FAO RICE CONFERENCE 04/CRS.17

February 2004

E

منظمة الأغذية والزراعة للأمم المتحدة

联合国粮食及农业组织

Food and Agriculture Organization of the United Nations

Organisation des Nations Unies pour l'alimentation et l'agriculture

Organización de las Naciones Unidas para la Agricultura y la Alimentación

FAO RICE CONFERENCE

Rome, Italy, 12-13 February 2004

TRADITIONAL RICE FISH SYSTEMS AND GLOBALLY INDIGENOUS AGRICULTURAL HERITAGE SYSTEMS (GIAS)

By:

Parviz Koohafkan
Chief

and

José Furtado
Consultant

Land and Plant Nutrition Management Service
FAO

Rome, Italy

TRADITIONAL RICE FISH SYSTEMS AS GLOBALLY IMPORTANT INGENIOUS AGRICULTURAL HERITAGE SYSTEM (GIAHS)

Prepared by Parviz Koohafkan[1] and José Furtado[2]

ABSTRACT: This paper is prepared for the **FAO Rice Conference on Sustainable Rice-based Production Systems: Challenges and Opportunities**. It describes the traditional rice fish systems as globally important ingenious agricultural heritage of the man kind in view of its outstanding contribution to food and livelihood security, its importance in term of biological diversity and genetic resources, landscape diversity, aesthetic beauty and cultural values and other ecosystem goods and services as well as the indigenous knowledge of land and water management developed to address harsh biophysical and socio-economical constraints. Rice-fish systems provide grain, protein (animal but also vegetable); biodiversity; efficient water use and nutrient cycling and retention; flood control and adaptive management practices to mitigate local climate variation and climate changes. They are also important to address global environmental issues such as climate change (emission of greenhouse gas in rice field is determined by farming practices, plant metabolism and soil properties; rain fed systems tend to contributed less emissions than irrigated systems), shared waters (retaining flood waters in shared catchments and river basins) and biodiversity (both rice ecotypes and fish species). Rice-fish systems are globally distributed with the expansion of rice production. However, they have been developed mainly in Asia and historical data reports their existence in Southeast Asia for over 6,000 years ago (Ruddle 1982).

I. GLOBALLY IMPORTANT INGENIOUS AGRICULTURAL HERITAGE SYSTEMS(GIAHS); DEFINITION AND EXAMPLES

In many countries specific agricultural systems and landscapes have been created, shaped and maintained by generations of farmers and herders based on diverse species and their interactions and using locally adapted, distinctive and often ingenious combinations of management practices and techniques. Building on dynamic local knowledge and experience, these ingenious agri-"cultural" systems reflect the evolution of humanity, the diversity of its knowledge, and its profound harmony with nature. They have resulted not only in outstanding aesthetic beauty, maintenance of globally significant agricultural biodiversity, resilient ecosystems and valuable cultural inheritance but, above all, in the sustained provision of multiple goods and services, food and livelihood security and quality of life.

Globally important Ingenious Agricultural Heritage Systems (GIAHS) are defined by FAO as:

Remarkable land use systems and landscapes, which are rich in biological diversity evolving from the ingenious and dynamic adaptation of a rural community to its environment, in order to realise their socio-economical, cultural and livelihood needs and aspirations for a sustainable development.

---

[1] Chief Land and Soil Fertility Management service, FAO, Rome
[2] Retired World Bank Expert, Consultant, UK

GIAHS throughout the world testify the inventiveness and ingenuity of people in their use and management of biodiversity, inter- and intra-species dynamics, and the physical attributes of the landscape, codified in traditional but evolving knowledge, practices and technologies. Ingenious agro-ecosystems reflect human evolutionary transitions intimately linking socio-cultural systems with biophysical systems. They use traditional knowledge systems, 'trial-and-error' and experimental learning, insight and innovations. Their ingenuity has resulted in resilient agro-ecological systems in marginal, extreme or very specific ecologies. These systems are organised and managed through highly adapted social and cultural practices and institutions. Some examples are illustrated in Annex 1.

Such agricultural systems can be found, in particular, in highly populated regions or in areas where the population has, for various reasons, had to establish complex and innovative land-use/ management practices e.g. due to geographic isolation, fragile ecosystems, political marginalisation, limited natural resources, and/or extreme climatic conditions. These systems reflect often rich and sometimes unique agricultural biodiversity, within and between species but also at ecosystem and landscape level. Having been founded on ancient agricultural civilisations, certain of these systems are linked to important centres of origin and diversity of domesticated plant and animal species, the in-situ conservation of which is of great importance and global value. The commonality among such systems includes: (a) the ecosystem resilience and robustness that has been developed and adapted to cope with change (human and physical) so as to ensure food and livelihood security and alleviate risk and (b) the human management strategies and processes that allow the maintenance of biodiversity and essential ecosystem services (water recharge and quality, nutrient recycling, soil conservation, pest control, etc.) while generating livelihoods and quality of life.

