Analysis of the Terraced Construction Effect on Ecological-economic Coordinated Development in the Southwest China

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Abstract: *This paper through the correlation analysis and efficiency analysis, studied the differences between slope croplands and terraces on soil, water and fertilizer conservation in Southwest China. Meanwhile, it carried out a quantum chemical calculation of the ecological, economic and social benefits brought to the local Hani residents by terrace construction and concluded that terraced fields can promote the mutual coordination effect of water and fertilizer. Thus, it is beneficial for crop growth and development and increase grain output, to achieve the purpose of efficient water use and stable high yield. The results show that with the improvement of Hani ecological environment and the increase of land utilization, local ecological, economic and social benefits are significantly increased, which has laid a solid foundation for the agricultural industrialization development and implementation of sustainable agricultural development strategy in Hani. And also, it provides guarantee for the ecological, economic and social coordinated development of the county.*

Keywords*: Terraced construction, Coordinated development, Southwest Hani.*

Introduction

Hani terrace located in Yuan Yang County, Yunnan Province has a unique natural landscape and cultural landscape and declared world cultural heritage area in 2006-2007 [10]. Due to the population increase and economic development in protected area as well as low level of development and abuse of resources, it has caused great pressure and certain degree of damage to the resources and ecology of the area [4]. Many of the natural landscape and human landscape is facing the danger of degradation and disappearance. Parts of the areas are facing ecological imbalance and environmental degradation. Landslide, debris flow and other natural disasters often occur while water stress situation appears in successive years.

Hani terrace is the model of combination of China's ethnic minorities' traditional knowledge and traditional culture and natural environment. It is known as the "rivers-forest-village-terrace" ecological system with high coordination of human and nature. Since the 1980s, people have begun to pay close attention to the study of Hani terraced fields which is mainly concentrated in the origin and history of the Hani terraced fields, rice cultivating culture, terraces production and management mode, etc. Meanwhile, related researchs on the social structure, material life and natural outlook on life and social relationships of Hani people had been carried out. Hani terraced fields as a kind of typical nature-artificial complex ecosystem is with special composition, structure and function [3], which has important value on in-depth exploration of the relationship between human and natural ecological system. In order to better protect forests and water to meet the terraced farming and Hani terrace tourism product development needs, Red River State and Yuan Yang County both intensified the efforts on

nature reserve construction and management. To this end, this paper has carried on the related research on the Hani terraced fields ecosystem.

General situation in the study area and terracing effect

The general situation in the study area

Yuan Yang County is located in southern Yunnan Province, southern section of Ailaoshan pulse. And it is located between east longitude 102°27′-103°13′ to north latitude 22°49′-23°19′, east to the Jinping County and south to Luchun County, while west to Honghe County and north to Jianshui County. It is 74 km from east to west and 55 km from north to south [10].

Within the Yuan Yang County, there are high mountains and deep valleys with ravines and gullies criss-cross which belongs to deep cutting, Zhongshan geomorphic type. As a result of long-term exposure to the erosion and cutting to the north and south direction of Red River drainage system, it presents the central bulge and low north and south sides landform, with the terrain tilt from northwest to southeast and it is under "V" shape development [6]. The North Mountains are mostly pinnate horizontal canyons while the south ones are mostly dustpan shaped. Within the Yuan Yang borders, soil types change in accordance with the mountain elevation. There are dry red soil, laterite, purple soil, latosolic red soil, red soil, yellow soil, yellow brown soil and brown soil from low to high in the range of 150-2000 m. And paddy soil is also distributed in the terraced fields.

Located in the southern Ailaoshan, the climate of Yuan Yang is subtropical monsoon climate. Light, temperature, water and soil resources are rich in this district. Sunshine hours throughout the year are 1770.2 h, relative humidity 84.3%, and annual precipitation between 770-2400 mm. And mean annual precipitation is 1403 mm, annual average temperature 16.4°C, coldest average temperature between 7°C-17°C, most thermidor average temperature between 16ºC-29ºC. Extreme minimum temperature between –0.1°C-7°C, extreme maximum temperatures between 28°C-42.3°C. Above 10°C accumulated temperature for 4000-8700 and frost-free season is 200-364 d.

