Ecological Benefit Evaluation of Agricultural Heritage System Conservation

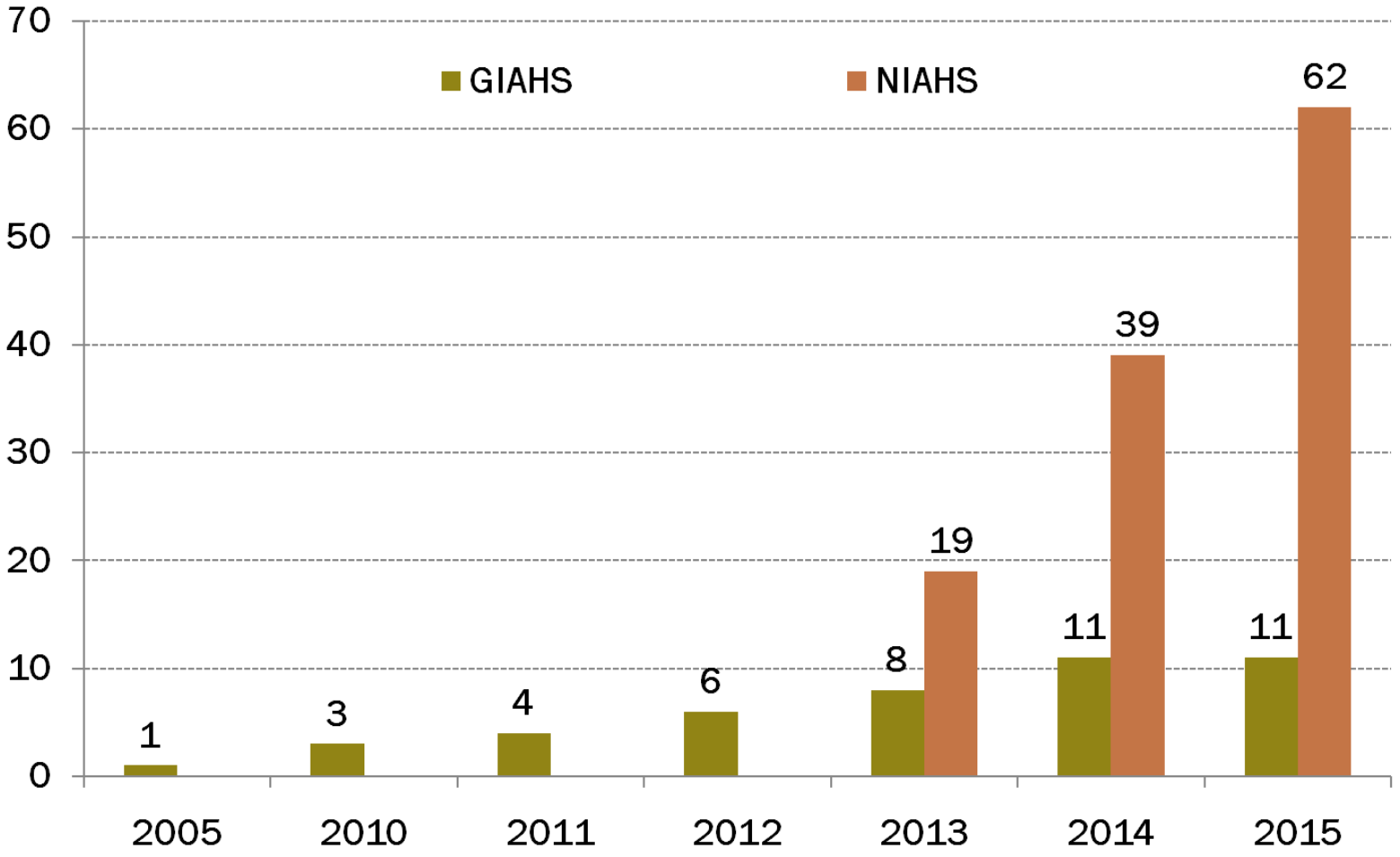
-A case study of Qingtian Rice-fish Culture System

Wang Bin
Research Institute of Subtropical Forestry,
Chinese Academy of Forestry
2016.06.14

