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# Ecological planning for land use and rural development of Taojiang County

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**Abstract**—Taojiang County, Hunan Province is one of the typical underdeveloped counties in China characterized by high population density, low economic development and rural poverty, natural resource deterioration and lack of infrastructure. In order to move forward sustainably, an ecologically-sound land use planning is carried out. In the study, land use and rural development strategies were proposed based on the results of land quality and land suitability assessments. The results suggested that: (1) agricultural land quality depends on many factors including land productivity, ecological sensitivity, risk of natural disturbance, location and their combination; (2) land suitability analysis should not be solely related to the compatibility of the resource requirements of certain land uses with the current resource situation, but should also include the impact of the land use patterns on resources and the environment; and (3) rural development of the county should emphasize a labor-intensive agricultural production system basing on land suitability. In this paper, the context and the methods of ecological land use planning applied in Taojiang County were presented.

**Keywords**: ecological planning; land use; land quality; land suitability.

## 1 Introduction

Land use planning is always a main issue in regional development. Most regional environmental problems, such as soil erosion, land degradation, water pollution and biodiversity loss, are directly or indirectly related to inappropriate land use. Conducting sound ecological land use planning is the basis of sustainable regional development.

The application of ecological knowledge in regional development and land use planning can be traced back to the works of George Marsh, Patrick Geddes and John Porwell in latter part of last century (Young, 1974; Seiner, 1987) and was chiefly developed during the 1930s when the Regional Planning Association of America was founded (MacKaye, 1940; Zube, 1986). But it disappeared from the literature after World War II. Owing to the environmental movement of the 1960s, ecological planning was restored as a response to regional ecological and environmental deterioration. Ian McHarg and his colleagues developed ecological planning as an approach to community, regional, and resource planning (McHarg, 1969), known as the McHargian Method

(Seiner, 1981), which has exerted great influence on subsequential ecological planning and renewable resource management (Seiner, 1981; Eber, 1984; Little, 1984; USDI, 1981; Urich, 1983). McHarg , however, was not alone indeveloping an ecological ethic for planning. Others who have made invaluable contributions include the wildlife biologist Aldo Leopold (Leopold, 1953), Canadian forester Angus Hill (Hill, 1961), Israeli planner Arthur Glikson (Glikson, 1971), landscape architect Philip Lewis (Lewis, 1969), and regional and resource planner Frederick Seiner (Seiner, 1981). Design with nature, emphasizing environmental constraints, was the dogma of ecological planning during this period. Since the 1980s, ecological planning has been developed by sharing the advances of modern ecological knowledge and methods, and computer applications, known as geographic information systems(GIS). Its emphases have shifted to coordinate the relationship between environment and development, and sustainability of regional development and resource exploitation with more ecological knowledge - based and quantitative analysis (Farmer, 1982; Caldwell, 1988; Agee, 1988; Morhan, 1990; Cook, 1991; Slocombe, 1993; Selman, 1993).

The Taojiang land use ecological planning program is aimed at establishing both economically and ecologically sound land use patterns to promote rural development. In this study, the ecological planning methods and GIS are applied to analyze and evaluate the land quality and land suitability, serving as the basis for land use planning. In this paper, the procedure and main results are presented and discussed.

## 2 Background of the project

Taojiang County is located in the northern part of Hunan Province. It is a typical Chinese underdeveloped county with high population density, low economic development, natural resource deterioration and lack of infrastructure. In 1991, the GNP was only 1034 RMB, and the output of the land was 1335.6 RMB per hectare. About 56% of the rural labor force was surplus, and many leave the county for the coastal area seasonally, according to the county annual statistics report. More than 40% of the total area suffered moderate or severe soil erosion. Because of unsuitable land use planning, agriculture is sensitive to natural disturbances. The economic situation in rural areas lacks obvious signs of improvement during the past few years.

The Taojiang County Sustainable Development Planning project sponsored by the Chinese academy of Sciences and the Government of Hunan Province, is aimed at establishing a case study applying sustainable development theory for rural development planning. The project involved the cooperation of Taojiang County Government and a multi - disciplinary research team including agricultural experts, ecologists, rural economists and geographers. The ecological land use planning was one of the sub - projects.

