JARQ 49 (1), 29 - 36 (2015) http://www.jircas.affrc.go.jp

REVIEW

Rice-fish Integration in Sub-Saharan Africa: The Challenges for Participatory Water Management

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Abstract

In light of the logistical challenges for gearing production and conservation efforts to the scale of the smallholder, there is growing interest in promoting Integrated Irrigation-Aquaculture (IIA), such as rice-fish culture, which has strong potential in Sub-Saharan Africa. Available literature has stressed institutional shortcomings in providing necessary services, including extension, training, and credit-lending; ways in which farmers could craft new water-management regimes if these services were available have not been well studied and are key to successful farming integration. In this paper, we analyzed the conditions for achieving integrated water governance, with reference to the available evidence relating to the rice-fish system environment, investment incentives, collective action, and property rights. Our analysis suggests that the system design should be adapted to existing farm conditions to minimize topographical and technical modifications and maximize successful adoption of rice-fish culture. Labor and capital requirements must remain within the bounds of investment capacity, which is limited and seasonal among African smallholders. Investments in IIA should promise an adequate profit margin to secure reinvestment. Since reinvestment is important for the advanced operation and maintenance of water facilities, sustainable rice-fish farming requires strong accountability in organizing water distribution, monitoring, and related rule enforcements. Therefore, a preliminary need is to understand farmers' socioeconomic characteristics and interests that affect participation and free riding.

Discipline: Participatory research
Additional key words: collective action, investment incentives, property rights, system environment

Introduction

Irrigation and aquaculture will play critical roles in ensuring food security, the basis for national economic growth and poverty reduction in Sub-Saharan Africa (SSA). However, aquaculture development has slowed to a crawl, despite the progressive depletion of marine and inland fisheries, and irrigation covers only 3.5% of the cultivated land area (Svendsen et al. 2008). This underdevelopment calls for reinforcing production gains from both sectors. Conversely, it is anticipated that, given projected population growth, rapidly expanding the irrigated area would result in water scarcity and compromise water-resource conservation (Gowing 2003). This is sparking new perceptions of the need to promote multiple water uses within irrigation systems, and improve awareness of the linkages between water-management activities and aquatic ecosystems (Bakker & Matsuno 2001). Extensive hydraulic engineering works associated with previous large-scale irrigation development have had a profound negative impact on many river ecosystems, reflected in a dramatic loss of biodiversity (Halls et al. 1999). Efforts should thus be geared towards developing irrigation systems that mitigate this negative impact by promoting complementary aquaculture production, although this has generally been overlooked (Gowing 2006).

Because of the future need for both production and conservation outcomes, Integrated Irrigation-Aquaculture (IIA) is expected to enable productive and efficient water use in SSA. Meanwhile, important implications that arise from recognizing multiple demands for water use include compatibility with livelihood strategies of African smallholders, who have secured income and food supplies by tapping natural resources and maximizing crop diversification. These strategies would ensure greater diversion of farm risks stemming from climate and market fluctuations, com-

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Received 11 December 2013; accepted 22 May 2014.

Table 1. Area and share of rice grown in different ecosystems in West Africa

	Rain-fed Lowland	Deepwater Floating	Irrigated Lowland	Mangrove Swamp	(Rain-fed Upland)	Total
Cropped area (1000 ha)	1,384	373	487	147	2,209	4,600
Share (%)	30.1	8.1	10.6	3.2	48.0	100

(Source: Lançon & Erenstein 2002)

pared to modern methods based on single-purpose irrigation technology packages. In line with such livelihood practices, IIA will help non-irrigators adopt irrigation in a resilient way, while providing an opportunity for irrigators to build up their existing hydraulic systems, some of which have been underperforming in operation and maintenance (O&M) practices. In particular, applying the concepts of multiple-use systems in the initial planning process will enhance the positive effects of investments in agricultural water management on smallholder livelihoods (Namara et al. 2010).