Contents

I. General Introduction

NO. of GIAHS & NIAHS in China, 2005-2015



GIAHS in China

陕西佳县古枣园

贵州从江侗乡稻鱼鸭复合系统

云南普洱古茶园与茶文化系统

云南红河哈尼稻作梯田系统

江西万年稻作文化系统

福建福州茉莉花种植与茶文化系统

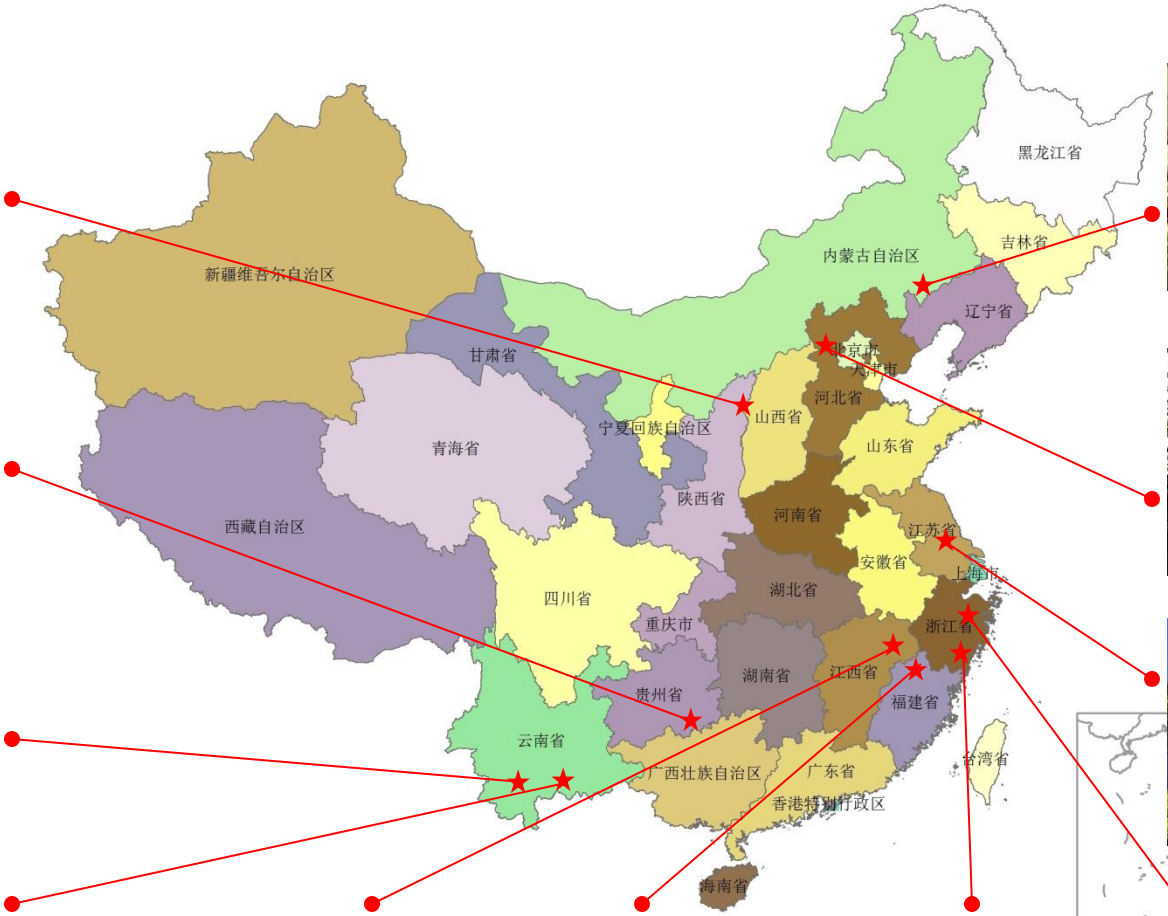
浙江青田稻鱼共生系统

内蒙古敖汉旱作农业系统

河北宣化传统葡萄园

江苏兴化垛田传统农业系统

浙江绍兴会稽山古香榧群



NIAHS in China

Purpose of Evaluation

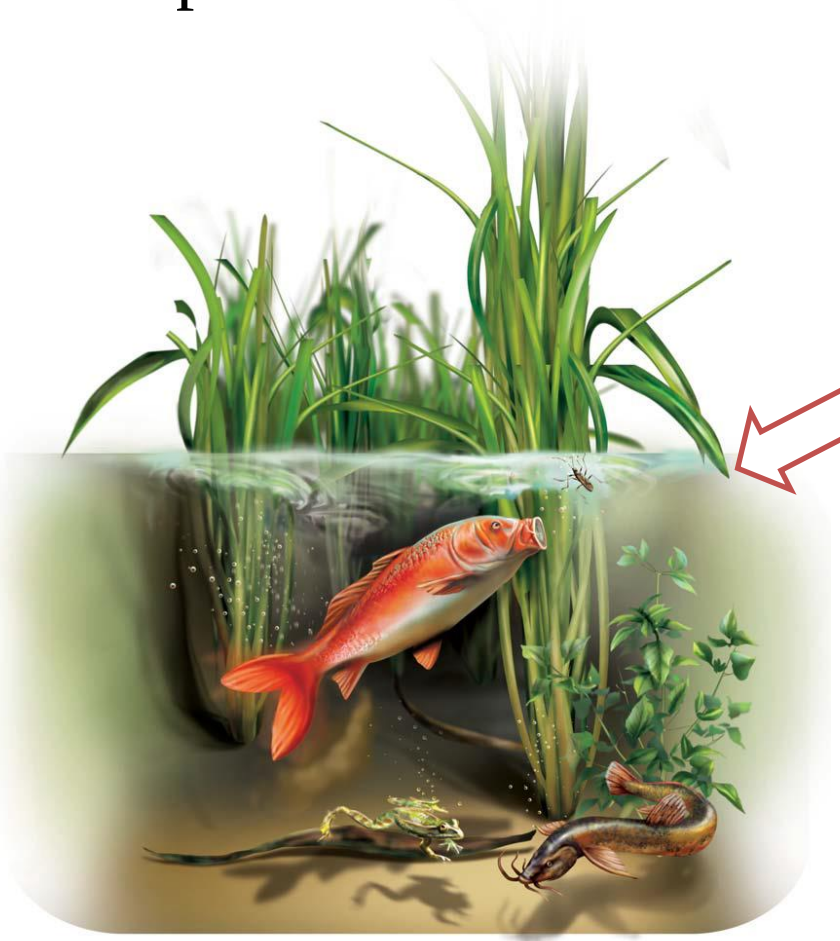
- Grasp and understand the status and trends of ecosystem structure and function, biodiversity and ecological environment after AHS conservation;
- Analyze the key problems of biodiversity conservation and the threat factors; establish the monitoring system of biological species resource;
- Clarify the focus and direction of the heritage conservation; put forward feasible countermeasures and suggestions for AHS conservation.

In 2015, we chose Qingtian Rice-fish Culture System as a case, and carried out the ecological benefit evaluation of AHS conservation.

Qingtian Rice-fish Culture System

- Qingtian County is in the central and southern of Zhejiang province;
- The tradition of raising fish in paddy field has a history of more than 1200 years;
- The first one in China and the first batch in the world for GIAHS conservation (In 2005).

- Feeding fish with insects and weeds-fertilizing field with fish manures
- Splendid rice-fish culture



maintain the normal circulation without using any fertilizers or pesticides;
gave birth to the splendid rice-fish culture.

Evaluation Methods

- Taking the year of 2005 (awarded the GIAHS) as the starting year and 10 years as an assessment period;
- Divided the assessment scope into three levels: first is the core area (Longxian); second is the expanding areas (Fangshan, Xiaozhoushan and Renzhuang); third is the whole county;
- Objects: farmlands, forests, wetlands, rivers; reservoirs; grasslands, urban, wastelands;
- Contents: agriculture and relevant biodiversity; ecosystem structure and function, ecological environment quality of paddy field and rural area.

