A methodology to assess the sustainability and resiliency of GIAHS sites: an example of its application in the rice-fish culture (RFC) systems in Longxian village, Qingtian County, Zhejiang Province, China

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The GIAHS Initiative uses the sustainable livelihoods framework (SLA) as an approach to understanding factors (shocks, trends, etc) affecting people's livelihoods (expressed as five types of capital) and the way these factors are linked to each other. Within the SLA framework, resources available to a specific community can be divided into five different capital assets (Figure 1). Based on these assets, a list can be drawn up of what assets are available in the community. Economic, environmental, social and institutional forces as well as human behavior influence land-use decisions by local people and depending on the strength of the capitals, communities respond to internal and external forces that influence the positive or negative tendencies of any of the five capital assets. This in turns determines the outcomes (levels of income, health, nutrition, food security, sustainable resource use, etc) of the livelihood strategy adopted by the community.

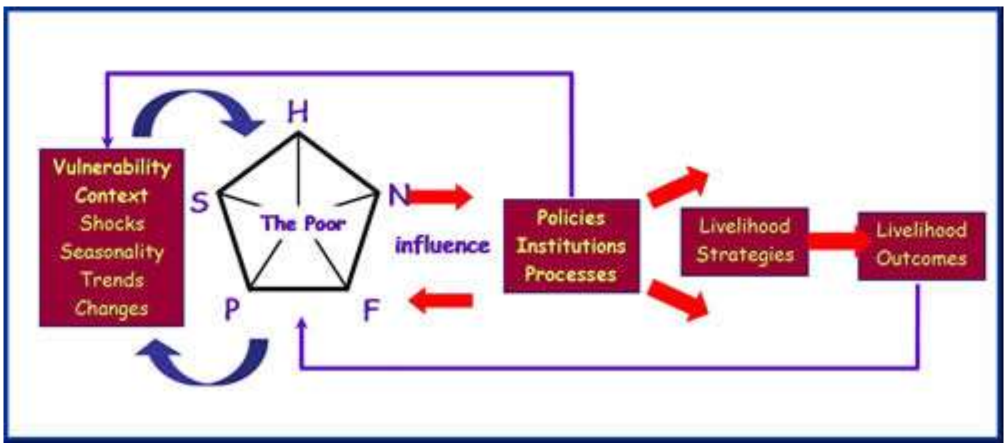


Figure 1. The sustainable livelihoods framework (http://www.ifad.org/sla/)

The SLA framework as presented in Figure 1 shows the main components of SLA and how they are linked. The framework seeks to provide a way of thinking about the livelihoods of poor farmers and the many factors that affect their livelihoods, the way they interact and their relative importance within a particular setting. By developing a series of indicators of the state of the art of each capital (Table 1) SLA can help in identifying more effective ways to support rural livelihoods by evaluating the capitals and suggesting ways to improving them. Rural communities that exhibit strong natural, social and human capital are less vulnerable to external stresses and usually can embark more easily in strategies that result in positive outcomes.

Taking the SLA framework as a basis, the methodology was modified and complemented with other assessment methods (i.e. Mesmis- , RASA-) to fit the circumstances for application in rice-fish culture (RFC) systems in Longxian village, Qingtian County, Zhejiang Province, China, during a visit on June 14-16, 2011 (for further details on the team and activities involved in the field trip see the report of Mary Jane de la Cruz, FAO- GIAHS National Project Coordinators' Field Survey and on-site training on SLA).