These systems, however, often face great challenges in adapting to rapid environmental and economic change and new and sometimes inappropriate policy environments, particularly in the contexts of conflicting land tenure systems, increased climate variability and land degradation, and economic and cultural globalisation. To survive and to continue to evolve, they must also be enabled to increase their productive capacity, to find their comparative advantage and "niche markets" to meet the rising expectations of their members, in terms of food security and quality of life.

The traditional rice fish system is one of the outstanding examples[3] of these globally important agricultural heritages of the man kind which needs the attention of global community in view of its multiples benefits.

RICE-FISH SYSTEMS, DEFINITION AND EXTENT

Rice is the dominant staple crop of tropical Asia with a long history of domestication, and has a rich diversity of cultivated ecotypes based on three varieties of Oryza sativa: indica, japonica and javanica. There are four basic rice agro-ecosystems each with particular edaphic

[3] See other examples of GIAHS in annex 1

conditions: irrigated ecosystems, upland (terraces), and lowland rain fed ecosystems, and flood-prone (very deep water) ecosystems. Fish culture in these systems is concurrent or rotational with rice, and at four intensities: traditional (capture), low intensity culture (no fertilization and feed), medium intensity (fertilization but no feed), and high intensity (fertilization and feed). Rice-fish culture enhance both rice and fish production, but production is most at low-medium intensities although the fish diversity is most in traditional and low intensity systems. Less than 1% of rice fields are used for fish culture probably due to risk aversion among peasant farmers interested in securing domestic consumption, in the face of some serious information, institutional, infrastructure and policy constraints. Rice-fish farming is innovative and adapting to changes in rice farming. They are important in terms of the global environment in producing greenhouse gases, containing low-moderate biodiversity with higher levels especially in traditional and low intensity systems, and retaining flood waters importantly in shared catchments and river basins. However, they are highly dependent on husbandry practices for biotope preparation, nutrient and water inputs and replacements, and for managing persistent physical and biotic failures. Rice-fish systems address some biotic failures such as weed and pest control.

Rice-fish farming systems co-evolved with wet rice cultivation in Southeast Asia over 6,000 years ago (Ruddle 1982), and are a sustainable form of agriculture (Heckman 1979; Kurihara 1989), providing invaluable protein especially for subsistence farmers managing rainfed systems. Traditional rain-fed (lowland and upland), flood-prone (deep water) and irrigated rice agro-ecosystems culturing indica and javanica rice varieties in tropical Asia and lend themselves for fish culture when water depths of 0.5-3.0 m occur in entire rice fields. However, optimization of rice fields for HYV production requiring shallow (5 cm) water has required structural changes to fields for fish culture, in the form of deep channels, trenches, drains or sump ponds within these fields or ponds adjacent to them. Rice-fish farming has been recorded in tropical and sub-tropical Asia over the past 150 years, and its combined production has been propagated most intensely over the past 15-20 years, coinciding with international emphasis on food production and security for a rapidly growing human population (Fernando 1993a). Transforming wetlands and rice fields for rice-fish production tend directly to benefit food production and income, and farm integration (Lightfoot, Bimbao, Dalsgaard and Pullin 1993). A rich variety of direct and mainly indirect beneficial and non-beneficial effects emanate from the interactions between rice and fish (Table 3), with many indirect non-beneficial effects exacerbated by intensification of rice-fish production.

There are basically two types of rice-fish farming systems in Asia, concurrent (or mixed) and rotational, each with four intensities of production: traditional (or 'capture' with wild fish 'seed') and low, moderate and high intensity with cultured fish 'seed' (dela Cruz, Lightfoot, Costa-Pierce, Carangal and Bimbao 1992). Fish stocking in these systems may range from <500 to 5,000 fish/ha in the high intensity systems with about 3,000 fish/ha being optimal (dela Cruz et al., 1992; Welcomme and Bartley 1998). More than 100 fish species are captured or cultured in fresh and brackish-water rice fields in Asia in varying combinations(dla Cruz et al., 1992; Ghosh 1992; Hasan 1990; Heckman 1979; Islam 1983; Newman-Meusch 1996), which constitute about two-thirds of fish species used in aquaculture (Williams 1997). More fish species are cultured in lowland humid tropical than in temperate or montane rice fields, and in freshwater than brackish water rice fields. The number of fish species cultured in any rice-fish system depends on the intensity of production, with about a dozen species in capture and low intensity systems and 1-2 species in highly intensive systems.