Evaluation Indicator System

Level 1	Level 2	Level 3
Ecological benefit evaluation	Agriculture biodiversity	Rice varieties
		Fish varieties
		Other crop varieties
		Livestock and poultry varieties
		Economic fruits
		Medicinal plants
	Relevant biodiversity	Biological varieties in paddy field
		Biological varieties in residential areas
		Biological varieties in forest lands
		Other wild animals
	Ecosystem structure and function	Ecosystem types
		Ecosystem structure
		Ecosystem services
	Ecological environment quality of paddy field	Soil nutrient
		Water quality
		Diseases and insect pests
	Ecological environment quality of rural area	Rural landscape
		Farmland landscape
		Water environment
		Household garbage
		Path between fields

III. Biodiversity

1. Rice varieties

- According to the research data in 2006, 28 traditional rice varieties have disappeared from Qingtian rice-fish culture system;
- There are mainly 4 traditional rice varieties which are still retained in the site since the heritage conservation was launched.

黑米 Black rice

糯米 Sticky rice

农垦58（粳稻） Japonica rice

红晚金（汕稻）Indica rice

2. Fish varieties

- Preliminary investigation shows that the population size of fish originally raised in Qingtian is dramatically shrinking, and even completely disappears in some villages.
- Instead, there are more and more newly breeding varieties (genetic diversity is relatively low).

青田田鱼 Qingtian fish

In order to protect the genetic diversity of Qingtian fish, the government has begun to protect the protospecies of Qingtian fish since 2013.

青田田鱼 Qingtian fish

鱼苗孵化 Hatch young fish

鱼苗筛选 Filter young fish

鱼苗捐赠 Donate young fish

3. Other Agriculture Varieties

- Crop varieties: basically remain the same;
- Livestock and poultry varieties: most of which are introduced species, mainly include pig, cattle, sheep, chicken, duck, and so on;
- Economic fruits: developed quickly due to the adjustment of agricultural industrial structure in recent years, including more than 20 species such as waxberry, orange, peach, pear and loquat, etc.
- Medicinal plants: the variety and area has showed an increasing trend annually in these years.

4. Relevant Biodiversity

Biological varieties in paddy field

Biological varieties in residential areas

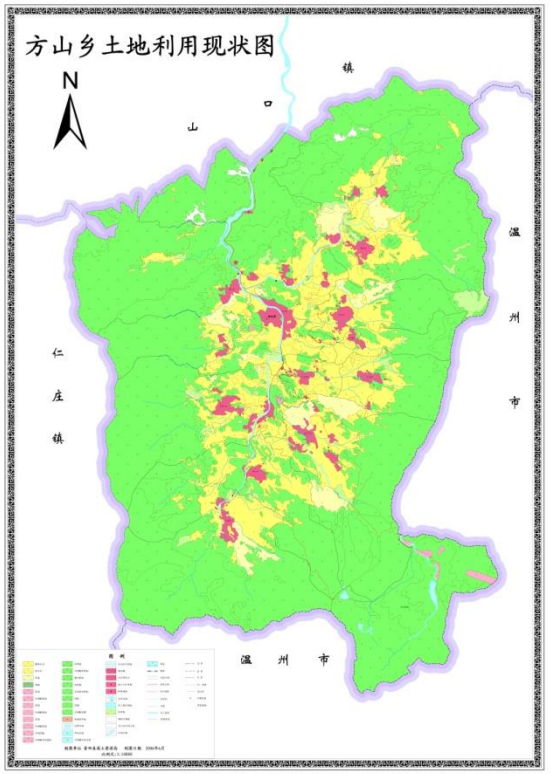
Biological varieties in forest lands

Other wild animals

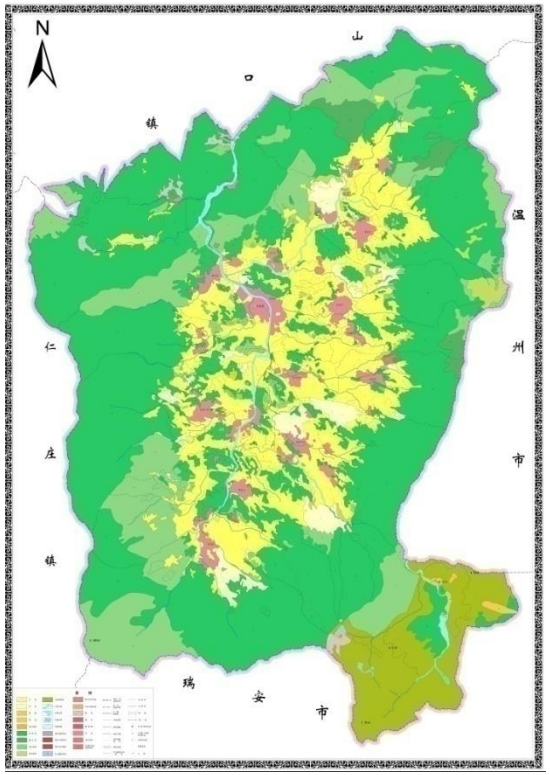
Survey showed no obvious change.

IV. Ecosystem Structure and Function

- Taking the Fangshan town and Longxian Village as the study area;
- Using the land use data in 2005 and 2013



