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# Sustainable development pattern and the strategy in the Three Gorges Reservoir Areas

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**Abstract:** The development pattern, development situation, and existing problems of land exploitation in Zigui County, Three Gorges Reservoir Areas of China were presented. The sustainable development mode and its strategy in the Three Gorges Reservoir Areas was also discussed. A sustainable development framework for low mountain regions, middle mountain regions and high mountain regions was developed, and management countermeasures for structural optimization of complex ecosystems were advanced.

**Keywords:** sustainable development pattern; strategy; Zigui County; the Three Gorges Reservoir Areas

## Introduction

The Three Gorges Project provides new opportunities for the development of the whole Yangtze River zone (Chen, 1997), but at the same time, it also brings a series of ecological and environmental problems, especially, the conservation of vegetation, the exploitation of land, the survival of 500000 rural immigrants, and the development of regional agriculture (Wu, 1998). The sustainable development mode for agriculture is the key for the survival of the 500000 county immigrants. For the purpose of improving regional ecological environment, reducing soil erosion, ensuring water quality, and increasing the economic income of the immigrants, it is important to probe into sustainable development modes of ecological agriculture (Tang, 1997).

Because of the mountainous relief, high population density, occlusive traffic, and slow development of urbanization, the development of agriculture and the economy has been inhabited in this region (Chen, 1997). To avoid further pauperization, it is necessary to discuss sustainable development modes and strategies of agriculture. These questions are closely related to the development of society, resources, and the economy in the Three Gorges Reservoir Areas, land exploitation, its existing problems, and the potentiality of agriculture development are discussed in this paper. The mode and strategies for sustainable agriculture development are advanced.

## 1 Basic characteristics of Three Gorges Reservoir Areas and main ecological problems in Zigui County

### 1.1 Basic characteristics of Three Gorges Reservoir Areas

The total area of the Three Gorge Areas (38 counties and cities) is 8847140 hm<sup>2</sup>, in which mountainous land accounts for 74%, hilly land accounts for 21.7%, and flat land accounts for 4.3%. The total area of the Three Gorge Reservoir Areas (19 counties and cities) is 7509813 hm<sup>2</sup>, of which mountainous land accounts for 78%, hilly land accounts for 18.2%, and flat land accounts for 3.8%. It belongs to the moist sub-tropical monsoon climate. In general, the conditions of water and heat are favorable for the development of agriculture. The average annual temperature is 15—19°C, and the average annual precipitation is 1000—1300 mm. The frost-free period is 290—340d, and the annual accumulative temperature  $\geq 10^\circ\text{C}$  is 5000—6000°C. The population density in this area averages 300 people per hectare. In the mountainous and hilly land, the population density is 140—200 people per hectare, while

in the valley and on the flat land, it is 300—600 people per hectare. The farmland per person averages only 0.06 hectare and farmland with a slope of more than 25° accounts for 46% of the total farmland. The average annual food production is 3450—4050 kg/hm<sup>2</sup>. There exists 6049700 hm<sup>2</sup> of farmland in the Three Gorge Areas (38 counties and cities) and 4988753 hm<sup>2</sup> of farmland in the Three Gorges Reservoir Areas. The farmland is distributed from at an altitude of 100m to 1400m, of the total farmland, dry farmland accounts for 71% and wet farmland accounts for 29%. The percentages of rained farmland at altitudes lower than 300m, from 300m to 500m, from 500m to 1000m, and 1000m to 1400m are 0.5%, 45.3%, 42.6%, and 11.6% respectively. For irrigated farmland, the corresponding percentages are 3%, 54.7%, 37.8%, and 4.5%. It was discovered that 46% of the farmland with a slope of more than 25° had been cultivated. This shows that the land in this region is over exploited (Zhang, 1997).