Intensive culture of rice and fish appears difficult for most peasant farmers producing rain-fed rice due to several factors, such as uncertainty in annual monsoon fluctuations and fish 'seed' supplies, the primary objectives of food provision and income generation in developing economies, the potential of accidental grazing on rice seedlings by herbivorous fish fingerlings when introduced too early in the cycle, and the bioaccumulation of pesticides and heavy metals in fish.

III. GLOBAL IMPORTANCE OF RICE-FISH FARMING SYSTEMS

Rice fish farming systems are globally important in terms of food production; and appear to be globally important in terms of three global environment issues: climate change, shared waters, and biodiversity. Methane is a major greenhouse gas emitted by rice fields, with emission determined by farming practices, plant metabolism and soil properties. Irrigated systems tend to contribute more emissions than rain-fed systems; however, there is poor knowledge on the effects of crop management practices, inputs used, varieties and cultivars used, and of fisheries integration on methane emissions for the application of appropriate mitigation measures, and the subsequent design of trade-offs between mitigation measures and rice and fish production (Ranganathan, Neue and Pingali 1995). Irrigated rice-fish systems are therefore of major concern for climate change; and, even though they may be under some form of public or private management, they need a subsidy for generating the information required for mitigation measures. There is scope for considering the applicability of global environmental subsidies from the Global Environment Facility for generating this information where national developing economies are unable to allocate them the desired priority. They are also innovative agricultural systems, with a variety of local designs adapted for cultural attributes, appropriate rice and fish species for husbandry, different kinds of water resources availability, timing and drainage, natural and artificial nutrient inputs for growth, biological and chemical control of pests and diseases, and for edaphic soil and water conditions. From a biodiversity perspective, rice-fish farming systems embody low-moderate rice genetic diversity due to intense varietal selection primarily for yields, and secondarily for system maintenance and economic viability; moderate-high fish species diversity for some protein production of secondary importance especially in subsistence production systems, and the low or no selection of varieties within species; and low-moderate aquatic biotic diversity due to transformation of complex swamp systems into simple agro-ecosystems (Fernando 1966). Fish species and aquatic biodiversity appear richer in traditional and low intensity rain-fed than in high intensity irrigated rice-fish systems. The adequacy of this biodiversity for different ecosystem functions, as in agro-ecosystems in general (Main 1999), needs careful examination in terms of the global environment in comparison to natural swamp ecosystems

IV. THREATS AND CHALLENGES TO RICE FISH FARMING SYSTEMS

Rainfed rice-fish farming systems are threatened by excessive application of chemicals, particularly pesticides, intensification of rice cultivation for basic staples for a growing human population, by intensification of mono-species fish culture, and by modern irrigation systems. For example, the rice-fish farming area in China had increased from 667 thousand hectors in 1959 to 985 thousand hectors in 1986 and 1532 thousand hectors in 2000[4]. However, it has decreased from 1532 thousand hectors in 2000 to 1528 thousand hectors in 2001 and 1480 thousand hectors in 2002. The management of rice-fish faming

[4] Ministry Of Agriculture of China, unpublished fishery state, 2003.

needs more labour and village cooperation than the mono rice production. A survey in Jiangsu province showed that half of farmers who adopted rice-fish farming technologies in 2002 would prefer growing single rice or other crops rather than rice-fishing farming in 2003. Some farmers claimed that if they dig the same area of rice field as a fish pond, they would make more money than the rice-fish farming. Some farmers who used to practice rice-fish farming reported that they prefer buying fishery products in markets to raising fish in their rice fields. The additional labour for managing the rice-fish systems costs nearly same as the values of fish products they produce. For fish to reach the marketing size, farmers often need to raise fish in the pond or rice field after rice is harvested. This competes for land and labour, which are increasingly scarce in rural China. However, the food safety, ecological functions and environment conservation as well as other ecosystem goods and services of rice fish farming systems are seriously undervalued. With multiple livelihood and ecological values listed above, the traditional rice-fish systems are a remarkable model of the biodiversity-enhancing agriculture.