Because of the influence of terrain conditions and the change of altitude, seven types of climate mainly in south subtropical, tropical and temperate are thus formed with the special three-dimensional climate characteristics. The dam area is alley terrain and is called dry-hot valleys (DHV) area due to the hot and dry feature. Average annual temperature is 25°C, maximum air temperature 42°C, with big evaporation capacity. The maximum evaporative capacity is in 1995 with 2306.5 mm. The dam high mountains are called dark and moist areas due to low temperature and big rainfall. The annual average temperature is 11.6°C, with the dam area temperature difference of 13.4°C. Cloud density is big and rainfall is rich.

There exists the Buddha mountain provincial nature reserve within the territory of Yuan Yang. The protected area is with a total area of 16187.1 hectare. There are completely distributed many types of forest ecosystem such as the mountain rain forest and monsoon evergreen broad-leaved forest, Zhongshan mossy evergreen broad-leaved forest, mossy dwarf forest and the mountain moss, etc. Forest coverage rate reached 69%, and it is one of the important main forest Hani terraced fields. The wildlife resources in the region is rich, with reptile 6 families, 8 genera and 10 species, Amphibians 7 families, 7 genera, 14 species; 9 families, 5 genera and 62 species of birds and beast of 17 families 28 genera and 31 species. There are 26 kinds of national and provincial protected animals and more than 1000 kinds of

wild plants. And there are 19 kinds of rare or endangered species and provincial key protected plants [4].

The role of terracing

After the terracing, immature soil reach the surface with its fertility without leaching loss any longer. And after fertilizer use, each indicators of soil fertility is improved and enhanced. Moreover, raw soil maturation process is the process of the coordinated development of soil fertility. The soil nutrient and soil enzyme activity and soil structure are closely related to each other and coordinated development of soil fertility improved the ability to resist the drought and flood disasters.

Landform class, slope direction and utility pattern all have influence on soil moisture, among which, plant using way has the biggest effect on terrance soil moisture, which main shows differences in crop growth and development, especially on the difference of the root. The root system of sloping crops is shallow; therefore, it is with high utilization of shallow water. 0-40 cm sloping fields use water more than terraces for about 6.6-7.7 mm. Since the root system of the terraced crops is deep, so it is for deep water use. And 40-180 cm terraced crops use water more than slope for about 41.3-46.4 mm. Due to the use of soil moisture in the growing period of the terraced crops, especially for that deep soil water use is more than the slope, thus the invalid evaporation is reduced and deep water saving is increased [2]. According to the monitoring, soil water content of a terrace built up for 1 year is more than that of the drought slope. In addition, along with the increasing length of farming, water keeps moisture effect become increasingly stronger. The increased moisture is mainly concentrated in 0-60 cm soil layer and average moisture content is 8.9%-14.45% higher than slope, with a maximum of 46.1%. Terrace soil water storage capacity in 0-50 cm soil layer is higher than dry slope for about 9.15-46.41 mm, thus improved the ability for regulation and use of water of the terraces.

Ecosystem characteristics of Ailao mountains

Yuan Yang is located in the southern section of Ailaoshan vein, and its terraced fields ecosystem is part of Ailaoshan ecosystem. Ailaoshan mountain climate condition is complex and varied. Climate vertical distribution is obvious. From the foothills to the top of the hill in the order there are south Asian tropical, subtropical, north subtropical and warm temperate zone, temperate zone, cool climate. Mountain climate vertical change rule are respectively: at an altitude of 1800 m above the high mountains, annual average temperature 11.6°C, year-round sunshine 1000 h, and there are many clouds overcast and rainy in this area. An elevation of 1400-1800 m on the mid-levels district, mean annual temperature 15°C, year-round sunshine 1630 h. This area is full of rainfall and the climate is mild. An elevation of 600-1400 m under the mid-levels district, mean annual temperature is 18°C, year-round sunshine 2020 h, frost-free season, this area is full of rainfall and the climate is warmer. At an altitude of 600 m below the valley, mean annual temperature 25°C, year-round sunshine 2430 h, frostless. Rainfall is less. The climate is hot with big evaporation.

