterioration. After the formation of reservoir, it will flood the habitats of many species or make the habitats reduction that lead to the decrease or depopulation of threatened and endangered animals and plants.

#### The Long Term Infection

After the construction of the Three Gorge Dam, because the change of hydrological condition can bring some long term impacts to the middle and down reaches and even to bayou area. These infections can be separated into two sections: the bogging and potential gleization of paddy field in middle and down reaches; satlinization in delta region. After the construction of the dam, because of saving water in the reservoir, the volume of rushing downstream increases from January to May that impacts water level naturally depressed in middle and down reaches, and causes drainage is not free. At the same time, it induces bayou brine ascending and soil satlinization. From October to December, the volume of flowing to down reaches will be reduced, the resisting power to salted tide weakens that makes soil and ground water satlinization and affects farmland and the quality of industry and drinking water. After the construction of dam, there will be some impact in certain extent to

climate around the reservoir. For example, the annual average temperature and precipitation will have a little increase and the uttermost highest and lowest temperature will decrease 4 °C and 3°C separately. Humidity also has some changes that have somewhat increase in spring, summer and autumn and a little decrease in winter (Xu 1995). Most of the reservoir area is mountain and hilly land and the quality of soil resource is bad. It is obvious that abundance migration will bring land excess reclamation so that it makes land bearing capability decreased gradually. This situation will bring hell and gone losing and ecological problem if we do not control and take measures earlier.

### CONCLUSION

In a word, the construction of dams can bring many impacts to region landscape and ecological environment. Some of these impacts are short term such as people migration and land inundating, others are long term such as adjusting water flux, changing hydrological condition and microclimate. Some of these impacts are positive such as generating electricity, improving climate condition, water supply, irrigation, preventing flood and waterlogging and shipping, others are negative such as resentment, resulted in environment fragility, water pollution, disease diffusion and species depopulation and so on. In china, because of the rapid development of construction of dams, these problems should be paid great attention and recognition. The construction of dam should make development and conservation coordination and should do abundance circumspect and right work in the aspects of location choosing, designing and planning, putting into practice of dam, protection of reservoir and the whole river basin. Making particular landscape and ecology planning promote the realization of harmonious development of dam and the river basin. We should exactly demonstrate, reasonably design and choose location, strictly monitor. Essential measures should be applied for protecting landscape and ecological environment and preventing infraction and disturbance which can be avoided. We should develop the dam reasonably and realize sustainable development of reservoir and the whole river basin.

### LITERATURE CITED

- Jackson, S. and A. Sleight. 2000. Resettlement for China's three gorges dam: Socio-economic impact and institutional tensions. *Communist and Post-Communist Studies* 33: 223-241.
- Lerer, L.B. and T. Scudder. 1999. Health impacts of large dams. *Environmental Impact Assessment Review* 19: 113-123.
- Lils, Y. 2001. Exploitation general situation of world dams. *Water Conservancy and Hydropower* 4: 31-32.
- Su, Y. 1992. Social enefit of tourism development of Xinan River reservoir. *Water Conservancy Economy* 3: 48-50.
- Vorosmarty, C.J., K.P. Sharma, B.M. Fekete, A.H. Copeland, J. Holden, J. Marble and J.A. Lough. 1997. Reserve and aging of continental runoff of large dams systems in the world. *AMBIO -A Journal of the Human Environment* 4: 206-215.
- Xiang, B., D. Chen and G. Yu. 1999. Resource exploitation and sustainable development in Qiandao Lake. *Zhejiang Forest Science and Technology* 2: 57-62.
- Xu, J., Z. Yang and Q. Li. 1999. Climate evaluation of the project of tourism exploitation of Qiandao Lake drainage basin country ecological environment. *Rural Ecological Environment* 15: 33-35.
- Xu, Q. 1991. Impacts of three gorge project on agricultural ecosystem in Yangtse River basin. *Chinese Journal of Application Ecology* 1: 77-84.
- Xu, Q. 1995. Research evolving of three gorge project impaction to ecological environment. *P. Chinese Academy of Science* 2: 158-162.
- Yu, Y. and J. Yang. 1991. Preparatory study of economic benefit Xinan River reservoir. *Huadong Normal University Transaction* 1: 109-112.
- Zhao, H. and L. Zhang. 2002. Attention the impact of dams to drainage basins environment. *Shanxi Irrigation Works Science and Technique* 2: 92-97.
- Zhu, D. 1999. Dams and environment problems. *Hydropower Station Design* 9: 6-11.

(Received December 18, 2003; Accepted February 5, 2004)