V. POLICIES AND ACTIONS TO REVERSE DEGRADATION OF RICE-FISH SYSTEMS

With multiple livelihood and ecological values listed above, the traditional rice-fish system is a remarkable model of the biodiversity-enhancing agriculture system. There is potential to build on this heritage for balancing the shortcomings of the chemicals-based agriculture and developing ecosystem approaches to managing wetlands and flood plains. Support and collaboration from local communities, local and national governments for demonstrating these systems as GIAHS, is confirmed in China, Philippines and elsewhere in Asia.

Public care for food safety and ecological conservation is now being addressed through policies on monitoring, eco-labelling (Green Food/Organic Food Programs) and eco-agriculture. In addition, ecotourism on agricultural landscape is also being promoted. There is good potential to integrate the traditional rice-fish culture into those new policy changes.

On the other hand, much has to be done to identify and remove inappropriate policies, institutions, and technologies that encourage shifting rice-fish systems to intensive mono rice or fish systems.

Incorporating rice-fish culture in IPM programs and creating a favourable environment for aquatic organisms in rice fields seem to be far more promising than any further refinement of fish culture techniques. In the Philippines, many farmers reported that once they stopped spraying with pesticides, fish returned to their rice fields, reducing the need to stock fingerlings. Since IPM programs often cover entire villages, the danger of fish poisoning from adjacent fields is minimized (IDRC, 2003). The extension of the system has potential to reducing use of POPs in agriculture.

Major actions

- Document changing patterns of the traditional rice-fish system;
- Evaluate impact of policies, institutions and technologies on farmers' practices of the rice-fish systems and identify those policies, institutions and technologies that encourage specialization of rice or fish production.
- Set up representative demonstration sites/villages through partnership between local communities, government and CSOs;
- Identify and demonstrate successful adaptations to social-economic changes, and explore the multiple values of the rice-fish system in the food safety, eco-agriculture, eco-tourism and ecological conservation.
- Develop networking on conservation and sustainable management of the rice-fish system among communities, local governments, and CSOs.

VI. CONCLUSIONS

Traditional and low intensity rice-fish systems appear interesting in terms of aquatic biodiversity conservation from a global environmental perspective. However, rice-fish systems function within a matrix of farming systems which, in turn, lie within catchments and river basin dynamics. At the catchments and river basin levels, shared waters become potentially important in terms of quantity and quality to sub-national and/or national jurisdictions. These qualities are determined by biodiversity, among others. The adequacy of biodiversity at the genetic and species levels, and at the farm, catchments and river basin level, needs to be assessed against design goals, adequacy measures, and potential risks. Hitherto, few such integrated assessments of rice fields or rice-fish farming systems has been conducted as in Lake Biwa, Japan, where there is a net outflow of nutrients from rice fields into the lake (M. Nakamura, personal communication). Traditional and low intensity rice-fish farming systems are important for aquatic biodiversity conservation at least at the catchments and drainage basin levels; and could potentially qualify for global environmental subsidies from the Global Environment Facility, especially where private sector interests would favour intensive irrigated production systems and the public sector in developing economies would be unable to allocate such systems and their integrated assessments a high priority. At the meso and macro-levels, it would be necessary to assess the linkages and effects of sector and macro policies on, and the regulatory, market-based and participatory (institutional) instruments critical for developing new partnerships for ensuring rice-fish systems sustainability and biodiversity conservation.

Rice-fish farming can be a low-cost, low-risk option for poor rice farmers in rice-farming countries, including Malawi, Bangladesh, China, India, Indonesia, Korea, Laos, Madagascar, Malaysia, the Philippines, Thailand, Cambodia, and Vietnam(IDRC, 2001).

Table 1: Rice Ecosystem Distribution in Agro-ecological Zones in Asia

Agro-ecological Zones	Rice Crop Area (M ha)	Rice Area in Ecosystems (%)			
		Irrigated	Rainfed Lowland	Rainfed Upland	Flood-prone
(A) Warm Tropics:					
Semi-arid	9.68	75.0	12.4	10.8	1.8
Sub-humid	28.94	23.3	53.9	10.6	12.1
Humid	44.52	42.2	32.0	10.3	15.5
(B) Warm Sub-tropics:					
Semi-arid	7.47	99.7	0.0	0.3	0.0
Sub-humid	23.91	76.6	13,8	5.2	4.4
Humid	18.35	92.1	6.4	1.5	0.0
(C) Cool Sub-tropics	0.4	100.0	0.0	0.0	0.0
TOTAL	133.27	56.9	26.7	7.7	8.7

Source: Garrity, Singh and Hossain (1996)

