This volume contains background documents and papers presented at the FAO-WARDA Workshop on Integrated Irrigation Aquaculture (IIA) held in Bamako, Mali, from 4 to 7 November 2003, as well as the findings of FAO expert missions on IIA in the West Africa region.

The rationale for IIA development lies in its potential to increase productivity of scarce freshwater resources for improved livelihoods and to reduce pressure on natural resources, which is particularly important in the drought-prone countries of West Africa where water scarcity, food security and environmental degradation are priority issues for policymakers.

Irrigated systems, floodplains and inland valley bottoms are identified as the three main target environments for IIA in West Africa. Many examples of current practices, constraints and potential for development of IIA are provided. The concept and economic analyses of IIA are reviewed, and an overview of regional and international research institutions and networks and their mandates as they relate to IIA is given. Key factors for successful adoption of IIA – participation of stakeholders and support for local development, an integrated, multi-sectoral approach to IIA and improved knowledge management and networking – indicate the way forward and are reflected in a proposal for IIA development in West Africa.
INTEGRATED IRRIGATION AND AQUACULTURE IN WEST AFRICA
Concepts, practices and potential

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PREPARATION OF THIS DOCUMENT

This document contains the proceedings, including 12 presented papers, as well as background documents and mission reports prepared for the FAO-WARDA Workshop on Integrated Irrigation Aquaculture held in Bamako, Mali, from 4 to 7 November 2003. Submitted presentations from the Bamako workshop were technically reviewed by the members of the Technical Secretariat of the Workshop (M. Halwart/FAO, I. Beernaerts/FAO, C. Brugère/FAO, P. Kiepe/WARDA and J.F. Moehl/FAO). All material, including the preparatory studies and analyses, were compiled and edited by M. Halwart and A.A. van Dam.

Halwart, M.; Dam, A.A. van (eds)
ABSTRACT

This volume contains background documents and papers presented at the FAO-WARDA Workshop on Integrated Irrigation Aquaculture (IIA) held in Bamako, Mali, from 4 to 7 November 2003, as well as the findings of FAO expert missions on IIA in the West Africa region. The rationale for IIA development lies in its potential to increase productivity of scarce freshwater resources, enhance food security and poverty alleviation, and reduce pressure on natural resources, particularly in the drought-prone countries of West Africa. Irrigated systems, floodplains and inland valley bottoms are identified as the three main target environments for IIA in West Africa. In irrigated systems, aquaculture is a non-consumptive use of water that can increase water productivity. Pens and floating cages are often used to grow fish in the source, delivery and disposal subsystems of irrigation schemes (dams and canals). Rice-fish farming is the most common form of aquaculture in the use subsystem of irrigation schemes. Continuity of water supply, the effect of aquaculture on water conveyance and the use of agrochemicals are the main points of attention for aquaculture in irrigation systems.

Apart from irrigation schemes, river floodplains and deltaic lowlands also offer opportunities for integration of aquaculture. By enclosing parts of these flooded areas and stocking them with aquatic organisms, food production can be enhanced. Examples of community-based rice-fish culture in Bangladesh and Viet Nam show that fish production can be increased by 0.6 to 1.5 tonnes per hectare annually. Another example is the use of seasonal ponds in the wetlands surrounding Lake Victoria (East Africa) which are stocked with water and fish by natural flooding and are managed using locally available resources like animal manures and crop wastes.