Table 1. Indicators typically used in an agroecological assessment of the GIAHS capitals

<u>Natural Capital</u>

1. General biodiversity: flora and fauna
2. Landscape matrix (inside fields and surrounding fields)
3. Agrobiodiversity: number of species, number of varieties or races, etc
4. Arrangement of crops-animals in time and space (monocultures, rotations, polycultures, etc)
5. Soil quality (structure, organic matter, depth, signs of degradation, ect)
6. Water (availability, ownership, quality, rights, etc)
7. Ecological services of local and global importance

<u>Human Capital</u>

1. Traditional knowledge (use of ancient practices vs modern , etc)
2. Use of natural signs to guide management (moon phases, etc)
3. Intergenerational transmission of knowledge

<u>Social Capital</u>

1. Level of organization (political, labor, market, etc)
2. Collective work and actions
3. Circuits of exchange of knowledge, technologies, seeds, etc

<u>Economic Capital</u>

1. Income
2. Dependence of external inputs
3. Access to credit, subsidies, extension, information, etc
4. Food security level

<u>Infrastructure Capital</u>

1. Access to reasonable levels of technology (mechanization, etc)
2. State of terraces, irrigation canals, etc
3. Access to markets, urban areas (level of isolation)
4. Ecotourism infrastructure and carrying capacity

Preliminary SLA analysis of the rural communities managing RFC in Qingtian County

RFC farming has been practiced in China for more than 1700 years, covering today about 1,5 million hectares mainly in the mountainous areas of southeast and southwest China.
Despite emigration of people (only 188 households left), in Longxian village (Qingtian County) RFC (which dates back to the Ming Dynasty (1368–1644)) is still alive covering about 60 hectares (13% of the Longxian village territory) demonstrating an ingenious farming approach that generates significant environmental, cultural and economic benefits to local rural inhabitants.

RFC systems are characterized by different varieties of rice, varieties with thick stalks and big leaves, strong resistance in lodging and a longer growth cycle. These systems contribute to the conservation of the local rice species, such as Oryza sativa indica, japonica and javanica, and the maintenance of genetic diversity of rice. The main biodiversity components of RFC include rice, fish, weeds, plankton, photosynthetic bacteria, aquatic insects, benthos, rice pests, water mice,
water snakes, birds, soil bacteria and aquatic bacteria, displaying a number of complex interactions which favor rice production and health (Box 1). The agrobiodiversity (rice diversity, fish and surrounding habitats) of RFC systems is one of the main components of the natural capital of these communities.

In the traditional Longxian village rural community, people have strong ties of kinship and practice mutual exchange activities as part of their social capital. Farmres display intimate knowledge of their local environment and agrobiodiversity as part of their human capital. Rural people seem to have relatively low financial capital (although many receive remittances form abroad and some are able to sell their fish products) and limited access to education, health services, credit, extension, etc. The livelihood strategies they use reflects this reality. They use their knowledge to exploit a variety of agricultural, aquatic and forest resources ensuring a supply of food, fuel and some income. Their community ties and relations of mutual help allow them to usually overcome episodes of vulnerability and shocks without outside help . Their unfamiliarity with financial capital leaves them at a disadvantage when involved in market transactions, especially when their products are undervalued by markets.

Most change in the Vulnerability Context is a product of external transforming trends and processes such as deepening government agrarian reforms , introduction of pesticides, fertilizers and modern rice varieties, intensive fish farming, migration to urban centers, increased labor costs and uncontrolled tourism, over which local people have little influence. One way of managing the Vulnerability Context is to help people become more resilient and better able to capitalize on positive aspects such as their cultural, social, human and natural assets. The goal of the GIAHS process in China is to support poor people to build up their assets via conservation of their native agrobiodiversity and associated forms of knowledge. The RFC-GIAHS sites constitutes an attractive natural (with mountains, forests, rivers, rice-fish fields and associated fauna, etc) and cultural landscape (traditional architecture, dialect and folklore, festivals, indigenous knowledge about RFC, etc) creating an attractive setting for sight seeing, sports (fishing, nature walks) and education-leisure tourism. There is therefore a great potential for developing markets for products with cultural identity (local souvenirs, arts and crafts, homestays, explorations for scientific and educational purposes, etc) as a mechanism for increasing people's ability to maintain maintain certain level of income stability which would also help in reducing vulnerability and ensure that livelihoods activities conserve the natural resource base.

From the brief observations and interviews conducted it is apparent that many of the key natural, cultural, social and human assets are still maintained in this Chinese rural community, which in turn ensures an adequate level of family's food security, and the ecological integrity of their farms. The question is how to maintain such systems through greater economic opportunities, without undermining the cultural, social and ecological base that characterizes them as a unique GIAHS site.