## 3. Methodology

### 3.1 Procedure of the land use planning

The procedure for the ecological land use planning consisted of five steps(Ouyang, 1993a). Defining land use planning goals: In order to ensure rural sustainable development in Tao-

jiang, the goals were, through land use planning, to initiate and analyze a new labor intensive land development program which would establish a new agricultural and rural economic structure, improve rural economic situation, increase land productivity, mitigate soil erosion and minimize natural climate disturbance to agriculture.

Collecting spatial and temporal environmental and economic data: Temporal and spatial data relating to land use, including the physical environment, resources, population and the rural economic situation were widely collected. The data, then, was digitized and served as a spatial database of natural conditions in the county, which were used to evaluate land quality and assess land suitability through spatial modeling using a geographical information system.

Land quality ecological assessment: Land quality was evaluated through integrating land productivity, land ecological sensitivity, risk of natural disturbance, location and accessibility.

Land use suitability analysis: In this step, the suitability of proposed land uses, depended on land quality and the requirements of rural development, were analyzed based on the relationship between the resource requirements of the suggested land use and present resource conditions. After assessment of the suitability of each suggested land use they were integrated into a comprehensive land suitability for agriculture.

Land development strategies and policy analysis: The land development strategies and policies were proposed and analyzed according to the requirement of Taojiang rural development and land suitability, and the final results were presented to the county government.

### 3.2 Scope of ecological survey for land use planning

Taojiang land use planning for agricultural purposes involved many aspects of the physical environment, current land use, rural population and economic situation, as well as the relationship between natural ecosystems and agricultural activities. The wide category of ecological survey was necessary to ensure ecologically sound land use planning. In this research, the survey list consisted of physical environment and natural processes, artificial environment, economic structure and social structure, as well as physical geographic factors (i. e., soil, climate, hydrology, and vegetation), land use, transportation, infrastructure, rural economy, agricultural structure, population, and administration structure (Ouyang, 1993b).

### 3.3 Land quality evaluation

Agricultural land quality was determined by geographical and climatic conditions, physical and chemical characteristics of soils, economic factors and their combination. With respect to agricultural processes and the relationship between crops and the environment, agricultural land quality consists of four aspects: land productivity (Li, 1990; FAO, 1990; 1991); ecological sensitivity (MAB, 1987; Ouyang, 1993b); natural disturbance risk; and location and accessibility (Qiu, 1987; Hu, 1987). Land productivity reflects the comprehensive performance of radiation, temperature, water and soil and their combination. The ecological sensitivity of land reflects its resilience to agricultural activities. The natural disturbance risks reflects the impact of inclement weather (for instance, flooding, drought, frost and so on) on agricultural production. Accessibility represents the economic effect of human activity , such as transportation and infrastructure of the land (Fig. 1).

### 3.4 Land suitability analysis

Taojiang land use suitability analysis for agricultural purposes was based on following procedures (Fig. 2): Firstly, the proposed land uses were determined according to the results of land quality assessment and the requirements of the rural development. The main category of suggested land uses included field crops, fruit orchards, tea, bamboo, commercial forest and protected area. Then the resource requirements and environmental constraints of the suggested land uses were analyzed. Thirdly, the degrees of suitability of suggested land uses were simulated and analyzed by an ecological niche suitability model (ENSM, Ouyang, 1993b; 1994). Finally, the overall land use suitability of Taojiang was determined based on the criteria of (a) suitability priority, the higher the degree of suitability of the land for a certain land use, the higher its priority for that use; (b) making good use of land productivity and economic potential.