Following the first three chapters which set the stage for IIA in West Africa, the fourth chapter presents a review of IIA systems in 13 West African countries which demonstrates the considerable potential for further development. Traditional marsh aquaculture systems exist in many West African countries and should be developed further, together with fish culture in irrigation schemes. The following chapters deal with current practices and constraints in Burkina Faso, Mali, Niger, Nigeria and Senegal. In addition, examples of development approaches in Côte d’Ivoire and Guinea are given. Concepts of economic analyses of IIA are reviewed and illustrated through an example of integrated aquaculture in Madagascar. This is followed by an overview of regional and international research institutions and networks. The final two chapters summarize the key factors for successful adoption of IIA – participation of stakeholders and support for local development; an integrated, multisectoral approach to IIA; and improved knowledge management and networking – and indicate the way forward in the form of a proposal for IIA development in West Africa.
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<td>Acronym</td>
<td>Description</td>
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<tr>
<td>AFVP</td>
<td>French Association of Volunteers of Progress (Association française des volontaires du progrès)</td>
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<td>ALCOM</td>
<td>Aquatic Resource Management for Local Community Development</td>
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<td>APDRA-CI</td>
<td>Aquaculture Association and Rural Development in the African Humid Tropics–Ivory Coast (Association pisciculture et développement rural en Afrique tropicale humide–Côte d’Ivoire)</td>
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<td>APDRA-F</td>
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<tr>
<td>ARI</td>
<td>African Rice Initiative</td>
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<td>ARID</td>
<td>Regional Association for Irrigation and Drainage</td>
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<td>ASI</td>
<td>Advanced Scientific Institution</td>
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<td>CBFM</td>
<td>Community-based Fisheries Management</td>
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<td>CIFA</td>
<td>Committee for Inland Fisheries of Africa</td>
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<td>CCFD</td>
<td>Catholic Committee against Hunger and for Development (Comité catholique contre la faim et pour le développement)</td>
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<tr>
<td>CGIAR</td>
<td>Consultative Group on International Agricultural Research</td>
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<tr>
<td>CIRAD</td>
<td>Centre de coopération internationale en recherche agronomique pour le développement</td>
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<td>CORAF</td>
<td>Conference of Agricultural Research Directors in West and Central Africa</td>
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<td>DGIS</td>
<td>Directorate General for International Cooperation, The Netherlands</td>
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<td>EPHTA</td>
<td>Eco-regional Programme for Humid and Sub-Humid Tropics of Sub-Saharan Africa</td>
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<td>FAO</td>
<td>Food and Agriculture Organization of the United Nations</td>
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<td>FFS</td>
<td>Farmer field schools</td>
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<td>HYV</td>
<td>High yielding varieties</td>
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<td>IAA</td>
<td>Integrated Agriculture-Aquaculture</td>
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<td>ICLARM</td>
<td>International Center for Living Aquatic Resource Management (now called WorldFish Center; CGIAR Center)</td>
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<td>ICOUR</td>
<td>Irrigation Company of the Upper East Region, Ghana</td>
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<td>ICRI SAT</td>
<td>International Crops Research Institute for the Semi-Arid Tropics</td>
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<td>IFAD</td>
<td>International Fund for Agricultural Development</td>
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<td>IFPRI</td>
<td>International Food Policy Research Institute</td>
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<td>IIA</td>
<td>Integrated/Integration Irrigation - Aquaculture</td>
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<td>IIRR</td>
<td>International Institute for Rural Reconstruction, Philippines</td>
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<td>IITA</td>
<td>International Institute for Tropical Agriculture</td>
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<td>ILRI</td>
<td>International Livestock Research Institute</td>
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<td>INRAB</td>
<td>Institut national des recherches agricoles du Bénin</td>
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<tr>
<td>INREF</td>
<td>Interdisciplinary Research and Education Fund, WUR</td>
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<td>INREF-POND</td>
<td>INREF Program for Optimisation of Nutrient Dynamics</td>
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<td>IPTRID</td>
<td>International Programme for Technology and Research in Irrigation and Drainage</td>
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<tr>
<td>IRRI</td>
<td>International Rice Research Institute (CGIAR Center)</td>
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<tr>
<td>IUCN</td>
<td>International Union for the Conservation of Nature</td>
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IVC    Inland Valley Consortium
IWMI   International Water Management Institute (CGIAR Center)
IWRM   Integrated Water Resources Management
MAE    Ministry of Foreign Affairs, France (Ministère des affaires étrangères)
NARS   National Agricultural Research Systems
NGO    Non-Governmental Organization
OUA    Ouelessebougou-Utah Alliance
OUA    Organization de l’unité africaine
PPCO   Central Western Fish Culture Project (Projet piscicole Centre-Ouest), Côte d’Ivoire, 1992-1996
PPGF   Fish culture project in Guinée Forestière (le Projet piscicole de Guinée Forestière), 1999-2004
ROCARIZ Regional Rice Research and Development Network for West and Central Africa
SIFR   Strategy for Inland Fisheries Research
SIMA   System-wide Initiative on Malaria and Agriculture (CGIAR)
SPFS   Special Programme for Food Security
SSA    Sub-Saharan Africa
UNCED  United Nations Conference on Environment and Development
UNESCO United Nations Educational, Scientific and Cultural Organization
UNESCO- IHE UNESCO–IHE Institute for Water Education
VINVAL Project on the impact of changing land cover on the production and ecological functions of vegetation in inland valleys in West Africa, implemented by WUR (Alterra)
WARDA  WARDA–The Africa Rice Center (CGIAR Center)
WEDEM  Wetland Development and Management
WUR    Wageningen University and Research Center
WURP   Wetland Utilization Research Project
FOREWORD

Freshwater is quickly becoming one of the scarcest resources of the twenty-first century. Significant investment is required to optimize use of this highly-demanded resource by increasing total water productivity and efficiency of the multitude of irrigated systems, particularly in Africa. The Region’s water resources need to be developed for delivery of a wider variety of services contributing to increased production of food and enhanced economic growth for each unit of water consumed.