RASA: a methodology to assess the sustainability of GIAHS agroecosystems

As one travels through a GIAHS region it is clear that there is a diversity of farms, which vary in terms of biodiversity, levels of inputs, labor and production, surrounding environment, etc. One of the challenges that researchers evaluating GIAHS sites face, is to understand the factors that account for differences in performance between various farms present and to identify which farming systems are more sustainable and why, especially those that have been selected as GIAHS systems given their unique cultural and ecological features.

We use the Rapid Agroecological Sustainability Assessment (RASA) methodology to evaluate the sustainability and resiliency of the GIAHS sites. RASA uses a set of ecological, economic, social and cultural indicators consisting of observations and measurements that are done at the farm level focusing on a series of attributes such as biodiversity, soil quality, crop health, social organization, input use, etc which when analyzed simultaneously provide a quick agroecological assessment of the general *pulse* of each analyzed farming system. RASA consists of a series of observations and quick measurements that are done (by researchers and farmers in a participatory manner) at the farm level to assess soil fertility and level of degradation and whether crop plants are healthy, strong and productive, complemented by observations on the levels of biodiversity, external inputs used, food security at the household level, resiliency to external shocks, etc.

Indicators are important for the sustainable use and management of environmental resources. They give valuable information about the present status of the resources being measured, the rate and direction of change; they highlight priority actions to be taken when indicators exhibit low values indicating a non desirable condition or outcome.

RASA is a farmer-friendly method offering a set of flexible indicators comprising observation or measurements made at the farm level, to assess soil fertility and conservation and the health, strength and productivity of crop plants and in general how well endowed are the systems evaluated in terms of natural, economic, social, human and infrastructural assets.

A major challenge for the GIAHS implementers will be to devise a practical methodology to rapidly assess the sustainability of existing systems with simple indicators. Proposed indicators should be:

- easy to use by farmers;
- precise and easy to interpret;
- practical enough to facilitate making new management decisions;
- sensitive enough to reflect environmental changes and the effects of management practices on soil and crops;
- capable of integrating social, cultural, economic and biological dimensions; and
- relate to ecosystem processes, for example the relationship between plant diversity and pest population stability and/or disease incidence.

Most farmers possess their own indicators to estimate soil quality or the health condition of their farms and crops. For example, some farmers are able to identify weeds that grow only on acidic soils or on non-fertile soils. For others, the presence of earthworms is a sign of a fertile soil, and the color of the plant's leaves reflects the nutritional status of the soil. In any zone, it is possible to compile a long list of local indicators used by farmers. The problem with many indicators is that they are site-specific and may vary according to the knowledge of the farmers or the conditions of each farm. This makes it difficult to make comparisons between farms when the analysis is based on results derived from different indicators utilized by farmers in diverse ways.

In order to overcome this limitation, qualitative indicators relevant to farmers and the biophysical conditions of the area should be selected. Once such indicators are defined and selected, the procedure to measure sustainability should be the same and independent of the various situations in different farms of the studied region. Sustainability is defined then, as a group of agro-ecological requisites that must be satisfied by any farm, independently of its management, economic level, landscape position and other variants. Since the measurements made will be based on the same indicators, the results are comparable in such a way that it is possible to follow the evolution of the same agro-ecosystem along a timeline, or make comparisons between farms along various transitional stages. Most importantly, once the indicators are applied, each farmer can visualize the conditions of his/her farm, perceiving, which soil or plant attribute is doing well or not compared to a pre-established threshold. When the methodology is applied to various farms simultaneously, then it is possible to visualize which farms exhibit low or high values of sustainability. This is useful for farmers as it allows them to understand why some farms perform ecologically better than others while being able to think about what management modifications need to be done to improve farms exhibiting lower productivity.