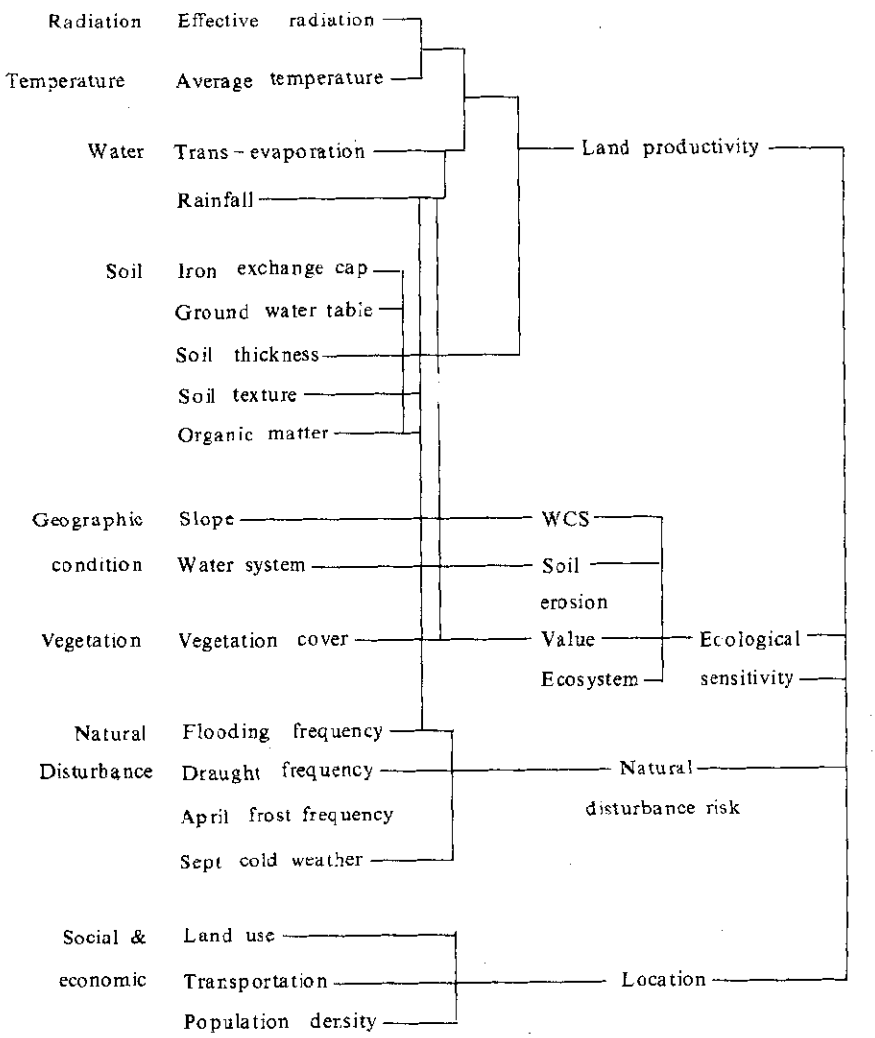


Fig. 1 Taojiang land use quality evaluation process

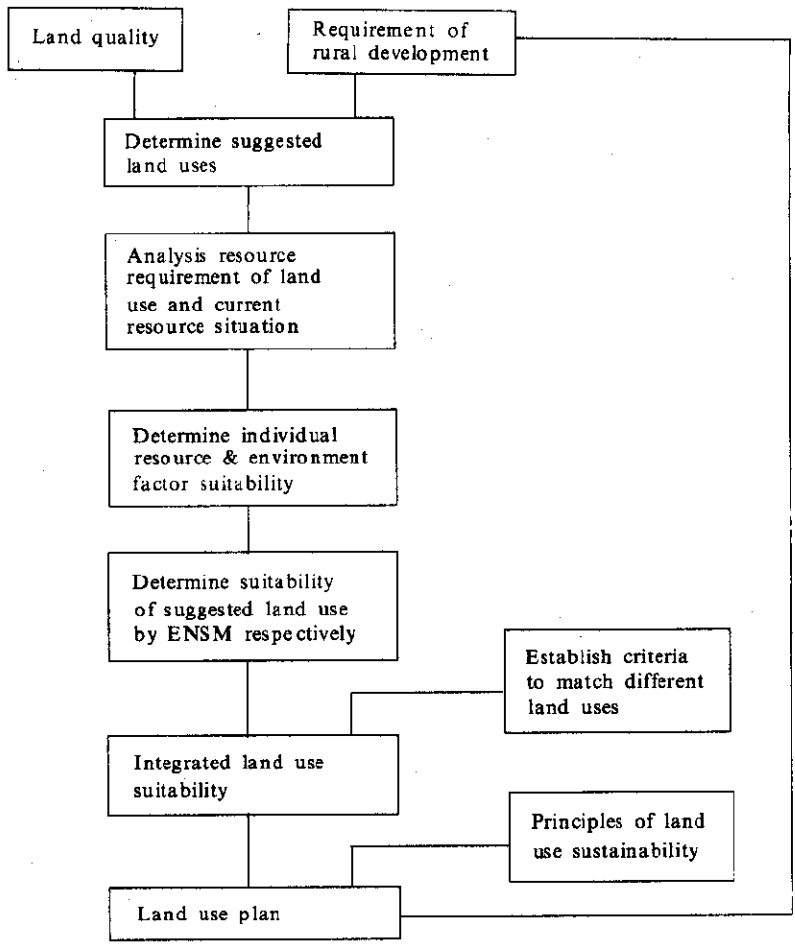


Fig. 2 Land use suitability analysis process

## 4 Land quality and land suitability

### 4.1 Physical environment and natural resource

#### 4.1.1 Geographical condition

Taojiang is located at the transition zone between Dongting Lake and Xuefeng Mountain. Its topography is very complex with 27.3% mountainous area, 44.1% hilly land, 26.4% plain, and about 3% watershed.

The Zijiang River, one of the four main rivers in the Dongting Lake water system, flows through the county, with 21.83 billion cubic meters discharge annually. There are three main tributaries flowing into Zijiang River in the county.

In Taojiang, there are seven type of soils, of which red soil covers 76.8% of the county. Paddy soil occupies more than 80% of cultivated land. About 84.4% of land is loam and clay loam in texture. On about 96% of the land, the soil organic matter concentration is less than 3.5%.

#### 4.1.2 Climate resource and climate features

Taojiang has a wet monsoon sub - tropical climate. The total radiation is 102.7 kcal per

square centimeter per year. Annual average temperature is 16.6°C, and ≥0°C accumulative temperature is more than 6000°C. The coldest month is January with an average temperature 4.3°C and a low temperature of −15.5°C. Both radiation and temperature reach their peak values in July, being 17.4 kcal. $cm^{-2}$. $a^{-1}$ and 28.9°C, respectively. The annual precipitation is 1553 mm, concentrating in April, May and June, consisting of 42% of total annual rainfall. In general, Taojiang is rich in radiation, temperature and water resources, mostly distributed from April to October, coincided with the season for crop plantation, although they vary spatially and annually because of the monsoon climate and complex topographic features.