Land use map in 2005



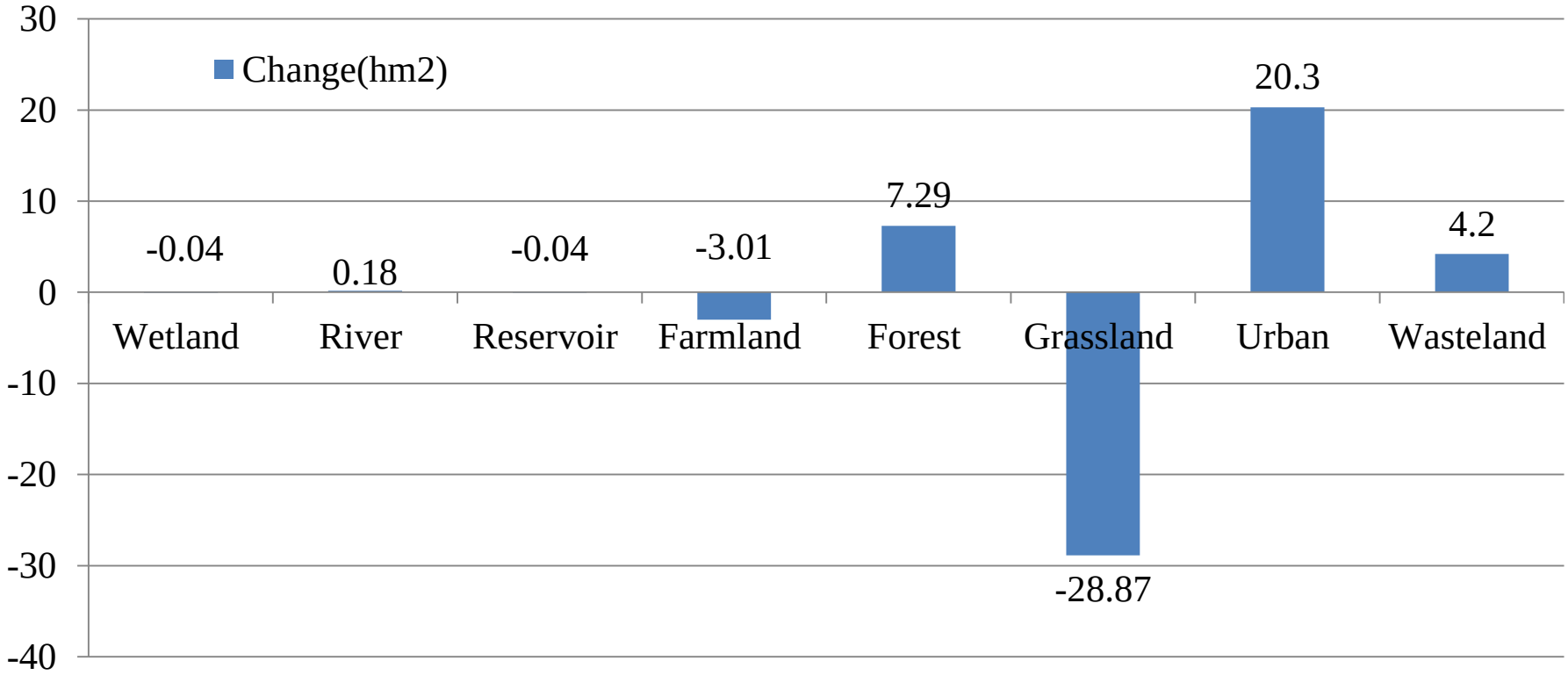
Land use map in 2013

1. Ecosystem Structure Change

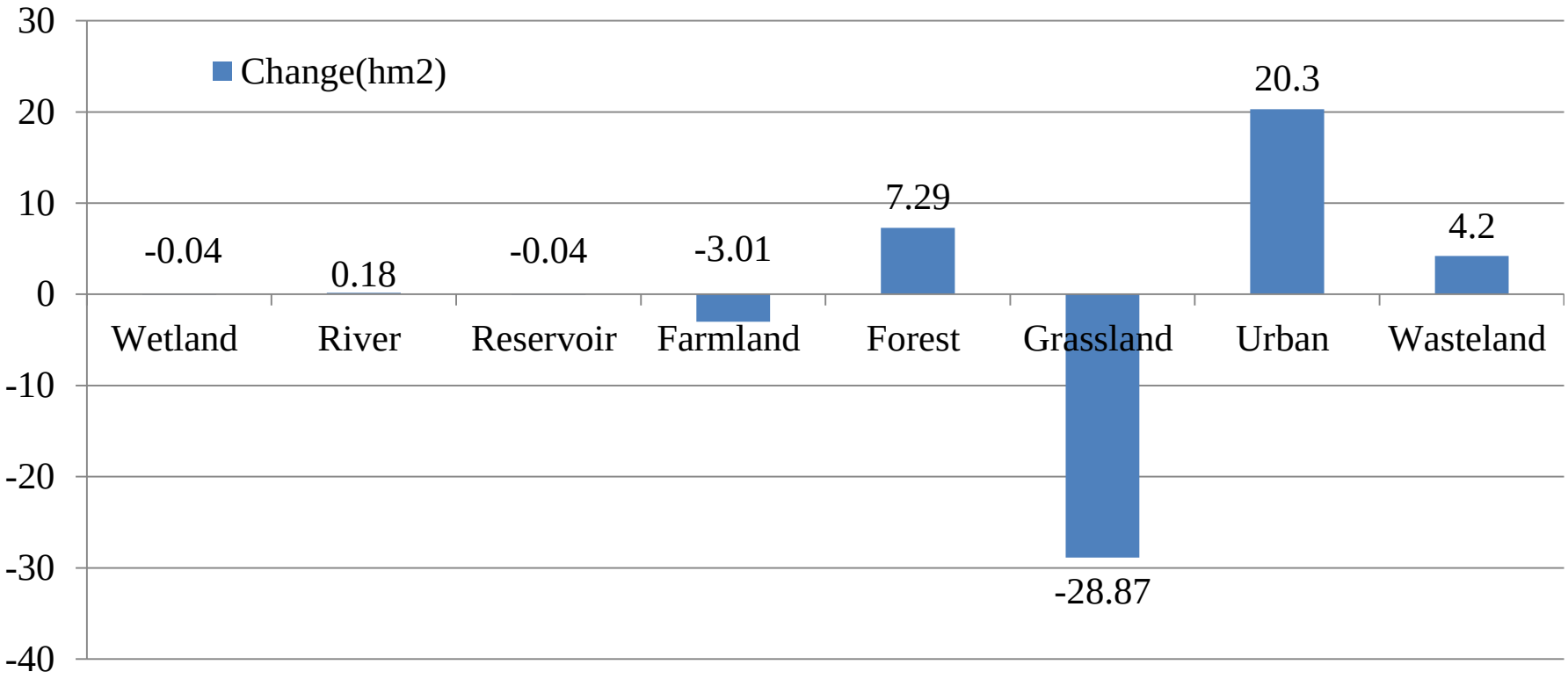
- According to land use data in Fangshan Town in 2013, the forest ecosystem occupies the largest area, followed by farmland ecosystem, while the wetland ecosystem area is the smallest.