Because of the unique Ailaoshan mountain climate, the vegetation has obvious characteristics of vertical distribution. The southwest slope is in vertical distribution, starts by MoJiang River valley, which is at an altitude of 1100-1800 m. And it is of Simao pine forest and monsoon evergreen broad-leaved forest belt. While in 1800-2200 m, it is Yunnan pine forest and half wet evergreen broad-leaved forest belt, and Zhongshan moist evergreen broad-leaved forest belt is in 2200-2800 m. There are mountain evergreen broad-leaved elfin wood and shrub land above 2800 m [9]. The northeast slope vegetation vertical series start by Yuanjiang River

valley. An elevation of 500-1000 m for the dry-hot valleys (DHV) vegetation zone, and 1000-2400 m for Yunnan pine forest and half wet evergreen broad-leaved forest belt, 2300-2300 m for Zhongshan moist evergreen broad-leaved forest. Above 2900 m, there are mountain evergreen broad-leaved elfin wood and shrub land.

In the Ailaoshan national nature reserve, Zhongshan moist evergreen broad-leaved forest in Yunnan Province is the rare special vegetation type in China with a total area of 503.6 km^2 and forest coverage rate reached 85%. This area accounts for 66.3% of the reserves. And it is to protect the water-source forests, green peafowls, *Presbytis Phayreis*, gibbons, etc.

The forest ecosystem of Ailao mountain areas is intact, which are mainly the evergreen broad-leaved forest. It is rich in biological resources and is one of the species gene pool of our country. There are verdant forests on the mountain as well as many different kinds of vegetation such as green maple, double fan fern, machilus gamblei, bamboo cane, grey bamboo and other rare tree species. There are 229 families, 1530 genera and 1530 species of seed plants. Also, there are wild *Panax Notoginseng*, *Eucommia Bark*, *Polyphylla*, *Amomum Villosum*, *Stephania Epigaea*, XiangJun, agaric and other medicinal materials. Animal resources are also very rich. There are golden monkeys, slow loris, gibbons, brown bear, black bear, pangolin scales, python, etc. Still, there are lots of birds here. Every fall of the year there are countless amounts of migratory birds doing southward migration from the Ailaoshan Dongpo.

Ecosystem characteristics of Hani terraced fields

Spatial pattern of ecosystems

Hani terraced fields ecosystem is an important part of Ailaoshan ecosystem [1]. Yuan Yang located in the Ailao mountain, its terraced fields ecosystem and mountain natural ecological system form the good nature-artificial complex ecosystem. The spatial distribution characteristics are shown in Fig. 1.

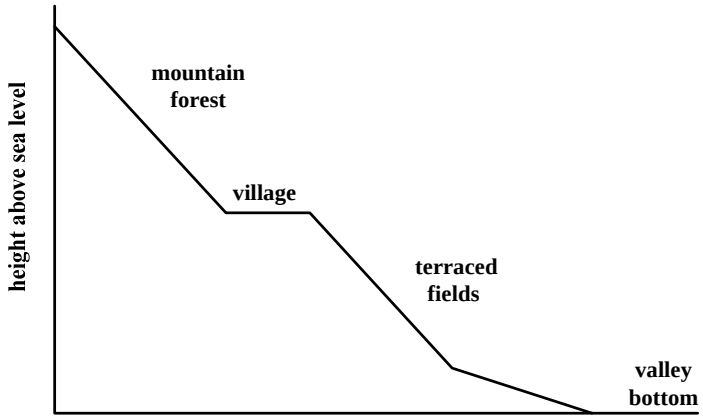

Fig. 1 Spatial pattern model of Yuan Yang terraces ecological system

The natural-artificial complex ecosystem includes the natural ecosystem composed by monsoon forest at the bottom of the mountain, monsoon evergreen broad leaved forest and Zhongshan moist evergreen broad-leaved forest, and the artificial ecosystem made up of central terraced fields and villages. Hani terraced fields ecosystem mainly distributed between 144-2000 m. Generally, a mountain which slope is more than 18°, is not conducive to development of crop production, but the Hani terraced fields are distributed in the slope between 15°-75°.