4.1.3 **Vegetation**

The vegetation of Taojiang belongs to evergreen broad leaved forests. However, there were no primary forests in Taojiang. All of the vegetation in either secondary or artificial. According to a survey in 1984, agricultural vegetation covers about 26% of the county, the artificial economic forests take 7%, and 52% are secondary forest, bamboo and artificial commercial timber lands. In Taojiang, bamboo is a very important renewable resource. There are about 36060 hectares of bamboo forest with about 48.5 million bamboos, the most in Hunan Province and the third most in China. Taojiang is one of the main bamboo production counties in China.

4.2 **Land quality**

Land quality indices used in the study and comprise of four aspects, i. e., land productivity, ecological sensitivity, natural disturbance, and location and accessibility. The land is ranked high if it is high in each category. If one or more aspects has some degree of disadvantage, the land will be ranked into one of 4 other classes.

4.2.1 **Land potential productivity**

The average land productivity in the county is 326250 kg/(ha. a), there are obviously spatial differences because of the uneven distribution of radiation, temperature and rainfall. The results suggest that the land of the county can be divided into five classes according to their potential productivity (Fig. 3). The high grade land can reach 403135 kg/(ha. a), while the fifth class only reaches 62573 kg/(ha. a), and some land has no any productivity. If the land capacity is defined as the total farmland productivity (including the land that can be used as farmland), the land capacity of Taojiang is about 784.6 million kg in the condition of present agricultural techniques.