Table 2: Impacts of Wetlands Transformation for Rice and Rice-Fish Culture

Resource Attributes	Impacts of Wetland Transformation		
	Natural Wetland	Wet Rice System	Rice-Fish System
Land & Water Use	Not used productively	Used productively for rice only	Used productively for rice-fish culture
Resource or Enterprise Integration	Integrated natural systems	Non-integrated resource systems or farm enterprises	Fish ponds linking & integrating resource systems & farm enterprises
Recycling of Organic Residues Crop residues, Manure	Organic matter recycled naturally	Organic residues not recycled	Organic residues recycled in rice-fish ponds & on land
Water Management	Water stored & purified especially during floods	Water shortage potentially late in dry season Household reliance	Ponds providing water during dry season Ponds serving as water catchments for

		on uncertain water supplies	domestic & livestock supply
Vegetable / Home Gardens	Natural aquatic vegetation gathered selectively	Vegetable / home gardens: - Experience water shortage late in dry season - Earn modest income	Vegetable / home gardens: - Receive irrigation water in dry season from ponds - Earn higher incomes
Soil Fertilisation	Natural soil fertilization through nutrient decomposition & recycling	Reliance on chemical fertilizers for crop production Over-use of exhausted soils	Reduced use of chemical fertilizers Use of nitrogen-fixing plants like Azolla Organically enriched pond mud as fertilizer
Fish Consumption	Fish captured at low intensity	Fish captured traditionally Fish purchased for food	Fish harvested from rice fields Fish providing additional income Fish purchase for food rare since supply abundant
Household Food & Income	Marginal provision of subsistence food	Providing rice but no fish Income from rice	Providing rice & fish for food Rice & fish providing additional income
Rice Culture	None	1 rain-fed crop per year	1-2 crops of rice & fish per year
Farm Income & Integration	None	Modest income before IRM	Increased income in spite of droughts & devaluation

Source: Adapted from Lightfoot, Bimbao, Dalsgaard and Pullin (1993).

Table 3: Direct and Indirect Effects of Interactions in Rice-Fish Systems

Types of Effects	Nature of Effects	
	Beneficial	Non-Beneficial [1]
Direct	Water use for rice & fish Space use for rice & fish Most nutrients (NPK) used by rice & fish N-fixation by Azolla for rice Predation on insect pests by fish Grain production enhanced Fish production enhanced [3]	Solar radiation captured by surface aquatic weeds [2] Nutrient uptake (NPK) by aquatic weeds [2] Rice seedlings grazed by fish
Indirect	Rice providing shade for fish Aquatic fauna & flora benefiting rice Organic matter produced by rice used by fish Aquatic soil microbes benefiting rice & fish Water oxygenation by fish benefiting rice Organic decomposition benefiting fish Nutrient recycling benefiting rice Lower fish prices due to fish production Access to cheap protein from fish production Employment & income diversification Production, marketing, processing, etc. diversification	Space for rice production reduced Accidental grazing of rice seedlings by herbivorous fish [4] Soil & water salinisation [5] from water use affecting rice Noxious gases (CH_4, NO_2) [6] released by anaerobic decomposition Weak system resilience due to low system complexity & biodiversity (both aquatic & terrestrial) Iron (Fe) toxicity in acid sulphate soils [7] Leakages through clay pan [8] by heavy machinery use Bioaccumulation of rice pesticides in fish Accidental release of introduced exotic species affecting natural ecosystems

Note:

Non-beneficial effects could be deleterious or competitive

Many competitive effects with rice do not concern fish per se, such as those of autotrophic algae (e.g. green and blue-green) and especially aquatic weeds (e.g. Salvinia, Hydrilla)

Fish form an important protein source especially for small-holders and poor farmers

Caused by excessive floods in adjacent wetlands

Caused by leaching of subsurface salts or accidental inflow of tidal waters

By-products of organic decomposition in anaerobic waters
Caused by changes in redox potential
Caused by use of heavy industrial machinery

Table 4: Potential for Rice-Fish Farming in Asia

Country	Ricefield Area (10^3 ha)			Rice-Fish Area (10^3 ha)	
	Rainfed	Irrigated	Total	Present	Potential
Bangladesh	9,002	1,227	10,229	?	615
China	2,296	30,902	33,198	986	5,000
India	26,644	14,349	40,993	?	2,000
Indonesia	3,659	6,230	9,889	94	1,570
Korea	111	1,118	1,229	<1	127
Malaysia	220	427	647	?	120
Philippines	1,953	1,473	3,426	1	181
Thailand	8,065	1,313	9,378	?	254
Vietnam	3,415	2,276	5,691	?	326
TOTAL	55,365 (48%)	59,315 (52%)	114,680 (100%)	?1,082 (?1%)	10,193 (9%)

Note: ? = No data available
Source: Lightfoot, Costa-Pierce, Bimbao and dela Cruz (1992).