## 1.2 Main ecological problems in Zigui County

### 1.2.1 Degradation of land

During the recent 30 years, because of unreasonable land exploitation, and vegetation degradation, there has been less litter restitution, which grievously effects the well-balanced bio-geo-chemical circle. The depth of the surface soil had been reduced 3—5 cm, and humus has vanished everywhere, and the quality of the soil has obviously degenerated. The average organic content dropped 0.5%—1.0% from the 50's to 1985, and from 1985 to 1992, it dropped 0.2%—0.6%. The annual productivity of the secondary forest which consisted of *Pinus massoniana*, *Pinus massoniana* and *Quercus* spp., and weed community per unit area dropped 6.2% and 12.4% from 1985 and 1956 to 1999 (Du, 1994). It means that soil fertility descended and lands degraded. So, it is very important to pay great attention to the problems of land degradation, probe into the reasons of land degradation, and find out optimum solutions to resolve these problems.

### 1.2.2 Unreasonable land exploitation

In the last 30 years, agriculture land use is the main land exploitation type and accounts for 94% of the total land. Forestry land accounts for 6% of the total land and is mainly orange orchard. This exploitation mode, creates several problems as follows:

(1) Low productivity of farmland, soil fertility declining, and area of farmland decreasing: In this area, the farmland per capita is much lower than that of the average level for China, and most of the land is mountainous land. The average cultivating index is 23%. The land cannot be used for concentrated cultivation because of its scattered distribution. In existing dry farmland, slope farmland accounts for 91% and land with a soil depth lower than 30 cm accounts for 37.9%. Land with organic content lower than 2% and N content lower than 0.1% accounts for 50%, and with K content that has quick effect accounts for 35%. Calcareous alluvium and purple soil accounts for 65%. So, farmland with low or middle productivity accounts for 78%.

(2) Frequent natural disaster: The unreasonable exploitation of too much slopeland has led to more frequent calamities, the unsuitable management of land and the inadequate infrastructure of farmland has also impaired its ability to resist natural calamity (Grant, 1998). For instance the existence of hot and drought factor is the key reason, which determines the production of Zigui County's farmland. The frequency of existence of a hot and dry season ranged between 30%—50% in the recent 30 years, but it rose to 50%—80% after the 80s. All of these caused the dry land's production to decrease 5%—10%; the worst part decreased by over 20%.

(3) Unreasonable exploitation and excessive cultivation: The insufficient design of land, the unreasonable exploitation mode and the immoderate exploitation of land (for example, the exploitation of >25° slope, excessive destruction of forest and lawn) caused the deterioration of the environment. The forest coverage in the Three Gorges Area decreased from 20% in the 1950s to 10% or less in the 1980s.

(4) Mono-cultivated management mode: Zigui County lies in a subtropical region with plenty of natural resources. The history of producing oranges, silkworm, tea, lacquer, and tobacco leaf is very long. But the land used for economic forest and long-term economic crops is only 8.35% of the whole

exploited land. Furthermore, variety is scarce, while the quality and the economic efficiency are low.

### 1.2.3 Soil erosion

Because of soil erosion and unreasonable management, soil fertility and land area has declined increasingly in this region. Forest denudation has led to serious soil erosion and degradation. In Zigui County, the soil erosion rate was 865000 t/a in 1980, and it rose to 1259000 t/a in 1980. All of these have led to the following results such as the area of bare mountain increasing, the riverbed hoisting, and serious silting up of ponds and reservoirs.

### 1.2.4 Point and non-point resource pollution

Along the bank of the Yangtze River in the Three Gorges Area, there exist hundreds of industrial corporations of different sizes. The increasing enlargement of the management scale of these corporations has led to serious pollution in some tributaries. Most of the corporations deal with primary production based on the exploitation of natural resources, and their scientific technology is under-developed. The economic benefits of these corporations are low, and it has led to inadequate devotion to controlling pollution. At the same time, these corporations are the mains supporting source for the residents of this area. How to increase scientific technology and seek advanced substitution industries is an urgent task in controlling the point resource pollution in the Yangtze watershed.

In the Three Gorges Reservoir Areas, there exist large areas of citron forests. Because of low soil fertility and frequent natural disaster, the dosage of pesticide and fertilizer has increased from year to year. In some regions, the pollution of pesticide and fertilizer greatly exceeds the self-purification capacity of the soil and water ecosystems. The main approach in controlling non-point resource pollution is to adjust the exploitation mode and cultivation structure, to manage multi-functional economic forests, and to enhance the resistance to natural disasters.