Competition for freshwater is among the most critical challenges being faced by developing countries. Although fisheries, including aquaculture, are usually non-consumptive users of water, they can constrain consumption by other users; fish stocks depending on particular water quantities and seasonal flows in rivers, lakes or estuaries. There is, therefore, a need to acquire a broader knowledge of these interactions and a better understanding of the diverse processes affecting local resource management contributing to crop and fish production as well as to other goods and services generated by aquatic ecosystems. In this context, FAO has identified Integrated Irrigation Aquaculture (IIA) as a key subject for interdisciplinary and interdepartmental collaboration.

In collaboration with regional partners such as the Africa Rice Center (WARDA), FAO has adopted IIA as an integral part of sustainable integrated water resources management (IWRM) focusing on the multiple uses of aquatic ecosystems. It is considered essential to encourage an enabling environment to achieve coherence from relevant policies at all levels to local natural resource management arrangements. Yet, many countries still have to develop national guidelines for IIA as components of national inland fisheries or aquaculture strategies. Without strategic planning tools to guide the establishment of pilot IIA activities, it is very difficult for those countries with the greatest need to appreciate the advantages from developing IIA.

Within this context, attributing the right value to food and the environment in multi-purpose agricultural water use systems, and particularly irrigated and swamp rice systems, is an important issue. In the future, major investment will be required to address this, focusing on the development of better methods for measuring economic value. In addition, it will be necessary to assist with corresponding improvements of governance systems that facilitate cross-sectoral water management decision-making processes and embrace an ecosystem-based approach.

FAO is committed to actively supporting the recommendations of this workshop, within its mandate and resources. The Organization will continue fostering strategic partnerships with development and research organizations on irrigation and aquaculture in Africa to further strengthen FAO’s normative work on policy and methodology development while ensuring national implementation on the basis of concrete requests from member countries’ governments.

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Ichiro Nomura  
Assistant Director-General  
FAO Fisheries and Aquaculture Department
FOREWORD

Africa Rice Center (WARDA) is committed to alleviating poverty in Africa through research, development and partnership activities aimed at increasing the productivity and profitability of the rice sector, while ensuring the sustainability of the farming environment. Key factors to reach these goals are intensification and diversification of rice-based systems. WARDA is working on several aspects of diversification of rice-based systems by studying the inclusion of vegetable production. Fish represents a new area of potential diversification for African farmers.

Integrated irrigation-aquaculture (IIA) offers an excellent opportunity for rice farmers to make more efficient use of water resources. It also introduces extra protein to their diet. Historically, protein was not lacking in the African diet. The prime limitation was not the availability of protein but whether it could be afforded. This situation is worsening: natural river fish stocks are rapidly being depleted and the price of fish is rising. Farmers are, however, starting to notice the potential in growing fish for home consumption as well as for the wider marketplace.

During multi-stakeholder consultation meetings, which are held regularly in Mali between the national agricultural research system Institut d’Economie Rurale (IER), farmer organizations and the extension service, rice-fish culture was selected in 2005 as the topmost research priority. This statement underlines the need and relevance for rice-fish research in the subregion.

Integrated irrigation-aquaculture is a relatively new area for WARDA. Fish culture was already subject of study in the Inland Valley Consortium (IVC), the Ecoregional Program that is convened by WARDA. However, these studies focused on fishponds in inland valleys and not on the integration of fish in rice fields, which is stimulating interest from rice farmers in different ecologies. WARDA was happy with the combined FAO and IVC initiative to hold a stakeholders workshop assessing the state of the art of IIA in West Africa and to explore ways of future collaboration that would help achieve joint goals.

This workshop resulted in a five-year collaborative research project bringing together WARDA, WorldFish Center, IER and — through its agricultural biodiversity activities in Mali — FAO as an affiliate partner. The project Community-Based Fish Culture in Irrigation Systems and Seasonal Floodplains aims at enhancing water productivity to improve and sustain the livelihoods of the poor in Mali. It is also part of an overall interdisciplinary action research project between three CGIAR centres (IFPRI, WARDA and WorldFish Center) and six countries (Bangladesh, Cambodia, China, India, Mali and Viet Nam). Because of this project new opportunities have been created for WARDA to be actively involved in further rice-fish culture research in West Africa. There is an option at a later stage of the project to extend the work in Mali to Senegal, which would fit in well with WARDA’s goals and aspirations and satisfy the expressed needs of rice farmers.