Applying RASA to the RFC systems of Longxian village

A set of qualitative indicators relevant to farmers and the biophysical conditions typical of RFC agroecosystems were selected, each with observable and quantifiable attributes:

<u>Natural Capital indicators</u>

- Soil quality: level of aggregation, soil cover, signs of erosion, amount of decomposing residues, presence of invertebrates, etc
- Crop health: plant growth, signs of nutrient deficiencies, disease or pest incidence or damage, weed pressure, production-yields, etc
- On farm agrobiodiversity: number of crop species per farm, presence of fish and azolla, number of rice varieties grown, ratio of local versus modern varieties present
- Integrity of surrounding landscape matrix

- Resiliency: capacity of the system to resist external shocks (extreme climatic events, pest-disease attack, lack of inputs) and rate of recovery from shock.

Human Capital indicators

- Human capital: maintenance of traditional knowledge
- reliance on traditional techniques and skills to manage agroecosystems and deal with biotic and abiotic constraints

Social capital indicators

- level of social organization
- participation in community affairs,
- role of women in management and decision making, etc

Economic capital indicators

- Dependence on external inputs: reliance on local resources, purchase and use of chemical pesticides or fertilizers, fuel, other inputs
- Access to institutional services (credit, extension, etc) and local-regional markets
- Food sovereignty: proportion of food consumed by the family produced on farm, food and nutritional variety

With these already well defined indicators (soil quality, crop health, crop diversity, resiliency food sovereignity, state of surrounding matrix, ,etc) the procedure to measure the sustainability is the same, independently of the diversity of situations found in the different farms on the studied region. Each indicator is valued separately and assigned with a value between 1 and 10, according to the assessment of the level of each indicator (1 being the least desirable value, 5 a moderate or threshold value and 10 the most preferred value). For instance, in the case of the soil structure indicator, a value of 1 is given to a dusty soil, without visible aggregates; a value of 5 to a soil with some granular structure whose aggregates are easily broken under soft finger pressure; and a value of 10 to a well structured soil whose aggregates maintain a fixed shape even after exerting soft pressure . Values between 1 to 5 and 5 to 10 can also be assigned accordingly.

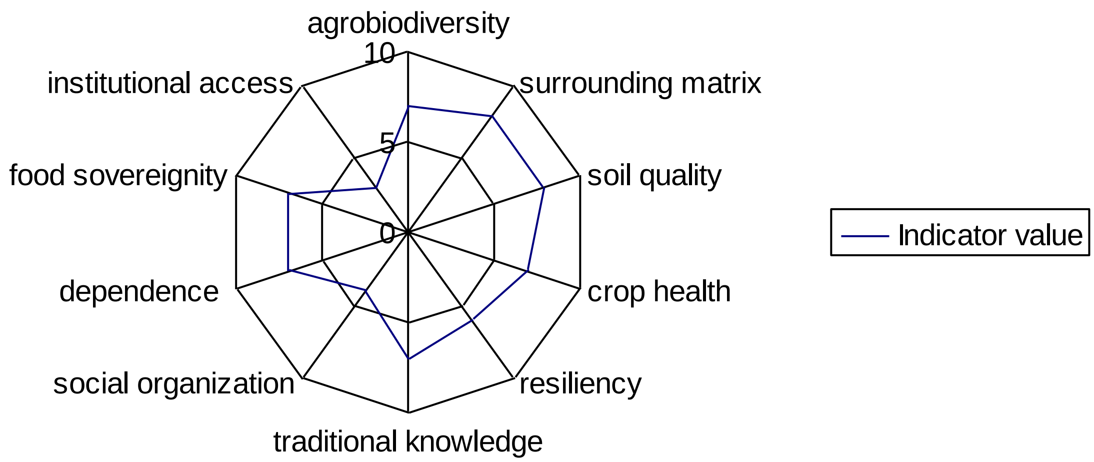
Farms with an average indicator value lower than 5 are considered below the sustainability threshold, and rectifying measures should be taken to improve the indicators with low values in the farm being assessed. The indicators are more easily observed by using an amoeba type graph as it allows one to visualize the general status of each indicator in relation to the threshold value of 5, considering that the closer the amoeba approaches the full diameter length of the circle the more sustainable the system is (a 10 value). The amoeba shows which indicators are weak (below 5) allowing farmers to prioritize the agroecological interventions necessary to correct soil, crop or system deficiencies.