Rice-fish system in SSA

Although IIA implies various combined-cropping practices, rice-fish culture is one of the primary practices attracting attention because of the experience in Asian countries, where farmers have benefited from rice-fish integration. Rice-fish culture has been practiced for centuries in countries including China (about 2000 years: Li 1992) and Indonesia, although it is relatively new in SSA (Brugère 2006a). However, the culture has been extensively utilized in wetland areas (e.g. floodplains) where rice paddies and inland fisheries were developed. In West African floodplains, for instance, farmers have traditionally captured wild fish in their rice paddies and kept them alive during the dry season in wells or holes (Miller 2006, Peterson et al. 2006, Sanni & Juanich 2006).

To date, rice-fish culture has been reported in several SSA countries (e.g. Halwart & Gupta 2004). Though available figures on integrated production are limited, they would show regional variation; a leading country is Madagascar, in which approximately 70% of freshwater aquaculture production comes from rice-fish culture (Refaliarison 2005). Since traditional marsh aquaculture exists widely in SSA, integration with rice has a priori potential; fish culture can be combined either extensively with rain-fed rice or intensively with irrigated rice. This potential appears particularly significant in West Africa, which has abundant lowland rice cultivation and is thus considered a supply hub for rice (Africa Rice Center 2007). In West African floodplains, 470,000 hectares used for extensive deep-water rice production could be used concurrently for fish culture (Prein & Dey 2006).

1. Potential of rice-fish development

(1) Physical potential

In SSA, three agroecosystems are generally viewed as key environments for IIA activity: inland valley bottoms (with no or partial water control), floodplains, and irrigated systems (with full water control) (Kiepe 2006). Rice-fish culture may also be introduced in coastal areas, given appropriate environmental consideration of fragile ecosystems such as mangroves. Because introducing fish to rice-growing areas often leads to polyculture, it could be particularly widespread in West Africa, which is endowed with the key environments required for rice cultivation (Table 1). However, the potential for rice-fish culture would vary among environments, which utilize different systems and modes of rice production.

In inland valleys and floodplains, which occupy the majority of current rice area (rain-fed rice), introducing fish can allow farmers to develop more productive (irrigated rice) systems, whereas in deep-water areas, farmers may also adopt semi-intensive or extensive integration of fish culture into floating rice systems. This integration may be achieved more readily in floodplain areas, where residents have experience of catching wild fish populations and managing fish production using extensive aquaculture techniques (e.g. ponds dug into the floodplain and dike-enclosed areas) (Welcomme 1976). In rice-fish farming in the Niger River floodplain, for instance, ponds would be stocked with fish from natural populations that enter the floodplain and from additional sources (Bamba & Kienta 2000). In irrigation systems, the integrated facilities would improve existing techniques and water use efficiency and rehabilitate abandoned water infrastructure. In Nigeria, for example, it is expected that rice-fish systems will be installed in many dysfunctional large- and small-scale irrigation systems (Miller et al. 2006). In a broader sense, promoting rice-fish culture would affect local land-use practices, mostly from upland cultivation to the development of lowland areas, which remain widely underexploited in SSA (Balasubramanian et al. 2007).

(2) Theoretical potential

Besides its physical advantages for SSA, the theoretical potential (i.e. opportunities and constraints) of IIA is recognized in environmental, health, economic, technical,

Table 2. Summary of the potential of IIA activities, including rice-fish culture in SSA

	Opportunities	Constraints
Environmental	• Efficient water use (wastewater management, water recycling/ reuse) • Salinity mitigation • Soil fertilization	• Flooding and drought • Predators (e.g. birds) • High agrochemical loads
Health	• Food diversification, improved nutrition • Control of water-borne diseases (e.g. malaria)	• Increased disease (without proper maintenance)
Economic	• High income generation (total income gain)	• Low return on labor (labor availability is critical)
Technical	• Weed control (e.g. grass carp) • Decreased pests and diseases • Use of low-cost and locally available inputs	• Slow response time of water regulation (large-scale systems) • Interference/additional burden of maintenance activities • Continuous water supply (threatened by climatic fluctuations)
Socio-cultural	• Distribution of risks and uncertainty • Women's independence (post-harvest, marketing)	• Fish theft • Competition for feed resources
Institutional		• Lack of extension, training, and research • Lack of input markets (e.g. fingerlings, feed, nets) • Lack of experience