Composition and structure of the ecosystem

Hani terraced fields' ecosystem composition and structure mainly includes the producers and consumers. The producers are made up of crops which are mainly rice, but also corn, wheat and other food crops, soybeans, beans, peanuts, sugar cane, cassava, tea and other economic crops, banana, pineapple, litchi, fruit trees such as tamarind, Shandong hog, and all kinds of vegetables [7]. Consumers include human and livestock, such as chickens, ducks, gooses, cattle, pigs, sheeps, etc., and human beings are the top customers.

Producers of Hani terraced fields' ecosystem (mainly rice) and consumers (mainly humans) have a very close relationship. After nearly one thousand years of history, Hani people domesticated wild rice to land rice, and then domesticated a lot of rice varieties according to the different environmental conditions such as climate, topography, and elevation and so on. It is estimated that there are thousands of Hani rice varieties and altitude is the main factor influencing the rice variety selection. Hani rice planting management style presents vertical differentiation with different elevations. At an altitude of 1600-1900 m, mid-levels with cold climate (north subtropical Zhongshan terrace wetland, terrace wetland south temperate zone mountains) often selects cold resistant rice varieties such as flower rice, small white rice, rice of the moon, wadi, cold water, throw bamboo rice, waxy, PiTao rice, fog dew rice, PiTao incense; at an altitude of 1200-1650 m, in mid-levels with moderate temperature (central Asian tropical sun terrace wetland, north subtropical Zhongshan terrace wetland), warm rice varieties such as old terrier rice, fine old terrier rice, barrow, grasshopper rice are chosen. At an altitude of 800-1200 m in the mid-levels with warm climate (south Asian tropical sun terrace wetland), heat resistant varieties such as old skin rice, old rough rice, large grasshopper rice and July rice are selected [5]. At an altitude of 150-800 m in hot valley (north tropical valley terrace wetland), heat resistant rice varieties are selected. Most adaptive area of the rice varieties is no more than several hundred hm^2. Many varieties are planted within several hm^2 or even less than 1 hm^2.

In the mountain natural ecological system, the bottom is the monsoon forest and sparse shrub grass, the floristic composition gives priority to pantropical composition while kind floristic composition is mainly tropical Asia (India – Malaysia) distribution. Monsoon forest is composed of trees, shrubs and herbs. The arbor species include: *Bischofia Polycarpa*, kapok, *Albizia Chinensis*, *Ficus Racemosa*, *Garuga Forrestii*, old man leather etc. The top of the mountain natural ecosystem are deciduous evergreen broad-leaved forest and evergreen broad-leaved mixed forest. Deciduous evergreen broad-leaved forest is distributed between 1400-1800 m area, dominant tree species include vertebral oak, neem, *Zizyphus Jujube*, wild walnut, wild cherry, huang qi, etc. Dominant evergreen tree species include mangrove, red oil fruit, *Schima Superba*. Evergreen broadleaf mixed forest is distributed above 1800 m elevation with dominant tree species of *Fagaceae*, a variety of castanopsis, golden rays of the sea water chestnut, *Magnoliaceae*, *Theaceae*, *Lauraceae*, bamboo, etc. In addition, in the top of the mountain ecosystem, there exist artificial ecological forests and water conservation forests.

Material and energy flow of ecological system

According to the composition and structure of the Hani terraced fields' ecosystem, the material and energy flow of ecological system is shown in Fig. 2.