Table 1 The area of different ecosystems in Fangshan town (hm^2)

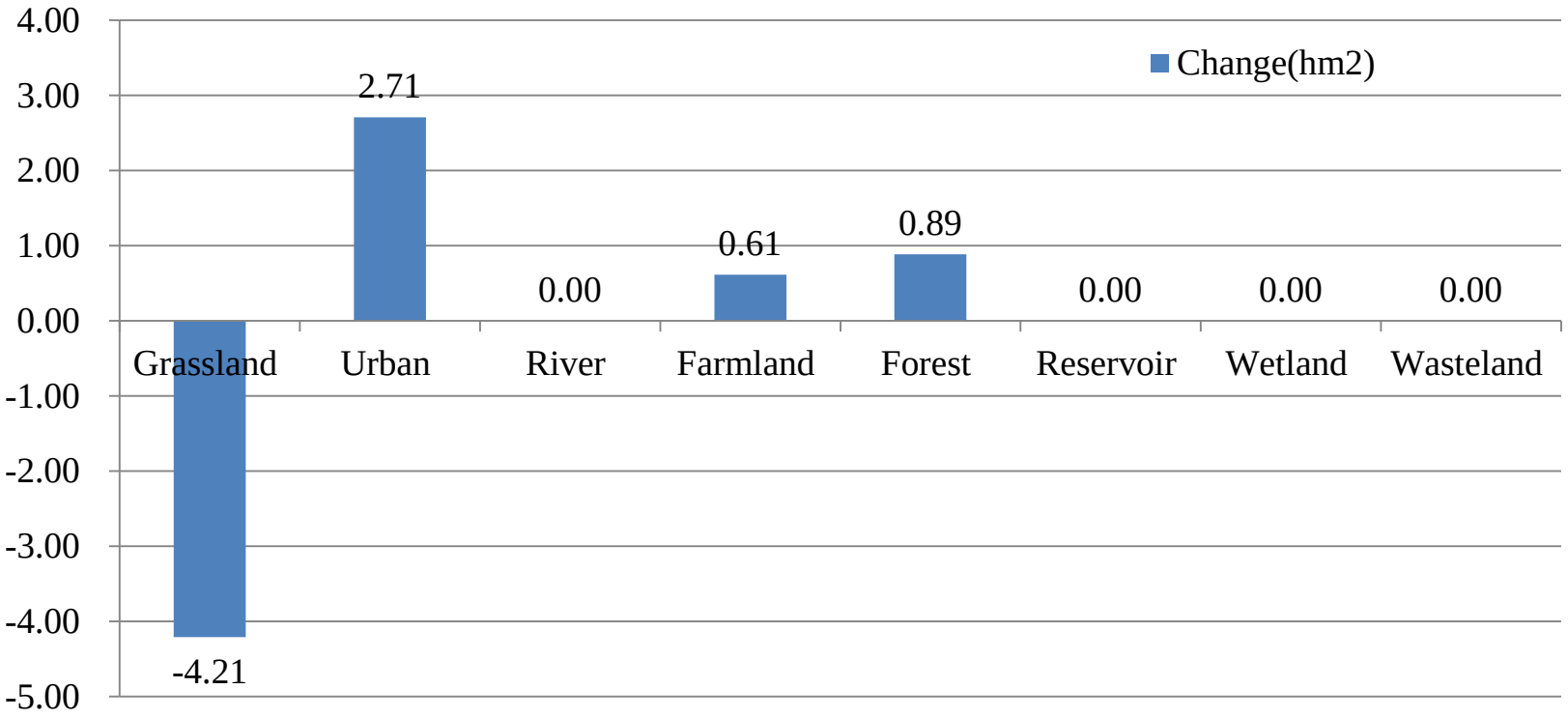
Ecosystem types	2005	2013	Change
Wetland	2.51	2.47	-0.04
River	25.32	25.50	0.18
Reservoir	9.56	9.53	-0.04
Farmland	863.79	860.78	-3.01
Forest	2755.75	2763.03	7.29
Grassland	317.02	288.15	-28.87
Urban	116.47	136.76	20.30
Wasteland	11.30	15.49	4.20
Total	4101.71	4101.71	0



- Urban: the fast speed of urbanization.
- Forest: the basis of ecological environmental protection in the heritage site is relatively strong.
- Wasteland: may be associated with the decrease of rural labor force and the abandon of farmlands.



- Grassland: may probably due to the urbanization.
- Farmland: most farmers in the heritage site has chosen to cultivate the land near their house and gradually abandoned the remote land.



- Longxian village: core area of the rice-fish system.
- Urban area increased rapidly. Many overseas Chinese like to build houses in hometown when they have certain economic basis.

2. Ecosystem Services Change

- Referring to the research, we constructed the calculating parameter (table 2) and use it to calculate the ecosystem services of different ecosystems in 2005 and 2013.

Table 2 Unit area ecosystem services of different ecosystems (RMB/hm^2.a)