4.2.2 **Soil erosion**

Soil erosion is one of the main ecological stress in Taojiang's agricultural system. In this research, potential soil erosion is assessed first, simulated on the basis of the spatial distribution of the slope and slope length, rainfall and its pattern, soil texture and soil organic matter, to determine the erosion sensitivity of the land. The real soil erosion is, then, simulated by introducing land use pattern and vegetation cover, which indicates the current state of soil erosion. The results suggested that more than 121.7 $km^2$ of the area subjected to very high soil erosion sensitivity with an erosion rate of about 4010 ton/(ha. a), mainly distributed in the upper basin of Taohuajiang Reservoir (Fig. 4), the largest reservoir and supply of irrigation water for 30% of the total farmland of the county. The results of real soil erosion showed that inadequate land use

and agricultural activities are its main causes of soil erosion. There are more than 213 $km^2$ land suffered some degree of soil erosion, close to double the simulated values.

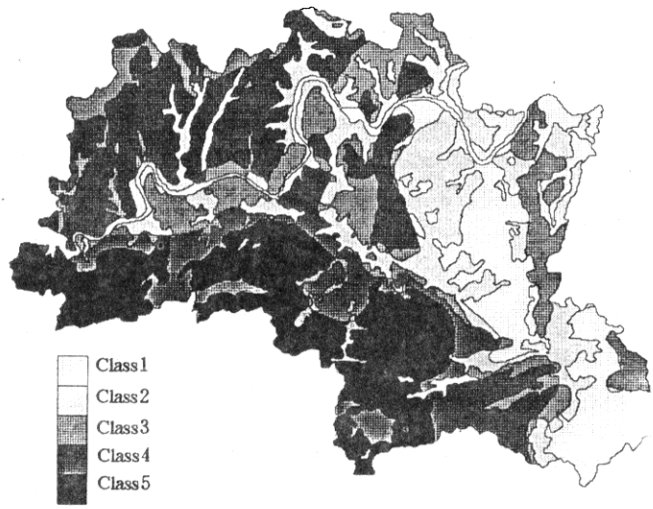


Fig. 3 Taojiang land capacity

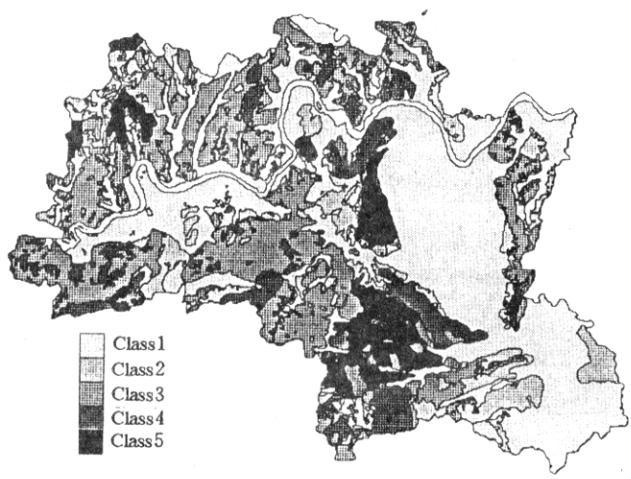


Fig. 4 Taojiang soil erosion

4.2.3 **Water catchment sensitivity**

Topographic features, soil erosion sensitivity and the relationship of the land to water bodies are used to define the sensitivity of water catchment. The results showed that the most sensitive area is distributed mainly in the upper basin of the Taohuajiang River, and there are areas with very high sensitivity along the Zijiang River.

4.2.4 **Natural disturbance risk**

In Taojiang, the natural disturbance to agriculture includes the cold waves in April, early May and middle of September, which affects sowing and planting of crops in spring and yield formation in September, as well as drought and flooding in summer and frost damage in winter. The results suggested that most sensitivity area is the lower basin of the Taohuajiang River,

while this area has the highest land of productivity potential.