Table 5: Some Constraints to Rice-Fish Culture Systems in Asia

Areas		Knowledge & Skills Constraints
Science & Information	Ecology	Agro-climatic features & ecosystem dynamics in different topographic, edaphic & cultural conditions Trophic dynamics, productivity & nutrient cycling Efficiency of rice-fish systems
	Soil Management	Soil quality Amelioration of poor soils, & fertilization
	Water Management	Natural flood cycles, irrigation & water management Water quality & monitoring, Wastewater uses
	Fish Species	Indigenous & exotic species, stocking rates and size, & species associations Compatibility of natural recruitment with cultured stocks Optimal growing & harvesting conditions for fish
	Fish Predators & Parasites	Predator & parasitic species causing losses Cost-effective treatment regimes
	Rice	Rice varieties, planting regimes & productivities for different fish species & culture (concurrent or rotational) combinations
	Rice Pests & Diseases	Pest control by predators and/or pathogens Integrated pest management (IPM) Effects of pesticide 'cocktails; on fish cultured for markets
	Farming Systems	Performance of & innovations in rice-fish farming systems Technologies especially for acidic & saline soils
	Economics	Data collection & economic analyses Profitability & cost-effectiveness
	Sociology	Natural aptitude, education & training Cultural attributes
Institutions	Governance	Farmers associations & cooperatives Land owners & ownership patterns Local administration, ombudsmen, & conflict resolution Information transparency
	Water	Water users association for equitable distribution

Areas		Knowledge & Skills Constraints
	Fish	Fish fry suppliers, producers & market traders Availability of ‘seed’ fish at the time & place required
	Rice	Rice seed suppliers, producers & market traders
	Labour	Hired labour & mechanization
	Agri-business	Fish & rice processors for markets Agricultural inputs suppliers, & extension services Security for fish price against theft, pests & natural hazards
	Markets	Market retailers & wholesalers, & mechanisms Market prices for differentiated commodities Consumer preferences for differentiated commodities
	Credit	Credit & financing for farming system especially small-holders & tenant farmers
Infrastructure	Rice Field	Design & engineering of dykes, rice beds, trenches/channels, sump/collection ponds, gates, etc. for different topographies and culture conditions for optimising rice & fish production
	Support Facilities	Communications & transport infrastructure for market access Freezer & storage infrastructure for marketing products ‘Open’ functioning of markets

Source: Based on dela Cruz, Lightfoot, Costa-Pierce, Carangal and Bimbao (1992).

REFERENCES:

1. Bachelet, D. and M.J. Kropff, 1995. The impact of climatic change on agroclimatic zones in Asia.
2. Bhuiyan, S.I., 1992. Water management in relation to crop production: Case study on rice. Outlook in Agriculture, 21(4): 293-299
3. Catling, D., 1992. Rice in Deep Water. 542 pp. International Rice Research Institute. London: Macmillan Press
4. Chang, Te-Tzu, 1987. The impact of rice on human civilization and population expansion. Interdisciplinary Science Reviews, 12 (1): 63-69
5. Dela Cruz, C.R., C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao, eds., 1992. "Rice-Fish Research and Development in Asia", eds., 457 pp. Manila: International Centre for Living Aquatic Resources Management
6. Dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao. ICLARM Conference Proceedings, 24: 457 pp. Manila: International Center for Living Aquatic Resources Management Grist, D.H., 1965. Rice. 5th Edition. 601 pp. London: Longmans Group
7. David, C.C., 1991. The world rice economy: Challenges ahead. pp. 1-18 in "Rice Biotechnology", eds. G.S. Khush and G.H. Toenniessen. International Rice Research Institute. Wallingford, UK: CAB International
8. Edwards, P., D.C. Little and A. Yakupitiyage, 1997. A comparison of traditional and modified inland artisanal aquaculture systems. Aquaculture Research, 28: 777-788
9. Fernando, C.H., 1996. Ecology of rice fields and its bearings on fisheries ands fish culture. pp. 217-237 in "Perspectives in Asian Fisheries: A Volume to Commemorate the 10th Anniversary of the Asian Fisheries Society", 497 pp., eds. Sena S. de Silva. Makati, Metro Manila: Asian Fisheries Society
10. Fernando, C.H., J.I Furtado and R.P. Lim, 1979. The aquatic fauna of the world's rice fields. Wallaceana (University of Malaya, Kuala Lumpur), 2: 105 pp.
11. Fish Culture in Rice fields: Rice–Fish Symbiosis, in Mackay, T. Kenneth (editer), Rice-Fish Culture in China. IDRC. 1995.
12. Furtado, J.I. and S. Mori, eds., 1982. Tasek Bera. The Ecology of a Freshwater Swamp. The Hague: Junk Publishers
13. Garrity, D.P., V.P. Singh and M. Hossain, 1996. Rice ecosystems analysis for research prioritisation. Ch. 3, pp. 35-58 in "Rice Research in Asia. Progress and Priorities", 418 pp., eds. R.E. Evenson, R.W.
14. Ghosh, A., 1992. Rice-fish farming in India: past, present and future. pp. 27-43 in "Rice-Fish Research and Development in Asia", 457 pp., eds. C.R.
15. Halwart, M., 1994. Fish as Biocontrol Agents in Rice: The Potential of Common Carp, Cyprinus carpio, and Nile Tilapia, Oreochromis niloticus. 169 pp. PhD Thesis, Hohenheim University, Stuttgart
16. Weikersheim: Margraf Verlag

