

Exploitation and utilization models for tidal flat resources at Hangzhou Bay, China

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Abstract. Hangzhou Bay is rich in tidal flat resources, which is favorable for agricultural production, and the prospect of tourism development is wonderful. But there are also problems regarding environmental pollution. Tidal flats are a kind of weak ecological environment. Based on the principles of exploitation and utilization, the exploitation and utilization models of tidal flat resources at Hangzhou Bay are proposed in order to achieve high economic benefit under market economic condition: ① Water and dry crop rotation; ② Replant fruit after cotton; ③ Mixed breed aquatics; ④ Combination of farming and fishing; ⑤ Combination of rice and poultry; ⑥ Ecological tourism; and ⑦ Natural protection.

Keywords: Tidal flat resources; exploitation and utilization principles; models; Hangzhou Bay

1. Introduction (Use “Header 1” Style)

The coastal area along Hangzhou Bay of China is of high population density and developed economy, but the contradiction between much population and little land is increasingly acute. Tidal flat becomes a kind of land resources with high exploitation potential [1]. For instance, Xiaoshan has reclaimed 31.2 thousand hm² of tidal flats in the recent 20 odd years, newly increased cultivation land accounts for 1/3 of the total, and 1/4 at Shangyu through the reclamation of tidal flat, which revived the huge pressure on the shortage of land resources. However, tidal flat is a kind of weak ecological environment [2]. Improper exploitation and utilization would not only take out the best economic benefit, but also result in the degeneration of land resources [3]. Therefore, in view of the main features and existing problems, models for the exploitation and utilization of tidal flat resources at Hangzhou Bay are proposed for discussion based on the example of the Jianshan reclamation area.

2. Main features of tidal flat resources

Jianshan reclamation area located in Haining City at the north bank of Hangzhou Bay is a trans-century key and large scaled water conservancy project of Haining City approved by the Reclamation Administration of Zhejiang Province and Qiantang River Administration according to the master planning and the principle of “River regulation combines with the reclamation of tidal flats, and the reclamation of tidal flats must obey river regulation” proposed by the provincial government.

2.1. Rich in potential land resources

There are about 5,500hm² tidal flats available at the Jianshan reclamation area. This project is to be implemented in 2 stages.

Observation data on the source of sediment at Hangzhou Bay shows that except to the 4.79 million t/a of sediment from the Qiantang River, 30% of the 486 million t/a sediment brought to sea from the Changjiang River is moved south and silted into Hangzhou Bay. As the reclamation of tidal flats has reduced the current

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movement, it is also promoted the fashion land by means of accelerating silt [4]. There are 9 sea dikes built in Cixi plain since the ancient sea dike was built during the Yuan Dynasty. The costal-line has been moved outside for 16km, and still keeps on its pace at the average speed of 39m/a [5].

2.2. Favorable condition for agriculture production

Jianshan reclamation area is open and flat, warm and humid in climate with obvious changes in the four seasons, rich precipitation and abundant sunshine. The annual average temperature is 15.9°C, annual average precipitation is 1,187mm, sunshine is 2002.9h, and the forestless season is 233d. There are about 10 mountains of various sizes at the north of the reclamation area, which block part of the cold wave, hence create a sound microclimate suitable for agriculture production in the area.

2.3. Wonderful prospect in tourism development

Jianshan estuary is the rising place of the famous wonder, Haining Tide, the first sunrays in the morning, the emergence of the tidal origin, intersection tide and return tide along the bank of the reclamation area. 100hm² East and West Lake has been built in the planned tourism area. Big Jianshan and Small Jianshan Mountains at the north provide wonderful scenery. There are also famous ancient temples such as Tidal God Temple, Kwan-yin Temple and Guanhai Pavilion. Mountain forests around the reclamation area is the inhabit area of migratory bird. There are thousands of birds gathered here in autumn and winter, which forms a lively vision with hundred kinds of birds sing at the same time.

3. Major existing problems

3.1. Heavy environment pollution

The coastal plain of Hangzhou Bay is an important industrial and agricultural production base and economic center in Zhejiang province. In the recent decade, following the increasing population and fast economic development as well as the increasing number of industrial enterprises, industrial and life waste water is discharged directly into the river or into the sea via river, the natural environment of the coastal water area and intertidal zone are impacted, and pollution accidents often occur, which have affected the ecological system of the tidal flats [6].

3.2. Weak scientific and technical force

The newly reclaimed tidal flats are located at remote and desolated areas, and most of the production personnel are farmers with education of middle school or lower. They are low in diathesis, technical personnel is extremely short, and thus it is very difficult to carry out tests and research such as “High yield experiment, spread of new technology, cultivate of new species and plant diseases and insect pests control”, which seriously restricts the in-depth exploitation of tidal flat resources.

3.3. Short of funds for development

The exploitation of tidal flats refers to various kinds of business activities on the desolated beaches. It is required to establish safety guard by building sea dike first. The second step is to prepare basic conditions, such as water and electricity supply and road access. And the third step is to construct the required production and life facilities. Therefore large funds are required. Currently, the provincial reclamation subsidy is too small, and the load term commercial banks are too short (mostly 1 year), and municipal fund is also quite tight. Therefore there is a big shortage of funds for the construction of reclamation area.

4. Exploitation and utilization model

Jianshan reclamation area has constructed with a large batch of agriculture infrastructures, including the largest 700 hm² underground irrigation system presently in Zhejiang Province through the implementation of the 2-stages state agriculture comprehensive development program with the investment of USD 2 million, which has created a sound condition in ensuring stable yields despite drought or excessive rain. Based on the major existing problems and the principles of exploitation and utilization, the thought of ecology shall be observed at all times during the reclamation of tidal flats. Construct the coastal protection forest project and farmland forest network project well, control the use of pesticides and fertilizers, and increase the investment

in science and technology, so as to carry out the “exploitation of tidal flat by means of science and technology” well. In the aspect of construction fund, private funds shall be greatly attracted together with the expansion of the investment field for an international large consortium, large institute and multinational companies.