sociocultural, and institutional contexts (Table 2). Rice-fish integration uses the same water for multiple purposes, thus improving water use efficiency, wastewater management (e.g. water recycling and reuse), and soil fertility (nutrient recycling, as a result of effluents and waste products generated by aquaculture). Introducing fish can also mitigate (or prevent) salt-related soil degradation resulting from irrigation and presents a major threat to the sustainability of rice cropping under semi-arid conditions in West Africa (van Asten et al. 2003). In addition to water and soil conservation, rice-fish integration enhances food security by improving diet, nutrition, and consumption. The integration can also enhance living standards by increasing and diversifying income. Studies have found greater farm output and income under rice-fish polyculture compared to rice monoculture in SSA (Kumah et al. 1996, Osuigwe et al. 2007). In the field, the integration may lessen farmers' management workload where fish such as grass carp and tilapia control aquatic weeds (e.g. Okafor 1986). Because fish can be harvested over time, rice-fish culture can enhance flexibility in managing food and income supply (e.g. conducting sales at off-crop and high-price periods), which implies risk dispersion, an important farming strategy for smallholders in securing a livelihood.

Wary of great opportunities, the literature stresses institutional constraints, namely extension, training, and research efforts that are insufficient to encourage farmers and fishermen to adopt IIA practices. Since credit institutions are underdeveloped in rural SSA, poor access to starting materials (e.g. fingerlings, feed, suitable nets) also hinders integrated production (Kumah et al. 1996). Moreover, local bases of input supplies, particularly hatcheries, must be established in the target communities to sustain rice-fish culture. Attention should also be paid to post-harvest activities; private-sector participation in fish processing should be encouraged because the demand for post-harvest transformation is currently growing in response to dietary shifts from traditional to marketed products (Brugère 2006a).

2. Local management regime for rice-fish production

As reviewed, the physical potential of rice-fish culture has considerable room for development, and the theoretical potential is well-acknowledged in literature, which often emphasizes institutional shortcomings that must be addressed to ensure market and credit opportunities and access to information, techniques, and training programs. However, there remains a lack of empirical research analyzing the long-term viability of IIA. In particular, the ways in which local institutions (e.g. farmers' organizations: FO; water users' groups: WUG), formed primarily to enable access to the services required, would sustainably direct water management required for rice-fish systems have not been well-explored. The end results of efforts to promote innovative methods in African agriculture often disappoints those responsible for developing and promoting such methods, even when all the requirements (e.g. low external inputs, high-yielding technology, significant training and extension efforts) seem present (Perret & Stevens, 2003).

Lessons from the development of irrigation and aquaculture in SSA also point to this issue. It is well known that related programs led by governmental and donor agencies have often failed to achieve expected outcomes, due to limited financial and organizational performance in O&M and deteriorating hydraulic facilities. In recent decades, government authorities have embarked on management transfer to local institutions, whereby the members (farmers), as users, are expected to make voluntary decisions and efforts for planning, designing, and managing water delivery and facility maintenance at the tertiary level. This echoes recent policy narratives and development discourse that have focused on Participatory Irrigation Management (PIM). However, the focus should not be on promoting PIM, but rather on shedding light on local initiatives that can spark such achievement. In this context, exploring successful rice-fish integration requires an insight into the workings of local water-governance practices. This paper, therefore, intends to discuss key conditions for local participation in rice-fish integration in the SSA context.

Conditions for local participation in rice-fish integration

1. Rice-fish system environment

The way in which rice-fish culture is systematized to accommodate farmers and facilitate their involvement in water use and management practices is considered crucial. To date, irrigation policy in Africa has acknowledged technological innovation for more intensive and modernized systems with effective water control. Such innovations, however, may not function in the context of African aquaculture, where the focus of development tends to have shifted to farmer-controlled, large-scale (extensive) aquaculture. For instance, based on a review of IIA experiences in the Sahel, Miller (2006) points out that the opportunity for aquaculture lies not in intensive systems that focus on maximizing production through capital- and technology-intensive practices concentrated on small spatial areas, but rather in extensive application of integrated aquaculture systems using cost-effective, locally available inputs over large areas. Extensively equipped wetland may provide environments that are better adapted for IIA activities, which would also resonate with principles of wetland conservation and sustainable water use, as defined in the Ramsar Convention (Brugère 2006a).