4.2.5 **Location and accessibility**

Location mainly relates to transportation conditions and the distance away from main cities in the region. As a whole, location and accessibility of Taojiang is a disadvantage. However, it still varies according to accessing to transportation. According to the results of location assessment, the land with good accessibility distributed along the public transportation lines and the Zijiang River.

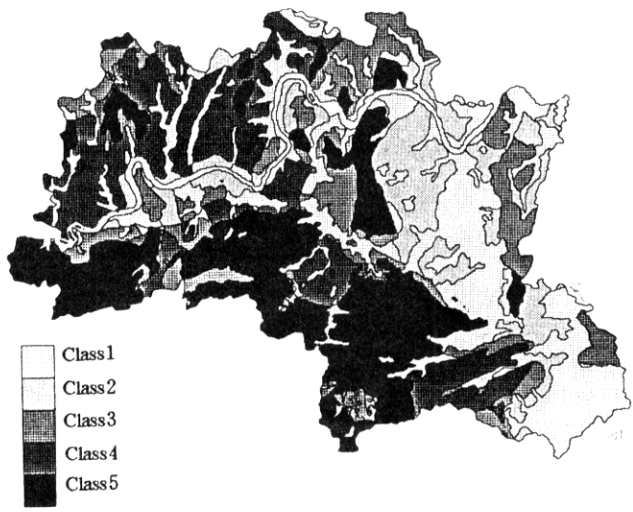


Fig. 5 Taojiang land quality for agricultural purposes

4.2.6 **Land quality**

Integrating the results of land into productivity, ecological sensitivity and location, the land quality of Taojiang can be divided into five classes (Fig. 5). The first class, generally with high land productivity, low ecological sensitivity and high grade of location, covers about 10.3% of the total land of the county, while the fifth class, whose main disadvantage are highly ecological sensitive, cover 14.6% of the total area. The priority of land use for this type of land is reforestation, some of them should be conserved as water resource forests or natural reserve.

4.3 **Land use suitability**

Deferent types of agricultural activities and crop patterns have different basic requirements and different influences and responses to ecosystems. A comprehensive ecologically based land use suitability analysis must consider both natural conditions and the requirements for rural social development. The suitability for five potential land development plants is estimated according to the characteristics of Taojiang agricultural resources and production. These broad categories include citrus fruit orchards, bamboo, tea, tilled crops and forest land. Previously developed residential land and the area used for commerce or industry are ellminated from consideration for land use development.

4.3.1 **Land suitability for citrus**

Citrus is one of the most profitable cash crops planted in Taojiang County. Factors influenc

ing land suitability for citrus are local topography, microclimate, slope and present land use. Results suggested that areas near surface water are in general most suitable for citrus. Other suitable areas are distributed mainly along the Zijiang River and in the southeastern basin plain area.

4.3.2 **Land suitability for bamboo**

Bamboo is one of the renewable resources with great potential and multi - use in Taojiang County. The overall climate conditions everywhere in Taojiang are very suitable for bamboo, so its development is mainly determined by the parent soil material and present land use, as well as by local transportation conditions. Results suggested that 94000 hectares are suitable for bamboo, of which 32000 hectares are in the "most suitable" category.

4.3.3 **Land use for tea**

Tea is one of the most important labor - intensive cash crops in Taojiang County. Its production depends mainly upon the relationship between humidity, soil texture, topography, distance from residential areas and present land use. The results showed that about 53000 hectares are suitable of which only about 8000 hectares are in the most suitable category.

4.3.4 **Land suitability for field crops**

Land suitability for field crops is related to climate conditions, rainfall, soil character (texture and organic matter content), potential erosion, flood risk, drought frequency, and topography. The results of this analysis indicated that about 25300 hectares have the highest suitability for this type of development. The most appropriate lands for crop production are mainly distributed in the lower valley area south of the Zijiang River, adjacent to the Taohuajiang River, near some banks of the Zijiang River and in the southeast part of Taojiang County. Unsuitable areas are in the more mountainous region, especially in the southwest part of the county.