### 1.2.5 Flood disaster

Water is the chief limit factor for biological activity. Water quality and water quantities are two important aspects. Serious destruction of vegetation in Yangtze watershed has led to weak accommodation ability and frequent flood disasters. It endangers the survival of the people in this area. The great flood of 1998 illuminates this point.

## 2 Methods of investigation and research

Related data in the field of society, economy, resource, and ecological environment for the Yangtze watershed and this reservoir area was collected. The field investigation was carried out in Zigui County, and the Quxi watershed ecosystem was selected as a typical watershed. The contents include vegetation, soil, society data, and economic data. The analysis is based on theories of economics and system ecology.

## 3 Results

Food is the chief limiting factor for economic development in the Three Gorges Reservoir areas. To resolve the food problem, the ultimate approach is to exploit land and biological resources reasonably, and enhance land productivity. Agricultural income accounts for 65% of the total income in Zigui County, and 52% of the agricultural income comes from food crops. At the same time, the percentage of income from economic forests and crops is less than 4%. Good water and heat conditions are propitious to vegetation growth in Zigui County. So, to resolve the food problem and to improve the economy, the keystone measure is to adjust the food structure. It is unscientific to pursue crop production only. It is important to enlarge food production from woody plants and oil plants, to enhance the quantity and quality of agricultural crops, and to improve the management conditions of agriculture. It is also important to adjust the domain structure of agriculture, forestry, animal husbandry, and fishery, to strengthen the basic construction of multi-sectorial agriculture, and to maintain or enhance land productivity.

### 3.1 Sustainable development mode and strategy in low mountain regions (altitude lower than 600m)

Zigui County is located in a mountainous area of West Hubei Province. The total areas of Zigui

County, farmland, and dry farmland are  $2.27 \times 10^5 \text{ hm}^2$ ,  $2.97 \times 10^4 \text{ hm}^2$ , and  $2.48 \times 10^4 \text{ hm}^2$  respectively. The area of farmland on a slope of more than  $25^\circ$  is  $8530 \text{ hm}^2$ , and the area of bare mountain is  $3.45 \times 10^4 \text{ hm}^2$ . The annual food production is 144742t, and the annual agricultural production value is  $1.97 \times 10^8$  RMB Yuan.

### 3.1.1 Agriculture-forestry-fishery complex ecosystem development mode

In Zigui County, the area of low mountainous region (altitude lower than 600m) was  $48000 \text{ hm}^2$ , and it accounts for 21.2% of the total area of Zigui County. This area of farmland is  $6333 \text{ hm}^2$  and accounts for 21.3% of the total farmland in Zigui County. The area of dry farmland is  $4867 \text{ hm}^2$  and accounts for 19.6%. The area of farmland with a slope more than  $25^\circ$  is  $2467 \text{ hm}^2$  and accounts for 28.9% of that of Zigui County. The area of Bare Mountain is  $8000 \text{ hm}^2$  and accounts for 23.2% in Zigui County. The grain production accounts for 19.8% of the total grain production in Zigui County, and the agriculture product value accounts for 31.9%. The soil in this region is deep and suitable for agriculture. It is the dominant area for improving product value and is a good base for establishing an agriculture-forestry-fishery complex ecosystem.

### 3.1.2 Solid fishery development mode

Most of the low mountainous region will be drowned in 2008. In this region, the waters are concentrated, and it is suitable to develop high profit aquaculture. After the Three Gorges Dam has been established, there would be some reservoir bays, and these bays can be used to develop solid fishery. However, during the process of development of aquaculture, the water quality will likely deteriorate. So an appropriate approach for developing aquaculture should be exploited.

### 3.1.3 Tourism-virescence belt construction-environment protection development mode in dam and bank area

After the establishment of the dam, this region will be the main region for tourism and residence. Along with the rapid development of tourism and increase of population, new pollution problems will arise. Special attention should be paid to the virescence belt along the riverbank, the development of environment friendly industry, and the avoidance of new pollution in this region.