Table 2 shows the values obtained from the RASA assessments. Figure 2 depicts an amoeba, showing that most indicators (except institutional access to markets, credit and extension) exhibited values above the threshold of 5.

Table 2 Agroecological indicator values obtained from the RASA assessment in the RFC systems

agrobiodiversity	7
surrounding matrix	8
soil quality	8
crop health	7
resiliency	6
traditional knowledge	7
social organization	4
dependence	7
food sovereignity	7
institutional access	3

Figure 2. Amoeba representing indicators at RFC systems



The group arrived at these values after making the observations or holding group discussions on each indicator being assessed and then agreeing on the criteria for giving each indicator a particular value. To arrive at the values the group took seriously into account the observations that farmers made on each indicators. Following are some of the criteria (descriptors) that farmers used for the assessment of various indicators:

<u>Agrobiodiversity:</u>
Higher values given if > 3-4 rice varieties per field and more local than modern varieties.
Higher values if > number of fish species and if fish move as they aerate rice plants and control insects.
Density of azolla (high values if sparse- fish can eat, low value if dense-sign of eutrophication)

<u>Surrounding matrix</u>
Higher values if fields surrounded by forests . According to farmers forests are key for water conservation and abundance in fields.

<u>Soil quality</u>
Higher value to soils with lots of aggregates and that are not compacted, that have been heavily manured and rice straw incorporated into soil.

<u>Crop health</u>
Higher value to plants that exhibit green foliage, with leaves not easily broken, without signs of disease or insect attack.

<u>Resiliency</u>
Higher values to farms that have high rice varietal diversity, presence of fish and with good water and soil management. Some farmers also mentioned yield variation, risk of crop loss and food self sufficiency in variable years as key criteria for estimating resiliency

Traditional knowledge
Higher values to farms where farmers still preserve old cultural management techniques such as planting crops in terrace mounds, making and adding compost, using ancient local varieties,etc

Social organization
Most farmers rated low this indicator as they plant and tend their fields individually and rarely conduct farming activities collectively

Dependence
Most farmers continue using their own seeds, recycle rice straw and manure from pigs and ducks for soil fertility. Most farmers don't use agrochemicals.

Food sovereignty
< than 20% of the food consumed by families comes from outside the farms. In larger terraces farmers grow vegetables and/or practice rotations of rice and vegetables. Many grow vegetables in the terrace mounds.

Institutional support
Most farmers have little access to credit, extension, information and markets. Less than 30% of the rice and fish are sold outside of the province. At times dry fish is marketed abroad.

Although soil quality, crop health and agrobiodiversity exhibit values higher than 5, they could be improved. Despite the level of rice genetic diversity in the farms, most farmers grow 2-3 varieties including at least one modern variety. The diversity of other crop species grown is relatively low in such farms, thus increasing the number of crops species that could be grown in rotation with rice, or in adjacent plots (potatoes, garlic, other vegetable crops) is desirable to improve the value of this indicator. Soil quality could be improved adding composted organic matter to the soil or by growing green manure crops in rotation with rice. Such practices could make systems even more independent from costly fertilizers. Crop health could be improved as soil health improves but also by increasing plant species and genetic diversity. Resiliency is also linked to crop diversity and soil quality. By enhancing crop and fish diversity, in the case of extreme weather certain crops or varieties may fail and others withstand such shock. Enhanced agrobiodiversity is also essential for improved food security. Although during the visit it was evident that the community holds strong social ties, there seems to be no tradition of collective work in the fields. Sharing labor and knowledge could lead to better livelihood outcomes. A strong social organization could prove key to improve marketing and for demanding better government services (credit, technical assistance, market contacts, etc).