4.3.5 **Comprehensive land suitability**

In evaluating and creating a final land zoning plan each of the potential land use development scenarios, limitation factors and ecologically sensitive areas are considered. A comprehensive land suitability plan is made on the basis of the individual suitability along with the criteria of suitability priority and making good use of land productivity and economic potential. Results suggested that there are 21 % of land is suitable for field crops. This land is currently used for rice production, the main grain crop in Taojiang, 9.4% of land is suitable for citrus and other fruits; 4.6% of land suitale for tea; 17.3% of land is suitable for bamboo , and the other land can be used to develop commercial and economic forest; about 3% of land should be used as protected area because of its high ecological sensitivity to agricultural activities and their importance to water catchment(Fig. 6).

In addition, the county can be divided into three areas according to land quality, land suitability and the factors of rural economy and population. Area I consists of 21 township mainly situated along the lower reaches of the Taohuajiang River and in the southeast part of the county. This region has a relatively developed agricultural base, a high population density and a relatively high level of rural industry. 56% of the land is deemed most suitable for crops. Area II consists of 15 townships, the majority of which has hilly and low mountainous land. Much of the bamboo growing in the county is in this area. Area III, including 10 townships, is located in the

southwest part of the county. This area has a high annual rainfall, mountainous topography and a relatively undeveloped infrastructure and industrial base. About 24% of the land is highly sensitive to agricultural activities.

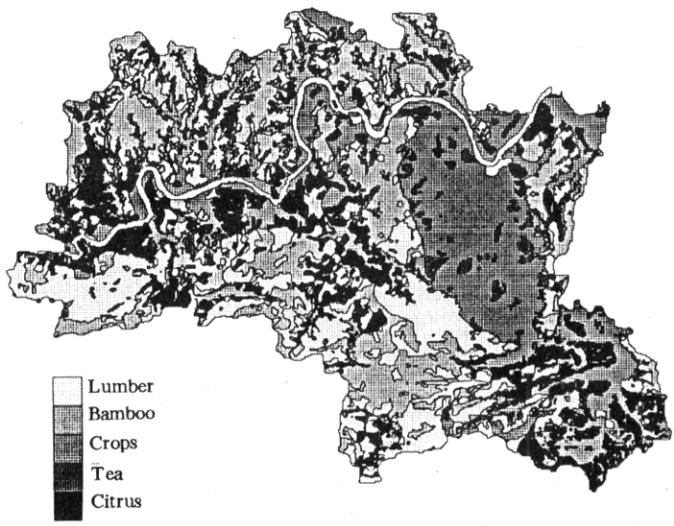


Fig. 6 Taojiang land comprehensive suitability for agriculture

## 5 Land use planning and rural development strategies

### 5.1 The principles for land use planning

#### 5.1.1 Make good use of land productivity

In Taojiang farmland is very scares, only 0.06 hectare per rural capita. Make good use of land productivity to produce enough grain and forage to meet the demands of the local population is therefore an important goal. In addition, as mentioned above, more than 70% of the total county area is hilly and mountainous. So it should also be a priority to use this land to develop fruit orchards and commercial forests to increase land output and improve the rural economic situation.

#### 5.1.2 Minimize ecological risk

Without careful land use planning, highly and mountainous land development will cause soil erosion, wildlife habitat damage, important water catchment destruction and biodiversity loss. It is, therefore, necessary to plan land use patterns and land development according to its ecological sensitivity to minimize ecological risks.

#### 5.1.3 Minimize risk from natural disturbances

For geographical and climatic reasons, different parts of Taojiang suffer from different type of climatic disturbance, causing huge damage to Taojiang's agriculture. Close attention should be paid to mitigate natural disturbances to agriculture should also be paid great attention through careful land use planning.

#### 5.1.4 Make best use of local superiority to increase economic value

To develop high economic value agricultural products, such as fresh fruit, vegetables and other cash crops is possible by taking advantage of transportation, labor force and special resource conditions.

5.1.5 **Maintain soil fertility**

Maintaining soil fertility is one of the most important aspects of land use sustainability. It can be improved if soil fertility features are considered as one of the factors determining crop distribution and rotation in land use planning. Combining modern and tradition agricultural techniques to develop labor-intensive ecological agriculture should also be encouraged.