17. Hasan, M.R., 1990. Aquaculture in Bangladesh. pp. 105-139 in “Aquaculture in Asia”, 396 pp., eds. M. Mohan Joseph. Mangalore: Asian Fisheries Society (Indian Branch)

18. Heckman, C.W., 1979. Rice Field Ecology in Northeastern Thailand. The effect of wet and dry seasons on a cultivated aquatic ecosystem. Monographiae Biologicae, 34: 228 pp. The Hague: Junk Publishers

19. Herdt, R.W., 1991. Research priorities for rice biotechnology. Pp. 19-54 in “Rice Biotechnology”, eds. G.S. Khush and G.H. Toenniessen. IRRI. Wallingford, UK: CAB International

20. IDRC, 20003, Rice-Fish Culture, Website: info@idrc.ca

21. IRRI, 1984. Terminology for Rice Growing Environments. Los Banos: International Rice Research Institute Islam, M. A., 1983. A Report on Aquatic Culture in Bangladesh. Fisheries Information Bulletin, Bangladesh, 1(2): BGD/79/015, 28 pp.

22. Juliano, B.O., 1993. Rice in Human Nutrition. FAO Food & Nutrition Series, No. 26. Rome: Food & Agriculture Organization of UN

23. Koohafkan, A.P.2002 Concept note on Globally Important Ingenious Agricultural Heritage systems, Land and Water Development Division, FAO, Rome

24. Koohafkan, A.P., Boerma, D. Niamyr-Fuller, M, 2003, Sustainable Management of Globally important Ingenious Agricultural Heritage Systems, PDF-B project document, UNDP, FAO, GEF

25. Kurihara, Y., 1989. Ecology of some rice fields in Japan as exemplified by some benthic fauna, with notes on management. Internationale Revue der gesamten Hydrobiologie, 74: 507-548

26. Kurasawa, H., 1956. The weekly succession in the standing crop of plankton and zoobenthos in paddy fields. Parts 1 and 2. Bull. Res. Sci. Jpn., 41-42: 86-98, and 45: 73-84

27. Lightfoot, C., B.A. Costa-Pierce, M.P. Bimbao and C.R. dela Cruz, 1992. Introduction to rice-fish research and development in Asia. pp. 1-10 in “Rice-Fish Research and Development in Asia”, eds. C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao. 457 pp. Manila: International Center for Living Aquatic Resources Management

28. Lightfoot, C., M.A.P. Bimbao, J.P.T. Dalsgaard and R.S.V. Pullin, 1993. Aquaculture and sustainability through integrated resources management. Outlook on Agriculture, 22 (3): 143-150

29. Little, D.C., P. Surintaraseree and N. Innes-Taylor, 1996. Fish culture in rainfed rice fields of northeast Thailand. Aquaculture, 140: 295-321

30. Mackay, T. Kenneth (editer), Rice-Fish Culture in China. IDRC. 1995. pp.4

31. Moulton, T.P., 1973. More rice and less fish – some problems of the ‘Green Revolution’. Aust. Nat. Hist., 6: 322-327

32. Newman-Meusch, E., 1996. Participatory Assessment of Ricefield Fisheries in Atsaphangtong District, Savannakhet Province, Lao P.D.R. M.Sc. Thesis, 76 pp. Auburn, AL: Auburn University

33. Ni Dashu and Wang Jianguo, Different Methods of Rice–Fish Farming in Mackay, T. Kenneth (editer), Rice-Fish Culture in China. IDRC. 1995.