As interventions to improve the indicators are deployed, the impact of such interventions can be evaluated at the household level by defining indicators that address the following questions:

- do they enhance family's nutrition and health?
- do they regenerate and conserve soil, and increase (maintain) soil fertility?
- do they conserve and encourage agrobiodiversity?
- do they prevent pest and disease outbreaks?
- do they increase food production and contribute in attaining food security?
- do they improve the family's income ?
- do they maintain agricultural production under variable years?
- do they reduce investment costs and farmers dependence on external inputs?
- are they conducive to increasing the degree of farmers organization?
- Do they increase human capital formation?

Box 1 The agroecology of RFC systems in China

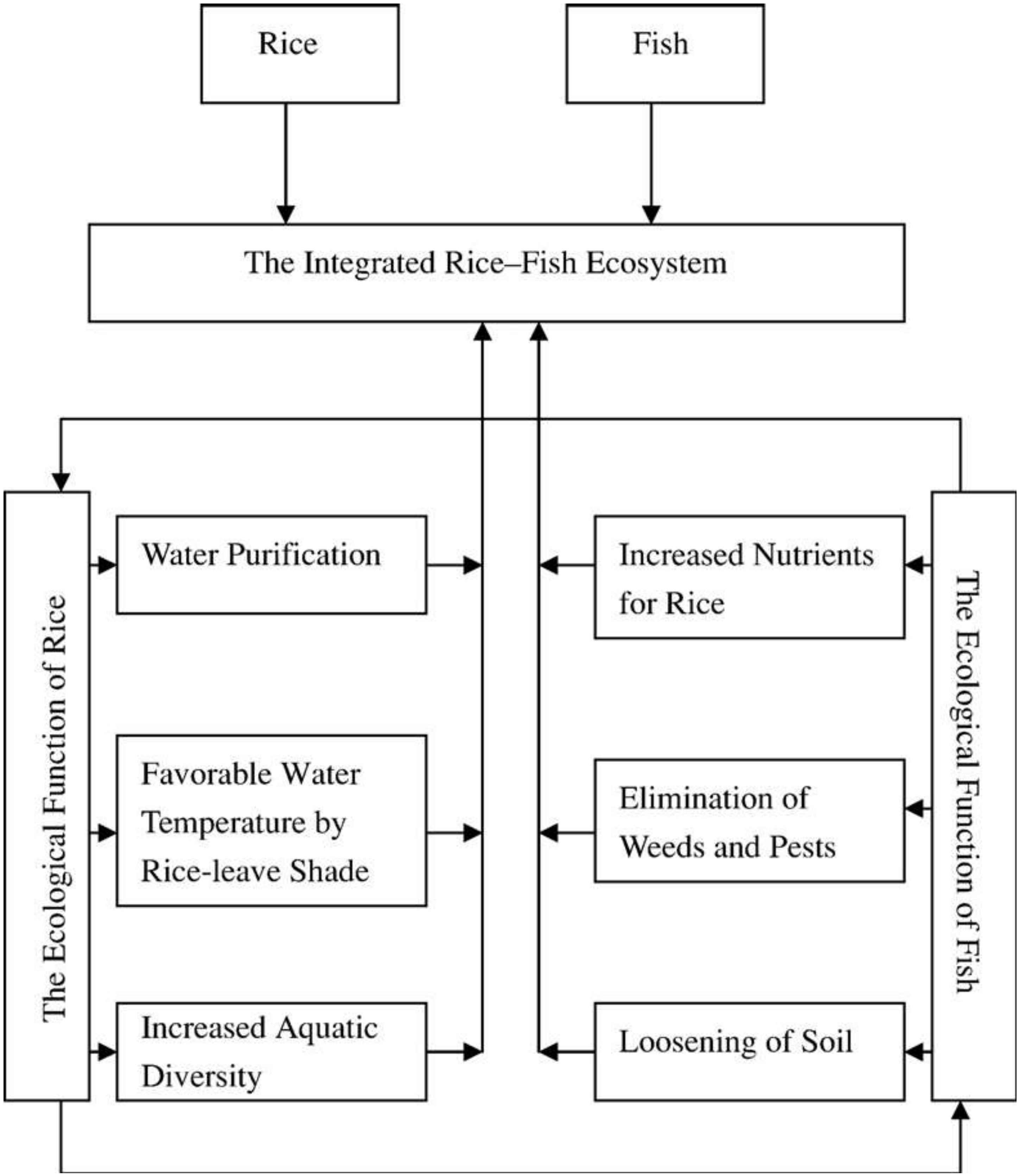
In comparison with modern, high-input rice production, rice–fish culture requires different varieties of rice, varieties with thick stalks and big leaves, strong resistance in lodging and a longer growth cycle. These systems contribute to the conservation of the local rice species, such as *Oryza sativa indica*, *japonica* and *javanica*, and thus to the maintenance of genetic diversity of rice.