Because IIA systems are intended to achieve (or reconcile) production and conservation outcomes, the central design question would not be whether to implement a large- or small-scale operation or an intensive or extensive practice. Rather, the design should be well adapted to existing farm conditions, which vary greatly among environments, and should minimize capital, labor, technological changes, and excess investment. Such design will be key to smallholders' involvement in rice-fish culture; allowing it to serve as a tool for developing local water-management capacity. Such minimal modification needs to be reflected in the actual design of integrated systems, which are often grouped into two types: direct integration (i.e. fish raised in the paddy field) into concurrent or rotational practices, and indirect integration (i.e. fish raised outside the paddy field) into upstream or downstream pond systems. While the direct integration types are often referred as "rice-fish" systems, site-specific integration processes, including identification of favorable fish locations (niches), will be featured in the system design. Depending on the design, further integration (e.g. diked vegetable cropping, livestock watering and waste use) may be promoted subject to farmer's interests and available resources.

2. Investment incentives

For systems in environments suited to rice-fish farming, there must be a focus on upfront investments, including elaboration of field and water infrastructure, which are often achievable by collaboration with farmers. For instance, direct integration involves constructing sufficiently tall dikes, which are not generally present in rice-growing areas of inland valleys and floodplains or in most rice-irrigation schemes. Other required investments may include preparing weirs/screens, drains, and fish refuges (e.g. trenches and sumps) excavated in fields to enable fish to grow and survive after drainage for rice harvest. Given that smallholder agriculture is susceptible to climatic fluctuations that cause flash floods and drought, the logistical challenges to fulfilling the required hydraulic conditions may preclude rice-fish integration. In the Office du Niger, in Mali, farmers were hesitant to introduce fish because of the type of irrigation engineering used to create their rice fields (Peterson et al. 2006).

Provided that infrastructural modifications remain within the bounds of farmers' physical, technical, and managerial capacities, they still must benefit continuously from the integrated activity to recoup the upfront investment and reinvest in the system. The revenues must therefore be sufficient to offset the additional costs generated by the integration, including those of O&M of the facilities and management of the rice crop and fish. Although reports on the performance of rice-fish trials in SSA are often encouraging, showing little decrease in rice yield and an increase in gross income (Kumah et al. 1996, Osuigwe et al. 2007), evidence for increased net income remains limited (Brugère 2006b, Nnaji et al. 2012). This uncertainty about profit gains is consistent with a review of findings in Southeast Asia (Yamada et al. 2000). Moreover, the financial impact on household budgets may be limited when family labor is insufficient (Kabré 2000). The feasibility of rice-fish systems may thus be determined largely by labor availability, which is limited and highly seasonal among smallholder households. Conversely, the return on labor could be low because of increased interference and the burden of maintaining the upgraded facilities. In particular, for systems requiring complete water control, water use in paddy fields involves labor-intensive cropping practices (e.g. paddling, leveling, transplanting), for which mechanical alternatives are limited and financially inaccessible for many rural inhabitants of SSA. Unless labor and capital requirements related to the additional water use and control are reconciled with farmers' investment capacity, their commitment to the integrated activity could quickly wane.

In this context, it is important to focus on the subsistence calendar, which may preclude farmers from taking on additional water management due to overlaps with other farm and non-farm activities. As mentioned earlier, SSA smallholders derive their livelihood not from intensified crop production but rather from various enterprises (e.g. rain-fed farming, animal husbandry, fishing, trading, and other jobs) that allow them to diversify their income and food supplies and disperse their risk. Provided these activities are available, farmers may not be motivated to apply the effort required to complete the necessary tasks, including system O&M, which is even more strenuous in rice-fish systems. Lessons from irrigation management transfer (IMT) in Africa support this point; successful cases of IMT are limited to a few farmers, who derive much of their livelihood from irrigation farming, which is, in turn, just one of several livelihood activities for most beneficiaries who cultivate tiny plots. The time, effort, and resources that smallholders may be willing and able to invest in activities associated with irrigated plots will be very limited if it involves sacrificing other livelihood options (Shah et al. 2002).