5.2 **Land development strategy**

5.2.1 **Planning agricultural activity according to land quality and land suitability**

At present, some land use patches are both economically and ecologically unreasonable. For example, land with slopes of more than $30^0$ are still used for annual crop plantation, which is not only economically unbeneficial, but also result in severe soil erosion. Planning agricultural activities according to land quality and land suitability should be encouraged and incensed through policy and investment to achieve both economic and ecological benefits. The results of this project-suggested that: (a)the high-grade land should be used mainly for good production to meet the requirements of the large and still increasing population; (b)most of the economically inefficient and ecologically damaged hilly and mountainous land can be used to develop either fruit orchards or commercial forests; (c)bamboo is an important renewable resource in the county, and intensive commercial bamboo forests could serve as the base for a rural bamboo processing industry; (d)there are several fruit plants which can be chosen for fruit development (the land suitability should be considered in the distribution planned); (e) the land with high-grade location can be developed for high value cash crops, such as commercial fresh vegetables; (f)most ecologically sensitive land should be protected as important water catchment reserve area.

5.2.2 **Establish a labor-intensive agricultural production system**

There is a very large labor force in the county, as well as a tradition of labor-intensive agriculture. However, question remains how to establish a more economically efficient and ecologically sound agricultural production system. This study suggests that it is difficult for the household agricultural system with 0.2—0.7 ha arable land to improve economic efficiency without proper production organization. There are five main suggested land uses.

Grain production: On the basis of land quality and land suitability, it is suggested that the south-eastern part of the county focuses on grain production through choosing new rice variety with high yield and high quality both to meet food demand and raising economic revenue.

Vegetable production: It is suggested that the land along main transportation lines be used to develop fresh vegetable plantations to supply vegetables for the main cities in the region such as Changsha, Yiyang and Xiangdan, and even the cities in north China.

Commercial bamboo forests: The county has a unique climate and soil conditions for bamboo. About 35000 ha of hilly and mountainous land in the central and northwest part of the county have high suitability for bamboo. This land can be used to establish commercial bamboo forests with extensive management and sustainable resource utilization.

Fruit production: The hilly land with moderate slopes should develop fruit orchards. In the eastern basin of the county, pear, peach, and other deciduous fruit orchards can be developed. In the land near large watersheds and the northwest part of the county, citrus is the right fruit to be developed. In the southwest part of county, date and Chinese chestnut are the best choices.

Tea production: There are about 6000 ha of tea orchards in the county at present. On the basis of land suitability, the tea plantation can be expanded to 7000 ha. However, the emphasis of tea production in the county should be put on improving its quality and raising the yield.

Foliage production and husbandry: In Taojiang, family-scale husbandry plays an important role in the rural economy. To meet the foliage demand of the further development of husbandry, foliage production based on local resources must be established. Forage production should be mainly distributed in the central and southeast part of the county.

### 5.3 Develop hilly and mountainous area by establishing sustainable commercial forests and fruit orchards

In Taojiang, although land is very scarce, most of the hilly land is not used effeciently. Developing this land by establishing sustainable commercial forests and fruit orchards is an important choice for rural economic development. On the basis of land suitability, the central and northwestern parts of the county are most suitable for citrus and bamboo forests. In the southeastern part and eastern basin of the county, most of whose slope is less than $30^0$, deciduous fruit orchards can be established such as pear and other deciduous fruit, which is less vulnerable to winter frost. In the southwestern part, most of the mountainous land is ecologically sensitive to agricultural activity. For this land, commercial forests and tea garden are suggested land uses. Important water catchment and areas with severe soil erosion should be protected and reforested.

### 5.4 Incentive and training to encourage farmers to plan agricultural activities according to land suitability

Most farmers use their land either according to the tradition or by copying neighbors who have received great economic benefit from their land use partttern. However, the local government loan and investment policy can play an important role in shaping land use. Therefore, farmers can be encouraged to plan their agricultural activities according to land suitability through policy and investment, as well as through demonstration of proper land use.

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