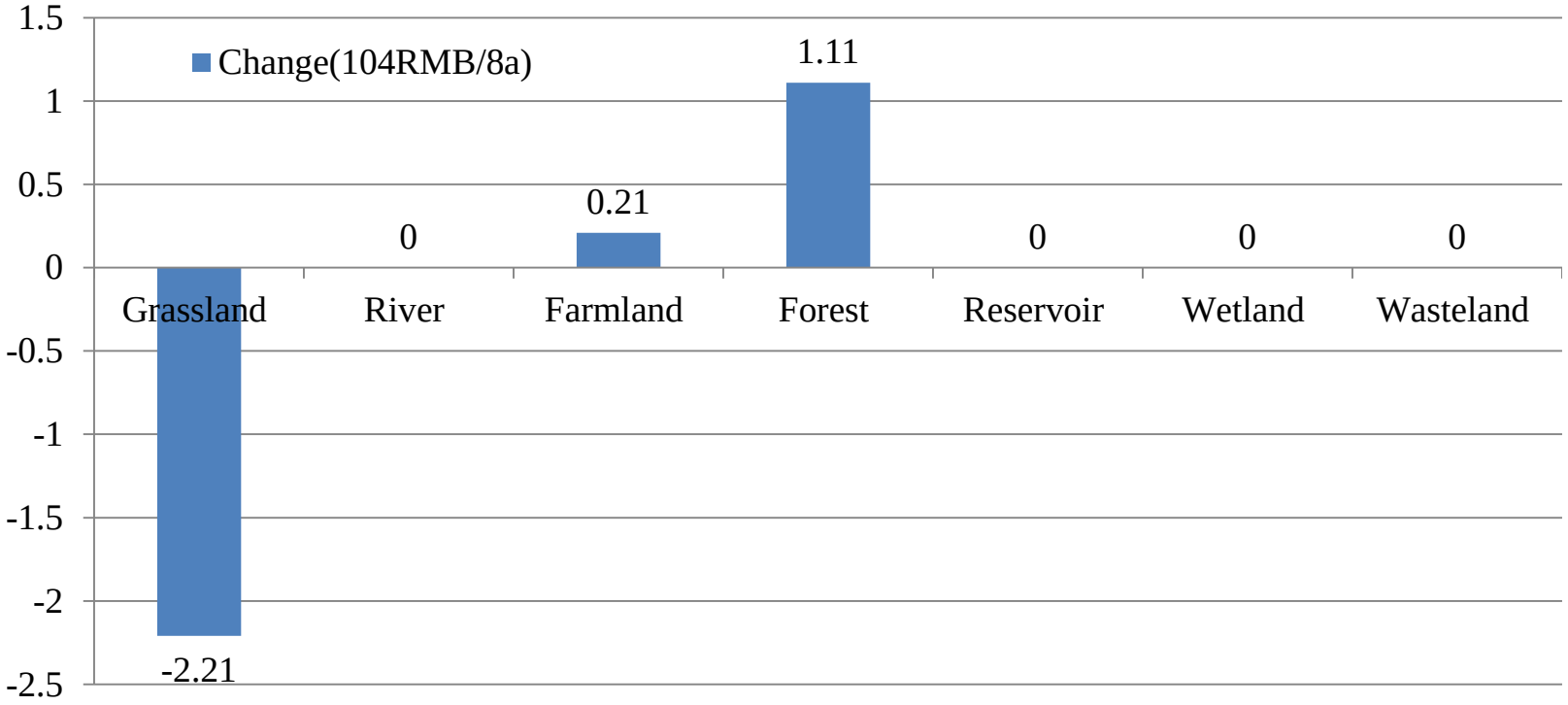
Level 1	Level 2	Grassland	River	Farmland	Forest	Reservoir	Wetland	Wasteland
Provisioning services	Food production	193.11	238.02	449.1	148.2	238.02	161.68	8.98
	Material production	161.68	157.19	175.15	1338.32	157.19	107.78	17.96
Regulating services	Gas regulation	673.65	229.04	323.35	1940.11	229.04	1082.33	26.95
	Climate regulation	700.6	925.15	435.63	1827.84	925.15	6085.31	58.38
	Water temperature regulation	682.63	8429.61	345.81	1836.82	8429.61	6035.9	31.44
	Waste disposal	592.81	6669.14	624.25	772.45	6669.14	6467.04	116.77
Supporting services	Soil conservation	1005.98	184.13	660.18	1805.38	184.13	893.71	76.35
	Maintain biodiversity	839.82	1540.41	458.08	2025.44	1540.41	1657.18	179.64
	Landscape	390.72	1994	76.35	934.13	1994	2106.28	107.78

Export Knowledge based valuation method of ecosystem services in China. Xie Gaodi (2008)

Table 3 The ecosystem services of different ecosystems in Fangshan Town (10^4 RMB/a)

Level 1	Level 2	Grassland	River	Farmland	Forest	Reservoir	Wetland	Wasteland	Grassland	River	Farmland	Forest	Reservoir	Wetland	Wasteland	**Total**		**Change**
		2005	**2013**	**2005**	**2013**	**2005**	**2013**	**2005**	**2013**	**2005**	**2013**	**2005**	**2013**	**2005**	**2013**	**2005**	**2013**	
Provisioning services	Food production	6.12	5.56	0.60	0.61	38.79	38.66	40.84	40.95	0.23	0.23	0.04	0.04	0.01	0.01	86.63	86.06	-0.57
	Material production	5.13	4.66	0.40	0.40	15.13	15.08	368.81	369.78	0.15	0.15	0.03	0.03	0.02	0.03	389.67	390.13	0.46
Regulating services	Gas regulation	21.36	19.41	0.58	0.58	27.93	27.83	534.65	536.06	0.22	0.22	0.27	0.27	0.03	0.04	585.04	584.41	-0.63
	Climate regulation	22.21	20.19	2.34	2.36	37.63	37.50	503.71	505.04	0.88	0.88	1.53	1.50	0.07	0.09	568.37	567.56	-0.81
	Water temperature regulation	21.64	19.67	21.35	21.50	29.87	29.77	506.18	507.52	8.06	8.03	1.52	1.49	0.04	0.05	588.66	588.03	-0.63
	Waste disposal	18.79	17.08	16.89	17.01	53.92	53.73	212.87	213.43	6.38	6.35	1.62	1.60	0.13	0.18	310.60	309.38	-1.22
Supporting services	Soil conservation	31.89	28.99	0.47	0.47	57.03	56.83	497.52	498.83	0.18	0.18	0.22	0.22	0.09	0.12	587.40	585.64	-1.76
	Maintain biodiversity	26.62	24.20	3.90	3.93	39.57	39.43	558.16	559.64	1.47	1.47	0.42	0.41	0.20	0.28	630.34	629.36	-0.98
	Landscape	12.39	11.26	5.05	5.08	6.60	6.57	257.42	258.10	1.91	1.90	0.53	0.52	0.12	0.17	284.02	283.60	-0.42
Total		166.15	151.02	51.58	51.94	306.46	305.39	3480.15	3489.35	19.47	19.40	6.18	6.08	0.71	0.97	4030.70	4024.15	-6.55

- The total value of ecosystem service in Fangshan town has reduced from 40,307,000 RMB/a in 2005 to 40,241,500 RMB/a in 2013.
- The reduction of ecosystem service may be largely caused by the increase of urban area.
- Service value of forest ecosystem has increased, river and desert ecosystems has slightly increased; while grassland, farmland, reservoir and wetland ecosystem have showed a reducing trend.
- Except the service of raw material production, all the other service functions have reduced. Soil conservation and waste treatment reduced the most.



- Longxian Village: the ecosystem services of farmland and forest ecosystem have increased, indicating that the heritage conservation in Longxian Village has made some achievements in recent years.