Farmers' adoption of technology will be determined not only by their available resources but also by social conformity. In rural African settings, maintaining community ties is important for the survival of both the household and community and requires strong conformity with behavioral norms, which is reinforced by those in positions of authority. Concerns about social status and non-monetary penalties associated with deviation from community norms may affect individuals' decisions about new methods even more than profit motives (Moser & Barret 2006). Such conformity may also adversely affect IIA adoption. While active water control remains scarce in most SSA inland valleys and floodplains, irrigation farming is not a dominant livelihood activity, even for farmers in areas that have adopted such schemes. Furthermore, in many such areas, there is a general perception of aquaculture as an activity of secondary importance. Social conformity (and charismatic leadership) may not favor farmers attempting to practice rice-fish integration.

3. Collective action

To share information and techniques to regulate water use and facilitate O&M practices, rice-fish farming involves farmers' initiatives to develop collaborative activities. Similar to single-irrigation farming, these activities involve maintaining irrigation structures, implementing water-use monitoring and its related rules (and sanctions for any violations thereof), and collective decision-making (e.g. through meetings) for their planning, execution, evaluation, and adjustment. Sustainable rice-fish culture hinges on sustained involvement in those activities. In SSA, however, challenges exist for such participatory requirements.

The coordination required among multiple organizations, if any even exist, is the initial challenge, such as in cases where institutions for irrigation and aquaculture (e.g. WUGs, fishermen's associations) coexist in the envisaged area. Although such areas may be highlighted for promotion, harmonizing institutional bodies will be critical to reconcile the interests of rice and fish cultivators. In the Kou Valley of Burkina Faso, where a rice-fish trial was implemented, conflicts arose over water allocation since fish cultivators were interested in the integration but rice farmers were skeptical about it (Kabré 2000). The second challenge, free riding, lies within an organization or group and typically affects common-pool resource management. This issue may be acute in rice-fish culture, since introducing fish can lead to the outbreak (or suspicion) of fish theft and competition for local food resources, while any lack of knowledge and experience of regulatory water use would further increase the potential for free riding. The more free riders are involved, the more other members anticipate such free riding, which, in turn, prompts them to reduce their participation (i.e. shirking). Frequent free riding and shirking results in inequitable distribution of capital and labor within the organization, which would render members less interested in collaboration.

Because water management is more sensitive in IIA compared to monoculture, constant free riding and shirking can have a fatal impact on the sustainability of rice-fish farming. In systems with full water control, fish installation requires continuous attention to canal flow (e.g. water depth, velocity), conveyance capacity, and operational performance, which affect the rearing environment. In large-scale systems, farmers must also contend with a slow response time of water regulation that can upset the volume, temperature, and other factors required for fish growth and survival. Regardless of the accepted view that introducing fish decreases mosquito larvae (malaria) and snails (schistosomiasis), this reduced proliferation of infectious pests and diseases would be contingent on appropriate O&M of water facilities. The water table is also critical to successful rice-fish culture, particularly in low-lying areas; the water supply can be excessive, as when flash floods wash fish away, or insufficient, with fields drying out too early in the season (Sanni & Juanich 2006). In irrigation schemes, fish loss can also be caused by overflooding of rice plots by neighboring farmers (Kumah et al. 1996). Constant monitoring of water quality and timely exchange of water are also required to control fish disease and mortality rates. These advanced and subtle water-distribution and on-farm practices are a new attempt for many farmers in SSA and depend largely on receptiveness to regulatory arrangements.

Information sharing is also important in this sense. Rice-fish culture involves increasing the sophistication of water-control and crop-management techniques (e.g. applying rice varieties, fish species and density, and chemical inputs appropriately), all of which are essential to ensuring water quality and fish growth. As the water depth must be regulated for both paddies and fish, biological interactions must be properly understood for varietal selection and stocking density. Although rice-fish systems are considered an effective form of Integrated Pest Management (IPM), poor access to the knowledge base or capacity building may trigger the use of excessive agro-chemicals, particularly bioaccumulating insecticides (for crop protection or mosquito control), which pollute water and render it unsuitable for fish culture. Because social networks will play a vital role in sharing the required information and skills, there is a need to explore locally crafted organizations and draw on their key characteristics, including size, membership, and governing structure.