On the basis of observing the principles of exploitation and utilization, the following models are adopted in the exploitation and utilization of tidal flat resources at Hangzhou Bay in order to achieve high economic benefit under market economic condition [7]:

4.1. Water and dry crop rotation

This model is suitable for a reclamation area with abundant fresh water resources. It generally starts from irrigated rice, then start to plant dry crop, mainly cotton, when the salt content at 1m layer is below 0.2% through 1~3a de-salting. In case salt content in the soil is rising, crop rice for 1~2a again. This model is fast for soil reformation and easy to achieve high and stable yield, normally the annual yield is 12,000~15,000kg/hm² for rice or 1,000~1,200kg/hm² for cotton. In order to improve economic benefits, it could also have a crop of watermelon and later rice in the following year after one year of rice crops to achieve water and dry crop rotation in the same year. Normally the yield for watermelon is 30,000~45,000kg per hm² and 6,000~7,500kg for rice.

4.2. Replant fruit after cotton

This model is suitable for reclamation area lack of fresh water resource. Start to plant cotton with high resistance to salt when drainage facility is ready. The salt content at 1m layer could be reduced around 0.2% through 3~5a of natural de-salting. Then replant economic fruit such as citrus. The replanted citrus area in the reclamation area of Ningbo has achieved more than 3,000hm². The yield of cotton in the first year is relative low, around 450kg per hm², and gradually increases to about 900kg. Through years of de-salting by cotton planting, replanted citrus can normally have the first harvest in 3a and the normal yield from 5a is about 15000~45000kg per hm².

4.3. Mixed breed aquatics

Breed aquatics in reclamation area are mainly of the 4 kinds of common fresh water fishes since a long time ago. In order to have better economic benefits, top grades of aquatics such as river crab, eel, snapping turtle, giant freshwater prawn, and American prawn should be exploited. The breeding of river crab in Shaoxing reclamation area has reached more than 5,000hm², Jianshan reclamation area bred more than 60 hm² of American prawn, Taiwan grass shrimp and Samoan crab in 2001 with sound production, and the annual sales income was more than USD 14,000 per hm². Test results show that mixing the breeding of fish and crab could achieve better comprehensive benefit as they live in different water layers. The yield of fish and crab per hm² can be 7500~9,000kg and 150~450kg respectively.

4.4. Combination of farming and fishing

In this model, low-lying places are excavated into fishponds for fishing (such as fish, crab and shrimp); the excavated soil is used to build terraces for agriculture (plant rice, cotton, fruit, vegetable or succulence). This model has both land-based crop and water-based breeding and both of them are mutual reliance. For instance, fishpond needs frequent removing of sediment, which could supplement fertilizer for the terrace and prevent the lowering of surface. The terrace could plant grass for fish and water in the pond could also be used for irrigation. Based on the survey at the experimental farmland in Shangyu city on mulberry based fish pond, the output of mulberry and fish can be USD 7,000 per hm² by planting grass in the mulberry garden for fishing and sediment from the pond as fertilizer. Compared with individual mulberry garden and fishpond, the combination could increase profit for 20~25%.

4.5. Combination of rice and poultry

Combination of rice and poultry is a kind of innovative green and environmental exploitation and utilization of tidal flat resources, namely to breed duck in the field while planting rice. The number of duck per hm² is decided based on the growing period of rice. The advantages of this model are: a, the stool of duck can be used as fertilizer and reduce the use of chemical fertilizer; b, duck eats worm and pest and can reduce

the use of pesticide; c, duck eats short and small weeds and can reduce the work in weeding; d, duck working in the field can loosen the soil just like weeding. Compared to individual planting of rice or breeding of poultry, this model can reduce both of the costs, improve the comprehensive benefit and reduce public nuisance. It is an ideal way for the development of green product and is of obvious economic and social benefits.

4.6. Ecological tourism

The coastal area of Hangzhou Bay is of long history and is rich in tourism resources. Based on the harmonic development between human and natural, Jianshan reclamation area will be built into a demonstration area with flourishing economy, beautiful scenery and coordinated ecology. Through the adjustment of industrial construction and the optimization of landscape construction, speed up the construction of ecological sightseeing agriculture zone, ecological tourism and holiday resort and forest recuperation park, so as to achieve the common development of agriculture, forest and tourism. It is planned to build 5 functional areas: *a*, East and West Lake Tourism Area (lake area 100hm²); *b*, forest park area (to build a 1 thousand hm² of forest park); *c*, sightseeing agriculture area (1 hundred hm² of sightseeing orchard and 1 thousand hm² of special aquatics); *d*, sports and exercise area (climbing mountain for watching sun rising and 200hm² golf field); *e*, resort villa area (150hm²).

4.7. Natural protection

The tidal flats at Hangzhou Bay have developed extreme rich biological diversity, including 149 species of wetland waterfowl alone. It has become the most important winter living and migrating stops for the black mouth gull and black face egret, which are endangered species in the world. Therefore Bird Life International has listed the Andong Wetland in Cixi at Hangzhou Bay as an important bird area. However, the tidal flat wetlands at Hangzhou Bay are facing even larger scaled and faster reclamation. A consequence may be that the biological diversity will be severely interfered with. It is necessary to conduct an overall planning, reserve some tidal flats as natural reserve areas based on the natural distribution law of the wetland ecosystem, otherwise some species could become extinct.

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