V. Ecological Environment Quality

1. Soil nutrient

- Fishes could absorb organic through swallowing and digesting, and their excreta could transform 30% to 40% of the organic matters into fertilizer, which increases the organic matter content and nutrient in the paddy fields.
- The movements of fishes could constantly turn over the soil so as to enlarge the soil porosity and increase the oxygen, which is also helpful to accelerate the decomposition of organic matters.

The soil test report shows that the paddy soil in this area is slightly acidic with high organic matter content, which is especially suitable for planting rice.

Table 4 The test report of soil quality in paddy field in Longxian village

Items	Limit value	Result	Decision
pH		5.92	
TP（%）		0.026	
AP（ppm）		12.5	
Available K（ppm）		92.5	
TN（%）		0.133	
SOM（%）		3.41	
DDT（mg/kg）	≤0.50	6.67×10^{-3}	Up to standard
HCH（mg/kg）	≤0.50	$<1.0\times10^{-5}$	Up to standard
Pb（mg/kg）	≤250	32	Up to standard
As（mg/kg）	≤30	4.04	Up to standard
Hg（mg/kg）	≤0.30	0.08	Up to standard
Cr（mg/kg）	≤250	<30	Up to standard
Cd（mg/kg）	≤0.30	<0.2	Up to standard
Cu（mg/kg）	≤50	19	Up to standard

2. Water quality

- The swimming of fishes could increase the dissolved oxygen in the water, so as to improve the water quality.

According to the water sample test report, the water quality of rice-fish culture system is better than that of the general paddy fields.

Table 5 The test report of water quality in paddy field

Items	Limit value	Result	Decision
Las（mg/L）	≤5	Not detected（<0.05）	Up to standard
pH	5.5-8.5	8.17	Up to standard
Total salt content（mg/L）	≤1000C（Non saline land area ） ≤2000C（Saline land area）	21	Up to standard Up to standard
Chloride（mg/L）	≤350	2.7	Up to standard
Sulfide（mg/L）	≤1	Not detected（<0.005）	Up to standard
*T Hg（mg/L）	≤0.001	Not detected（<0.0001）	Up to standard
Cr（mg/L）	≤0.01	Not detected（<0.0001）	Up to standard
Total arsenic（mg/L）	≤0.05	Not detected（<0.007）	Up to standard
Chromium(six value)（mg/L）	≤0.1	Not detected（<0.004）	Up to standard
Cu（mg/L）	≤0.5	Not detected（<0.01）	Up to standard
Zn（mg/L）	≤2	Not detected（<0.006）	Up to standard
Se（mg/L）	≤0.02	Not detected（<0.00025）	Up to standard
Fluoride（mg/L）	≤2（General area） ≤3（High fluorine area）	Not detected（<0.05）	Up to standard
Cyanide（mg/L）	≤0.5	Not detected（<0.25）	Up to standard
TP（mg/L）	-	Not detected（<0.01）	Up to standard

3. Diseases and insect pests

- Five years of field experimental study shows that controlling sheath blight and rice planthopper by fishes is similar to conduct pesticide treatment in rice monoculture system.

Ecological mechanisms underlying the sustainability of the agricultural heritage rice–fish coculture system

Jian Xie[a], Liangliang Hu[a], Jianjun Tang[a], Xue Wu[a], Nana Li[a], Yongge Yuan[a], Haishui Yang[a], Jiaen Zhang[b], Shiming Luo[b], and Xin Chen[a,1]

[a]College of Life Sciences, Zhejiang University, Hangzhou 310058, China; and [b]Department of Ecology, South China Agricultural University, Guangzhou 510642, China

Edited by Stephen R. Carpenter, University of Wisconsin, Madison, WI, and approved October 13, 2011 (received for review July 12, 2011)

For centuries, traditional agricultural systems have contributed to food and livelihood security throughout the world. Recognizing the ecological legacy in the traditional agricultural systems may help us develop novel sustainable agriculture. We examine how rice–fish coculture (RF), which has been designated a "globally important agricultural heritage system," has been maintained for over 1,200 y in south China. A field survey demonstrated that although rice yield and rice-yield stability are similar in RF and rice monoculture (RM), RF requires 68% less pesticide and 24% less chemical fertilizer than RM. A field experiment confirmed this result. We documented that a mutually beneficial relationship between rice and fish develops in RF: Fish reduce rice pests and rice favors fish by moderating the water environment. This positive relationship between rice and fish reduces the need for pesticides in RF. Our results also indicate a complementary use of nitrogen (N) between rice and fish in RF, resulting in low N fertilizer application and low N release into the environment. These findings provide unique insights into how positive interactions and complementary use of resource between species generate emergent ecosystem properties and how modern agricultural systems might be improved by exploiting synergies between species.

Global food security is becoming an acute problem because of the increasing world population (1), the limitation of agricultural resources (e.g., land and water) (2), and the effects of global climate change on crop production (3, 4). World agriculture currently faces great challenges in producing sufficient food while minimizing the negative environmental effects of crop cultivation.

In the past 50 y, crop yields have substantially increased, mainly resulting from the use of chemical fertilizers and pesticides, the development of new crop varieties, and the improvement in cultivation methods. The heavy application of chemical fertilizers and pesticides for long periods, however, negatively affects the environment, induces pest resistance to pesticides, and increases agricultural costs (5, 6). As a consequence, modern agriculture now requires "rethinking" (1, 7), and such rethinking should include reconsideration of traditional agricultural systems (8–10).

For many centuries, traditional agricultural systems have contributed to food and livelihood security throughout the world (8). Because traditional agricultural systems have been created, shaped, and maintained by generations of farmers who used management practices that were matched to local conditions, and because these systems are based on diverse species and species interactions, traditional agricultural systems reflect a successful adaptation to different environments and are rich in biological diversity (8, 11, 12). The recognition of the ecological legacy of these traditional agricultural systems and the integration of these unique experiences into our future farm designs could help us to develop more sustainable agriculture. In fact, studies of such traditional systems have already helped scientists create novel farm designs (5, 13–15).