Kanayo F. Nwanze
Director-General
Africa Rice Center — WARDA
INTRODUCTION

West Africa's population is expected to grow from the present (2003) level of 260 million to approximately 490 million by 2025. Today, the urban population corresponds to 40 percent of the total and urbanization is expected to continue to increase. With these changing demographics, demand for food will rise in the sub-region during the next 25 years and irrigation will need to expand to meet the urban requirement for fruits, vegetables, rice and fish through aquaculture.

Coastal and inland fisheries are stagnating or declining in the sub-region, which presents a real concern in terms of fish supply and food security. The development of aquaculture appears as a possible solution for this growing supply gap in the future.

The existing population of the region can scarcely be supported by prevailing domestic agricultural production without relying increasingly on irrigation. In the Sahel region, irrigation reduces risks associated with the extreme rainfall variability but is difficult to implement due to this same high unpredictability of available water. This inherent scarceness of water creates an imperative to use whatever is available as rationally and economically as possible. Wherever water is being used, it is critical to examine how it can be reused or how output from current uses can be increased.

Irrigation schemes are logical targets for efforts to enhance water productivity and efficiency. Biological environments created by irrigation schemes are favourable for aquaculture in general, and fish culture in particular. In the case of rice-fish farming, the integration of irrigation and aquaculture is the association of two farming systems, either on the same plot, or on adjacent plots where by-products of one system are utilized as inputs by the other. The aim is to increase the productivity of water, land and associated resources while contributing to increased fish production. The system of integration can be more or less complete depending on the general layout of the irrigated rice plots and fishponds. The fishpond can be located either above the irrigated plots (in this case, the plot is fertilized with water from the fish pond), or on the same plot (where the symbioses is complete), or below the irrigated plot (where fish farming is conducted in the drainage water coming from the irrigated plot). However, the integration of irrigation and aquaculture is not limited to rice-fish farming. Small storage reservoirs in irrigation schemes as well as irrigation canals can be suitable for raising fish using cages or pens.

Several regional and international meetings have established frameworks for programmes of integrated inland water resources management. The Expert Consultation organized jointly in May 1999 in Accra by FAO and the International Programme for Technology and Research in Irrigation and Drainage (IPTRID) on the Water Vision for Food and Rural Development in West Africa, recognized the need to improve water productivity and water efficiency. Increasing water productivity is central to producing food, to fighting poverty and reducing competition for this essential resource. Integrated Water Resources Management (IWRM) is an important concept that translates the vision into action, promoting the coordinated development and management of water, land and related resources in order to optimize economic and social welfare without compromising the sustainability of ecosystems.

The Ministerial Declaration of the Third World Water Forum (Japan, 16 - 23 March 2003), recognizing the increasing pressure on limited freshwater resources and on the environment, emphasized the need for good governance in water management, with stronger focus on household and community-based approaches by addressing equity in sharing benefits, with due regard to pro-poor and gender perspectives in water policies. At the Ministerial Conference, governments committed themselves to the preparation of IWRM plans by 2005 in accordance with the Plan of Implementation of the World Summit on Sustainable Development (WSSD, Johannesburg, 26 August - 4 September 2002).
Fish farming and other forms of aquaculture are one component of integrated water management that produces food of high nutritional quality, and often high economic value. The 21st FAO Regional Conference for Africa (Yaoundé, February 2000) acknowledged the importance of aquaculture and recommended that FAO “assist governments in elaborating effective aquaculture policies and streamlining public sector support to foster increased aquaculture production”. The Conference endorsed the policy objective of increased food production and food security through expansion of efforts in areas of sustainable land and water use development.

The Bangkok Declaration, elaborated during the global Conference on Aquaculture in the Third Millennium (Bangkok, February 2000), echoed these sentiments, stating that “the potential of aquaculture to contribute to food production has not been realized across all continents” while “aquaculture complements other food production systems and integrated aquaculture can add value to current use of on-farm water resources”.