The main species present in the RFC system include rice, fish, weeds, plankton, photosynthetic bacteria, aquatic insects, benthos, rice pests, water mice, water snakes, birds, soil bacteria and aquatic bacteria engaged in complex ecological interactions (see diagram). In China, fish that are usually seen in this system include *Ctenopharyngodon idellus, Cyprinus carpio* (Feng carpio, Heyuan carpio, Oujiang red carpio), *Carassius auratus* (silver Carasius auratus), *Tilapia nilotica, Mylopharyngodon piceus*, *Hypophthalmichthys molitrix*, *Mysgurnus anguillicaudatus*, *Oreochromis niloticus* and *Barasilcorus asotus*. *Cyprinus carpio*, an omnivore, can lay eggs under natural conditions in ponds or lakes, making it easy for farmers to collect them. This is the reason why Cyprinus carpio is the main fish species used in rice–fish systems. Oujiang red carp is an indigenous species that is found in the southern mountainous regions of Zhejiang province, such as Qingtian County.

In this integrated RFC ecosystem, rice provides shade for fish, especially in summer when the water temperature in the field can be lowered to a certain extent. The decaying leaves of rice offer favorable conditions for the multiplication of microorganisms, which are the main fish feed. Fish, on the other hand, help to loosen the surface soil on which rice is planted, bringing about increased permeability and oxygen content of the soil, as well as enhanced vitality of microbes. Thus, the decomposition of nutrients in the soil is quickened, making it easy for rice to absorb. Fish make another contribution by preying on pests and weeds. Moreover, their excreta serve as both a natural fertilizer for rice and enrichment for soil. The bio-control of rice pests is one of the prominent features of rice–fish farming. Researchers have reported a low incidence of insect pests and plant disease occurred in rice–fish integrated farming compared with monoculture rice farming, showing that fish play an effective role as a bio-control agent against rice pests. Several reports have pointed to the fact that, in RFC systems, fish can prey on the rice plant hopper, the rice leaf hopper, *Naranga aenescens* , the rice leaf roller, and on *Parnara guttata* on the water surface, especially omnivorous fish such as *Tilapia nilotica* and *Cyprinus carpio*. As a result, the use of pesticides in rice–fish systems is substantially reduced to almost none. The natural enemies of rice pests in the system, such as spiders and parasitic wasps, have shown a considerable increase in RFC systems.

In China, azolla is added to the rice–fish system. The annual pure nitrogen that is fixed by azolla is 243–402 kg/ha. The content of coarse protein in azolla is as high as 25%, making it the ideal fertilizer for rice and feed for animals. In RFC systems, azolla is used to feed fish, the excreta of fish to fertilize the soil and the enriched soil to promote the growth of rice. The nitrogen that is fixed by azolla is the main source of nitrogen circulating in the system.

Source: Lu, J and X.Li 2006 Review of rice-fish-farming in China- one of the globally important ingenious agricultural heritage systems (GIAHS). Aquazulture 260: 106-113


Rice
Fish
The Integrated Rice–Fish Ecosystem
The Ecological Function of Rice
Water Purification
Favorable Water Temperature by Rice-leave Shade
Increased Aquatic Diversity
Increased Nutrients for Rice
Elimination of Weeds and Pests
Loosening of Soil
The Ecological Function of Fish