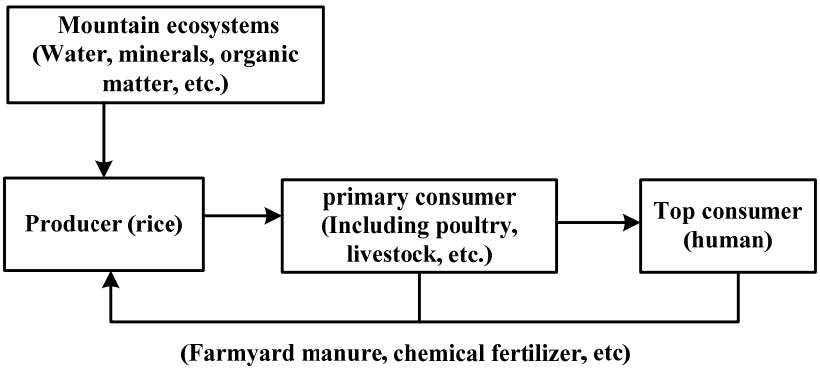

Fig. 2 Material and energy flow of Hani terraced fields' ecosystem

The material and energy flow of the Hani terraced fields' ecosystem are mainly water and nutrient flow, starting from the top of the whole mountain ecosystem-forest ecosystem, flowing to the terrace ecosystem, crop producers and people and animals, then after layers of reuse in terrace ecosystem, flow into the river [8].

The most basic energy of the whole ecological system is from the sun light energy. By the plant photosynthesis, the sun light is converted into organic matter and energy available for animal and human use. In the terraced fields ecosystem, matter and energy with the form of rice, fish and shrimp, livestock, fruit, vegetables and timbers to provide life and production samples for humans. And through the output of manpower and animal power and all kinds of technology, farmyard manure and fertilizer are applied to protect the forest ecological system. Make regulation and control of material and energy flow of terraced fields' ecosystem to keep the stability of terraced fields' ecosystem and enable it to continue to provide the required material and energy, thus formed the unique terrace ecosystem function.

In the Hani terraced fields ecosystem, water and nutrient are the main carrier of material and energy flow of ecological system. In addition to the precipitation, terraced fields ecosystem water mainly comes from the upper mountain evergreen broad-leaved forest. The moisture of forest ecosystem comes from precipitation with river water evaporation and condensation. Yuan Yang mountains and valleys are with strong evaporation, the water vapour increases with the hot gas and cools down when meeting cold mass, then condensed into a thick fog and abundant rainfall.

There are 64 000 hm^2 forest within the Yuan Yang boarders. Among which there are 18 000 hm^2 virgin forests in Guanyin Mountain and 46 000 hectares of original and secondary forest distributed in every mountain. The area of the national key public welfare forest is 569 300 mu. These forests constitute the huge natural reservoir with its conservation of water forming countless brooks, springs and waterfalls in the high mountain to provide all terraces, dry land, and people use water. Yuan Yang has 167 000 mu of terraces, and Hani people focused on the terrace, from trenching dig canal to belongings, water allocation, management and maintenance, developed a set of strict and effective water system and constructed more than 4650 ditch main canals, which provides the agricultural water and domestic water for terraces ecological system.

Nutrients are key factors to maintain the stability of terraces ecosystem. The sources of nutrients of Hani terraced fields' ecosystem are from sanitary sewage sanitary sewer, garbage waste, poultry and livestock feces, etc. By the geographical advantage of upper village and down terraced fields, the local people invented the "flush fertilizer method". There is a public

manure pond dug in every village to storage the horses and cattle livestock manure wastewater which then turns into efficient farmyard manure. When the spring season comes, they will be flushed into the fields.

In addition, by the use of natural fertilizer method, it can provide fertilizer for those booting stage of rice. The nutrient cycling of Hani terraced fields ecosystem can not only increase the terraces fertility and improve soil fertility, but also reduce environmental pollution caused by people, forming a self cleaning system.