## 3.2 Sustainable development mode and strategy in middle mountains region (altitude between 600 m and 1200 m)

In Zigui County, the area of middle mountainous region (altitude between 600 m and 1200 m) was  $1.27 \times 10^5 \text{ hm}^2$ , and it accounts for 55.9% of the total area of Zigui County. The area of farmland accounts for 59% of the total farmland in Zigui County, and the dry farmland accounts for 57%. The farmland with a slope higher than  $25^\circ$  accounts for 50.8% of that of Zigui County and the area of bare mountain accounts for 61.9% in Zigui County. The grain product accounts for 62.2% of the total grain product in Zigui County, and the agriculture product value accounts for 54.7%. This region is the main area for agriculture, and it is also the main area causing ecological environment destruction and soil erosion.

### 3.2.1 Wood grain and oil agriculture development mode

Most of the lands in Zigui County, which can be designed to develop wood grain and oil, are located in the middle mountainous area, with an area of  $13867 \text{ hm}^2$ . Because of restrictions due to regional geographic conditions, if this area was developed as farmland, it would cause serious soil erosion and deteriorate the fragile ecological environment. In this area, economic forests and perennial economic crops should be developed, and a multi-industry wood grain and oil vegetable complex ecosystem should be established. In addition, soil erosion should be controlled, organic contents and other charlatanism should be maintained, making the ecosystem a finely tuned circle.

Developing economic forests is the main exploitation mode for the reservoir area. In the Three Gorges Area, farmland is insufficient, and the space for the potential development of main crops is limited. Developing economic forests and establishing woody species for providing food and oil products can mitigate the dilemma between immigration and shortage of farmland. This is the chief development measure to

exploit the slope land ( $< 25^\circ$ ) in the middle mountainous area and to establish economic forests and perennial economic crops as a product base.

### 3.2.2 Intensive agriculture (vegetable) management mode

The flat land in the middle mountainous region of Zigui County can be utilized for the development of intensive agriculture and horticulture. It will be the main measure to improve the economic benefit of this area.

### 3.2.3 Multi-industry economic forest management mode

In Zigui County, the middle mountainous region is the poorest region where there is single-variety and low-yielding orange forest ( $< 25^\circ$ ). To improve the economic situation of this area, the first step is to meliorate the single-variety and low-yielding economic forest; the other is afforesting the various, high-yielding and stable-yielding economic forest.

### 3.2.4 Afforestation and biodiversity protection management mode

The main ecological problems existing in the middle mountain area of Zigui County are: the high proportion of steep slope and the widely distributed barren mountains, so if this area was improperly exploited, the severe soil erosion will be accelerated and the environment deterioration process will be strengthened. The managing mode for this area should be close hills to facilitate afforestation and reserve biodiversity.

## 3.3 Sustainable development mode and strategy of development in high mountain region (altitude higher than 1200m)

In Zigui County, high mountainous land (altitude  $> 1200\text{m}$ ) covers  $52000\text{ hm}^2$  or  $22.9\%$  of the total land of the county. In the high mountainous area, the farmland accounts for  $19.7\%$  of the total farmland in Zigui County, and the dry farmland accounts for  $23.4\%$ . The farmland with a slope more than  $25^\circ$  accounts for  $20.3\%$  of that of Zigui County and the area of bare mountain accounts for  $18.0\%$  in Zigui County. The total agricultural product value accounts for  $13.4\%$  of that in Zigui County. In this area, the main crops are tobacco and tea, and they are mainly cultivated on the flat land or near residences. Reasonable exploitation of mountainous land afforestation are the inevitable selection of environmental protection and lessening the soil erosion. Establishing multi-functional economic forest-economic crops-medical vegetable ecosystems and a fine vegetable base is the chief measure to improve the economic benefit. On the high slope area, it is necessary to carry out afforestation and to establish nature reserve protection areas, to realize sustainable development.

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