Recognizing the need to expand on these kind of activities in its member countries, the Committee for Inland Fisheries of Africa (CIFA) at its eleventh Session in October 2000 in Nigeria unanimously endorsed the concept of a regional programme on Integrated Inland Water Resources Management in Drought prone West African countries and urged Member Countries and other stakeholders to find funds for its implementation.

In this framework, integrated irrigation and aquaculture (IIA) is a strategy to achieve agricultural productivity from every drop of water while improving the financial sustainability of investments in irrigation. Adopting integrated irrigation and aquaculture through a programme of Integrated Inland Water Resources Management will contribute to improved food security in drought-prone West African countries.

In practice, IIA is not new but simply a statement of a logical approach to resource use that has, in one way or another, been employed by residents of water-scare areas for centuries. Nevertheless, as a formal and structured programme, it represents a new, interdisciplinary approach that has heretofore not been actively promoted or supported. It is important to note that the systems targeted for IIA are integrated; this implies a higher level of interrelationship than more common associations. IIA technologies seek to reuse resources such that the whole is greater than the sum of the parts. To a large extent, these technologies remain to be aggregated and collated in a form that can be effectively distributed to stakeholders.

Much local knowledge exists concerning resource reuse. Floodplains, for example, have traditionally been employed for integrated production systems. Over millennia, farmers and fishers have naturally balanced different production environments and systems for the well-being of their families; these interrelationships being dealt with in time-honoured ways that have become part of rural communities’ way of life. Now, as populations concentrate, resources decline and there is an awareness that productivity and efficiency must increase to meet growing needs, these traditional systems must be analysed and used as the bases for integrated resource management, including IIA.

With this in mind, the Food and Agriculture Organization of the United Nations (FAO) and the West African Rice Development Association (WARDA) jointly organized a workshop on the development of IIA in West Africa in November 2003 in Bamako, Mali. The objectives of this Workshop were to review the achievements and constraints of integrated irrigation and aquaculture activities in the West African sub-region, to develop a common approach and shared methodologies for IIA, and to elaborate national strategies for the promotion of IIA. The findings and recommendations have been summarized in a Report (FAO/WARDA, 2005).

which highlights appropriate approaches to IIA development in the West African sub-region and elaborates the way forward for national IIA development in the sub-region\(^2\).

This volume represents the supplement to this report and contains all the papers presented at the workshop as well as studies and analyses that were commissioned by the FAO in preparation for the workshop. Submitted presentations from the Bamako workshop were technically reviewed by the members of the Technical Secretariat of the Workshop (M. Halwart, I. Beernaerts, C. Brugère, P. Kiepe and J.F. Moehl). All material, including the preparatory studies and analyses, were compiled and edited by M. Halwart and A.A. van Dam.

Many thanks to J. Peterson and A. Coche who assisted with the translation and verification of two documents. It is envisaged that this volume will be made available in French language. The entire document is intended to be available for downloading from the FAO Web site (http://www.fao.org).

It is hoped that this volume will make a marked contribution to developing relevant and appropriate IIA systems particularly in food insecure parts of West Africa.

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\(^2\) The Report also contains the contact details of all 45 country participants and resource persons who attended the workshop.
CHARACTERIZATION OF THREE KEY ENVIRONMENTS FOR INTEGRATED IRRIGATION–AQUACULTURE AND THEIR LOCAL NAMES

Paul Kiepe
Inland Valley Consortium, WARDA – The Africa Rice Center
Cotonou, Benin


Abstract

The paper provides a definition of wetlands and stresses the difference between wetlands as ecosystems and wetlands as production systems. The different classification systems available to refer to their specific usage are shown. Wetlands are defined as areas that are partly or completely inundated for some or all of the time. Tropical wetlands can be classified into four main groups: coastal plains, inland basins, river floodplains and inland valleys. Inland valleys represent 36% of total area covered by wetlands in sub-Sahara Africa; they are the upper reaches of river systems, in which alluvial sedimentation processes are almost or completely absent. The availability of a local classification of wetlands is pointed out: local names can provide important and unexpected information in site-specific studies. There are however risks of mistranslating them as one local name may encompass several different wetland types as we know them. Bearing this in mind, local classification provides a valuable tool in describing integrated irrigation–aquaculture (IIA) locations. With particular regard to IIA in West Africa, three key environments encompass the majority of IIA systems: (1) irrigated systems, (2) floodplains and (3) inland valley bottoms.