4. Property rights

To help farmers improve water management through rice-fish integration, the status of their rights to use the related properties must be assessed. For instance, different tenure conditions that apply to available structures may complicate their management; where a fish pond, constructed by an aquaculture project and communally managed by a group of fishers, is to be used to irrigate farms with infrastructure communally managed by an FO or WUG. Here, tensions may arise over the use of the irrigation water and facilities, and enforcement of the related rules.

Care should also be taken about the tenure status of the land and water to be used. In traditional African societies in particular, customary systems have predominant control over natural resources and allocation of use rights to members of the community. Those with interpreting powers (e.g. chiefs) often hold the rights to allocation of customary land, including wetland suitable for rice-fish culture. In private irrigation, organized by farmers without government or development agencies intervening, land rights (and implicitly water rights) may be transferred through traditional institutions. Even in irrigation schemes in which government authorities administer land and water resources, traditional authorities continue to coordinate the allocation of such resources, monitoring their use, enforcing related rules, and solving associated conflicts (Tonah 2008, Derbile 2012). The strong involvement of the traditional sector in resource management must also be considered, as well as noting that traditional authorities sometimes leave little room for people to benefit from the resources (van Edig et al. 2002). Haphazard tenure arrangements would cause a local backlash as has occurred under past irrigation schemes in SSA (Cotula 2006).

Regardless of farmers' reactions, their customary rights are often indeterminate and ambiguous, thus creating instability in areas, including those where rice-fish culture could be introduced. For example, in the inland valleys of southern Ghana, the dynamic nature of customary land tenure could have compromised rights to continuously use field and irrigation infrastructure developed for lowland rice production (Fujimoto et al. 2012). The land and water rights of smallholder irrigators in schemes may also be insecure, given their tendency to cultivate irrigated plots from which they can be evicted if they fail to earn enough to cover their water fees (Cotula 2006). Preparing for this contingency may be crucial for rice-fish integration in systems with complete water control within which charges are systematically enforced, and continuous demand for water for fish growth and the status of aquaculture as a non-consumer would complicate charging issues (Brugère 2006a). Rice-fish culture thus requires greater efforts to establish and execute arrangements to tackle tenure problems arising from the integration. In the Office du Niger in Mali, members of the fish cultivators' association are not interested in pursuing rice-fish farming, partially due to their limited access to irrigated land suitable for growing rice (Peterson et al. 2006). Existing rights to use available resources should be arranged to meet the requirements of the new property regime to be established by rice-fish integration.

Discussion

To craft a new water-management regime, it is important to focus on whether it can fit into the local context and be adopted and spontaneously sustained by residents. In cases of IIA, more sophisticated arrangements are required to manage irrigation water and facilities, implement rules and sanctions for any violations thereof (e.g. free riding), compared to single-irrigation farming. This is relevant to not only water volume but also water quality; arrangements are necessary when rice fields with fish are supplied with water from neighboring rice fields, which are cultivated without fish and have agro-chemicals applied that render the water unsuitable for fish culture. Such an arrangement to maintain water quality is critical to make rice culture compatible with fish culture. While community-based rice-fish culture has been successful in some parts of Asia (e.g. Prein & Dey 2006), SSA still faces many institutional challenges for irrigation, and even more exist for IIA activities. It is thus advisable to reexamine preexisting methods of using and managing natural resources, social relationships between farmers, and farmers' livelihood strategies and activities, all which can affect participation in water governance. Since the rice-fish system has features which resemble those of single rice irrigation and aquaculture, the results of past development projects combined with empirical diagnoses provide insights into requirements for sustainable integrated activity. This resonates with concern over recent promotion of smallholder irrigation in SSA; considerable knowledge and experience exists that has been poorly examined and thus rarely incorporated into current development practice (Kay 2001). Further technical and institutional support would enable rice-fish integration to take place, but would not necessarily sustain the activity if farmers' participation in water-use arrangements and facility maintenance is not adequately investigated and this remains a challenge in much of SSA.

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