Relationship between different ethnic groups and terraced fields ecosystem

There are seven different nationalities in Yuan Yang County which are distributed based on the mountain elevation height. An elevation of 144-2000 m of Heba area, there are mostly Dai people; at 600-1000 m canyon area, there mostly live the Zhuang people; 1000-1400 m in the mid-levels district, there lived the Yi people; 1400-2000 m on the mid-levels, there lived Hani people; above 2000 m high mountains, there lived Miao, Yao people. And Han people live in towns along the highway. There is a certain difference on service function management of the terraced fields' ecosystem of different ethnics.

Through the analysis and comparison of villages in Yuan Yang County, we found that QuanFu Zhuang village is a Hani settlement village with a population of 2255 people and arable land per capita 0.47 mu. In 2007, the rural economy gross income is 3.05 million yuan. Among which, the farming income 1.37 million yuan, accounting for 45% of total revenue; Animal husbandry income 1.1 million yuan, accounting for 36% of total revenue; Fishing revenue was 90 000 yuan, accounting for 3% of total revenue; Forestry revenue was 260 000 yuan, accounting for 8% of total revenue; Farmers per capita net income of 998 yuan, with an emphasis on planting industry, animal husbandry, etc. Water BuLong village is a mixed village of Yi people and Hani people, with a population of 3371 people. Among which, the Yi people constituting 75.92%, Hani people accounted for 24.08% and arable land per capita 0.97 mu. In 2007, the village economic income is of 8.232 million yuan, among which, farming income 3.1936 million yuan, accounting for 39% of total revenue; animal husbandry income 2.0262 million yuan, accounting for 25% of total revenue; Fishing revenue was 162200 yuan, accounting for 2% of total revenue; Forestry revenue was 50000 yuan, accounting for 1% of total revenue. Farmers per capita net income of 1248 yuan, mainly composed of crop production.

Through the sampling survey of Yi's family of Water BuLong village and Hani family of QuanFu Zhuang village, the results show that the two village rice planting area is about 0.5 mu per capita, rice is about 400 kg per mu. There are large differences between labor input, breeding pesticide and fertilizer use of the two villages. QuanFu Zhuang village has a five people family on average level, each agricultural labor input is 2.2 people; rear cattle 2.2 head (only), poultry 6.4 only; few use of fertilizer and pesticides, fertilizer rate per acre of 15 kg; Use more farmyard manure, dosage per acre 1170 kg. Water BuLong village has a 5.3 people family on average level, with agricultural labor input 1.6 people; livestock 4.2 head (only) and mainly for pigs; poultry 9.2 only; more use of chemical fertilizers with fertilizer rate per acre of 46 kg; Farmyard manure use less with dosage per acre of 390 kg.

The survey results show that Hani people of QuanFu Zhuang village still keep the traditional way of terrace management, its material and energy supplement for the terraced fields' ecosystem is mainly from the farmyard manure. It requires a lot of labor and time to improve food production and maintain the survival and development. While there are mainly Yi people

in Water BuLong village who input less manpower and time to management of the terraced fields ecosystem while use more fertilizers for material and energy supplement.

The Fig. 3 and Fig. 4 show that in the 50s-70s of the 20th century, the terraces ecosystem management of Yuan Yang County is mainly to invest a lot of labour and farmyard manure appliance. Since the 1980s, along with the use of chemical fertilizers, grain yield was improved.