During the recent expansion of modern agriculture based on substantial inputs of fertilizer and pesticides, however, many of these traditional agriculture systems have been disappearing (8). To preserve these important agriculture systems, the Food and Agriculture Organization, the United Nations Development Program, and the Global Environment Facility developed a program for "globally important agricultural heritage systems (GIAHS)" in 2005 (http://www.fao.org/nr/giahs/giahs-home/en/) (16). One of these GIAHS is the rice–fish coculture system that has been practiced by farmers in south Zhejiang province, China, for >1,200 y (17).

In this rice–fish coculture system, the fish is an indigenous, red, soft-scaled common carp (*Cyprinus carpio color* var.) with high genetic diversity (18, 19). The rice varieties in the system have been changing over time. In the last decade, high-yielding hybrid rice varieties have been dominant (20). The rice–fish coculture is considered a sustainable form of agriculture because it maximizes the benefits of scarce land and water resources by using relatively few chemical inputs, by producing both carbohydrate and protein products, and by conserving biodiversity (20–24). Despite other changes resulting from rapid development over the last 30 y in China, farmers continue to practice rice–fish coculture, in part because this system is an important component of traditional culture and local customs (e.g., rice–fish festivals) (21). Although the value of the rice–fish coculture has been recognized (for example, by its inclusion in the GIAHS project), the ecological mechanisms underlying the system have not been studied in depth.

The main purpose of our present study was to estimate the ecosystem stability of this rice–fish system and to determine how the stability is maintained. Our hypothesis is that the stability of this system results from mutually beneficial relationships between rice and fish. The study was conducted at the GIAHS pilot site of the rice–fish system in China (*SI Text*, section S1, and Fig. S1).

Results

Quantity and Temporal Stability of Rice Yield in Rice–Fish Coculture. We compared ecosystem stability of rice monoculture (RM) and rice–fish coculture (RF) with a farmer field survey and a field experiment. The temporal stability of rice yield was measured as the degree of constancy of yield around its mean over the same time interval (25). In the survey of farmer fields, we determined the temporal stability of rice yield with data collected annually from 31 sampling units (each unit containing 3–5 subsamples) during 2005–2010. In the field experiment (experiment 1), we determined the temporal stability of rice yield with data from each experimental plot during 2006–2010.

Survey results from farmer fields showed that rice yield did not differ between RM and RF over the 6 y (Fig. 1*A*, $F_{1,60} = 0.092$, $P = 0.763$) but that the temporal stability of rice yield was higher in RF

Author contributions: J.T., J.Z., S.L., and X.C. designed research; J.X., L.H., J.T., X.W., N.L., Y.Y., H.Y., and X.C. performed research; J.X., L.H., J.T., X.W., N.L., H.Y., J.Z., S.L., and X.C. analyzed data; and J.X., L.H., J.T., S.L., and X.C. wrote the paper.

The authors declare no conflict of interest.

This article is a PNAS Direct Submission.

Freely available online through the PNAS open access option.

[1]To whom correspondence should be addressed. E-mail: chenxin@zju.edu.cn.

This article contains supporting information online at www.pnas.org/lookup/suppl/doi:10.1073/pnas.1110491108/-/DCSupplemental.

4. Rural landscape

- Since 2005, the government try to improve the conditions of road, water, toilet, afforestation, brightness and beautification in the countryside each year by granting tens of millions of fund.

Improved the living conditions and the residential environment.

5. Farmland landscape

- Through the creative agriculture, the farmland landscape construction has achieved rapid development.

Samsara pattern

Heart pattern

6. Water environment

- Since the “Five water governance”, Qingtian County has actively explored the ways and methods of water control, which creates a good atmosphere of caring, supporting, participating and supervising the water environment.

7. Household garbage

- Since 2006, Qingtian County implemented the centralized waste collection and disposal. The centralized processing rate of rural waste in Qingtian reached to 51.4%, which significantly improve the ecological environment.

8. Path between fields

- In order to prevent the field paths from collapse as well as reduce the cost of peasants' labor, many villages with rice-fish culture system began to harden the field paths.

VI. Problems and Countermeasures

1. There are some dead ends for rural environment sanitation, it is necessary to further strengthen the governance.

2. Wild animals (egret) have lead to serious damages, which shall be dealt with by taking effective measures.

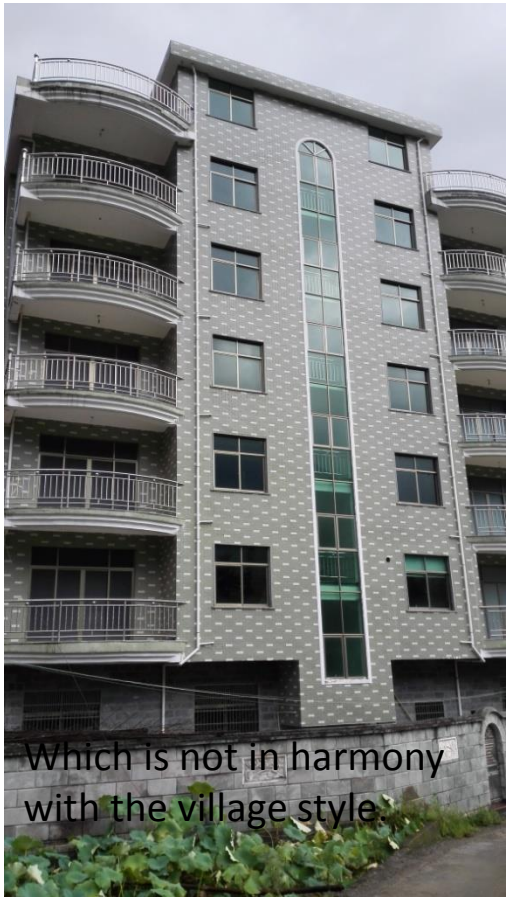
More and more began to fish in the rice fields;
Egrets belong to the second-class national protected animal;
People have to use net to prevent the egrets.

3. The path harden project can save labor and enhance efficiency, but its long-term ecological impact remains to be seen.

reduced the farmland biodiversity;
may become a barrier to biological communication.

4. Ancient buildings lack protection, and new buildings need unified planning and construction.

many old buildings have been dilapidated; more and more concrete structure buildings with 3 to 6 floors and luxurious styles are constructed.



Which is not in harmony with the village style.


Thanks !