34. Oka, H.I., 1991. Genetic diversity of wild and cultivated rice. Pp. 55-83 in "Rice Biotechnology", eds. G.S. Khush and G.H. Toenniessen. IRRI. Wallingford, UK: CAB International

35. Purseglove, J.W., 1972. Tropical Crops. Volume 1. Monocotyledons. London: Longmans

36. Ranganathan, R., H.I Neue and P.L. Pingali, 1995. Global climate change: Role of rice and methane emissions and prospects for mitigation. pp. 122-135 in "Climate Change and Rice", eds. S. Peng, K.T Ingram, H.U. Neue and L.H. Zistaa. International Rice Research Institute. Berlin: Springer-Verlag

37. Ruddle, K., 1982.Traditional integrated farming systems and rural development: the example of ricefield fisheries in southeast Asia. Agricultural Administration, 10: 1-11

38. Sall, S., D. Norman and A.M. Featherstone, 2000.Quantitative assessment of improved rice variety adoption: the farmer's perspective. Agricultural Systems, 66(2): 129-144

39. Spedding, C.R.W., J.M. Walsingham and A.M. Hoxey, 1981. Biological Efficiency in Agriculture. London: Academic Press

40. Von Uexkull, 1998. Constraints to agricultural productivity and food security in Asia: Challenges and opportunities. Ch. 1, pp. 3-20 in "Nutrient Management for Sustainable Crop Production in Asia", 394 pp., eds. A.E. Johnston and J.K. Syers. Wallingford, UK: CAB International

41. Xu, Y. and Y. Guo, 1992. Rice-fish farming systems research in China, pp. 315-323 in "Rice-Fish Research and Development in Asia". 457 pp. eds. C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao. Makati, Metro Manila: International Center for Living Aquatic Resources Management

42. Zhu, Y.Y., Wang, Y.Y., Chen, H.R., and Lu, B.R. 2003. Conserving traditional rice varieties through management for crop diversity. Bioscience 53 (2):158-162.

ANNEX 1: EXAMPLES OF TARGETED GIAHS

- Outstanding rice based systems: such as rice terraces and combined agro-forestry vanilla system in Pays Betsileo, Betafo and Mananara in Madagascar, and diverse rice-fish systems with numerous rice and fish varieties/genotypes and other integrated forest, land and water uses in East Asia and the Himalayas;
- Maize and root crop based agro-ecosystems developed by Aztecs (Chinampas in Mexico) and Incas in Andes (Waru-Waru) around lake Titicaca in Peru and Bolivia), with ingenious micro-climate and soil and water management, adaptive use of numerous varieties of crops to deal with climate variability, integrated agro-forestry and rich resources of indigenous knowledge and associated cultural heritage;
- Taro based systems with unique and endemic genetic resources in Papua New Guinea, Vanuatu, Solomon islands and other Pacific Small islands developing countries;
- Remarkable pastoral systems based on adaptive use of pasture, water, salt and forest resources through mobility and herd-composition in harsh non-equilibrium environments with high animal genetic diversity and outstanding cultural landscapes. These include highland, tropical and sub-tropical dry-land and arctic systems such as Yak based pastoral management in Ladakh, high Tibetan plateau, India, and parts of Mongolia; Cattle and mixed animal based pastoral systems such as of the Maasai in East Africa; and Reindeer based management of tundra and temperate forest areas in Siberia such as Saami and Nenets;
- Ingenious irrigation and soil and water management systems in drylands with a high diversity of adapted species (crops and animals) for such environments such as: ancient underground water distribution systems (Qanat) allowing specialised and diverse cropping systems in Iran, Afghanistan and other central Asian countries with associated home-gardens and endemic blind fish species living in under-ground waterways; and integrated oases in deserts of North Africa and Sahara, traditional valley bottom and wetland management e.g. in Lake Chad, Niger river basin and interior delta (e.g. floating rice system) and other like ingenious systems in pays Bamileke (Cameroon), Dogon (Mali) and Diola (Senegal);
- Complex multi-layered home gardens, with wild and domesticated trees, shrubs and plants for multiple foods, medicines, ornamentals and other materials, possibly with integrated agro-forestry, swidden fields, hunting-gathering or livestock such as home garden systems in China, India, the Caribbean, the Amazon (Kayapó) and Indonesia (e.g. East Kalimantan and Butitingui);
- Hunting-gathering systems such as harvesting of wild rice in Chad; and honey gathering by forest dwelling peoples in Central and East Africa.