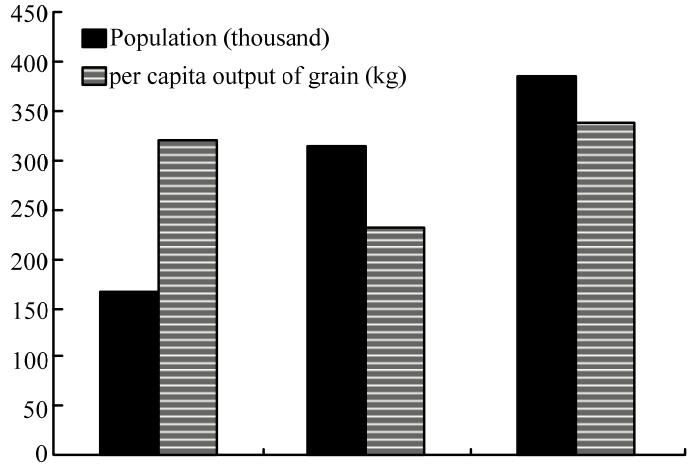

Fig. 3 Population and food change of Yuan Yang

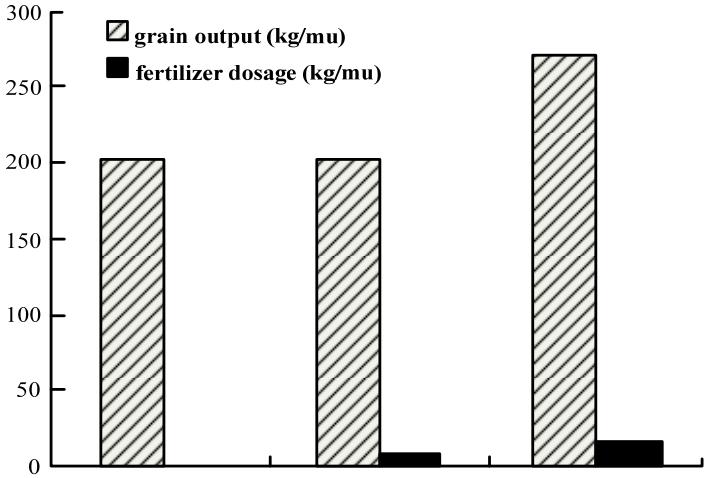

Fig. 4 Grain yield and fertilizer rate changes of Yuan Yang

Until the 1950s, Yuan Yang County's terraced rice is generally 100-150 kg per mu with high up to 300 kg. With the continuous improvement of productivity level, rely on the traditional plowed field and artificial cultivation of traditional rice varieties, terraced rice can reach 300-450 kg per mu. At the end of the 20th century, Hani people began to plant hybrid rice in terraced fields at an altitude of 1400 m below, which produced a great influence on the rice variety and custom of rice seed and seed selection in one thousand years.

Conclusion

The Hani terraced fields ecosystem is the cultural heritage Hani people formed in the long historical process. It is also the cultural heritage of our country and the world which has important research value and the demonstration significance. In the present economic construction, we should carry on more in-depth study on how to keep the sustainable development of the Hani terraced field ecosystem. Especially that we must strengthen the development of economy and building a well-off society while keeping the Hani terraced fields of traditional culture.

Most of Yuan Yang ethnic minorities live on traditional rice, therefore, food security relates with their survival, development and prosperity. In the rapid population growth while productivity level is relatively low, we should aim to improve food production as well as living standards of ethnic minorities. Hani rice culture retained the rich resources of rice varieties; we should strengthen the study of the genetic diversity of rice varieties and its protection. With the introduction of hybrid rice varieties and the heavy use of fertilizers, we also need to carry out extensive and in-depth researches on consequences and impact of Hani terraced fields ecosystem.

This paper have shown that level terrace as soil and water conservation project, is an important measure in arid and semi-arid mountainous area, hilly region and the loess gully region. The significant function of water and soil conservation and fertilizer protection help to improve agricultural basic conditions and promote the efficient development of agriculture.

Throughout the decades of economic development of Hani, terracing changed the vicious circle formed by the fragile ecosystem and won the agricultural production environment with more stable base. Moreover, terraced fields are not only the sum of number of pieces of terraces, but rather reflect the overall increase after “terrace effect”. As the improvement of ecological environment, the land utilization and unit of land productivity would be greatly improved. Thus, it can provide conditions for other industry development and made significant ecological, economic and social benefits. Besides, it as well laid a solid foundation for Haney agricultural industrialization development and implementation of the strategy of sustainable agricultural development, to achieve the coordination of the Hani ecological, economic and social development.

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