Introduction

The common denominator of the three key environments for integrated irrigation–aquaculture (IIA) – irrigated systems, floodplains and inland valleys – is that they are all wetlands. However, classification and characterization of wetlands are problematic, because there are many classification systems. One of the conclusions of the FAO-sponsored “Wetland Development and Management (WEDEM) Workshop on Sustainable Inland Valley Use” in 1996 in Cotonou, Benin, was the lack of a common approach to classifying and characterizing wetlands. This conclusion was not new; the issue had been raised on several previous occasions and it was one of the factors motivating the launch of the Inland Valley Consortium (IVC) in 1993. A closer look at classification systems of wetlands that are relevant for this workshop may shed light on the matter.

Wetlands

Wetlands are areas that are partly or completely inundated for some or all of the time. They generally include swamps, marshes, bogs and shallow waters. Wetlands are site-specific, complex ecosystems and are critical to the survival of many communities throughout the world. Wetlands occupy about ten percent of sub-Saharan Africa (Table 1). There are two conflicting views about wetland management: one agricultural and the other ecological. From an agricultural point of view, wetlands are assumed to form the basis of robust production systems, less sensitive to degradation than the adjacent uplands due to the frequent inflow of water, nutrients and organic debris. On the other hand, ecologists regard the same wetlands as fragile ecosystems that should be handled with care. A distinction should therefore be made between a wetland ecosystem and a wetland production system.
Table 1. The extent of wetlands in tropical sub-Saharan Africa and proportion of wetland types in total wetland, arable land and total land area (Andriesse, 1986).

<table>
<thead>
<tr>
<th>Wetland type</th>
<th>Area (km²)</th>
<th>Proportion of wetland type of total wetlands (%)</th>
<th>Proportion of wetland type of arable land (%)</th>
<th>Proportion of total land (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coastal wetlands</td>
<td>165 000</td>
<td>6.9</td>
<td>1.5</td>
<td>0.7</td>
</tr>
<tr>
<td>Inland basins</td>
<td>1 075 000</td>
<td>45.0</td>
<td>9.7</td>
<td>4.5</td>
</tr>
<tr>
<td>River floodplains</td>
<td>300 000</td>
<td>12.6</td>
<td>2.7</td>
<td>1.3</td>
</tr>
<tr>
<td>Inland valleys</td>
<td>850 000</td>
<td>35.6</td>
<td>7.7</td>
<td>3.6</td>
</tr>
</tbody>
</table>

**Wetland ecosystems**

The Ramsar Convention on Wetlands defines wetlands as "areas of marshes, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is flowing or static, fresh, brackish or salty, including areas of marine water the depth of which at low tide does not exceed six meters". The Ramsar classification divides wetlands into three main categories:

- Marine and coastal wetlands;
- Inland wetlands;
- Man-made wetlands.

The main categories have further subdivisions resulting in a total of about forty wetland types (Ramsar, 1999).

Wetlands have important ecological functions like water purification, groundwater recharge, carbon sequestration and protection against flooding and erosion. Wetlands also provide resting and nesting sites for many wildlife species. They can be regarded as a maternity ward and nursery for fish, amphibians, reptiles, birds and mammals, and are particularly important for shy and rare species.

**Wetland production systems**

The focus for this workshop is on wetland production systems. Wetlands have important economic functions like crop (e.g. rice) and vegetable production, as a source for thatching, fencing and basket weaving material, fishing and as a water source and grazing area for livestock in the dry season. While the Ramsar convention classified wetlands with the aim of safeguarding the biodiversity of sensitive ecosystems, agricultural research organizations classify wetlands according to a number of other criteria, as described hereafter with a presentation of three existing classifications which are relevant to the three key environments selected in the context of this workshop for IIA development.

**WURP classification of African wetlands**

The Wetland Utilization Research Project (WURP), funded by the Dutch Government (DGIS) and executed by the International Institute of Tropical Agriculture (IITA) and the University of Wageningen in the early 1980s, had as its main objective the development of inland valley bottoms for wetland rice cultivation. The first phase of the WURP was an inventory of information to identify the extent and categories of wetlands in the humid and subhumid zones of West Africa (Windmeijer and Andriesse, 1993). Four major wetland types were distinguished, based on geomorphological considerations:

- Coastal plains (deltas, estuaries, tidal flats);
- Inland basins (large drainage depressions);
- River floodplains (recent alluvial deposits);
- Inland valleys (locally also called dambos, fadas, bas-fonds, or inland valley swamps).

The extent of the four wetland types in Africa was estimated from extrapolation of the results from West Africa superimposed on the FAO soil map of Africa, as indicated in Table 1.
Table 2. Relative importance of rice production systems in West and Central Africa (WARDA, 1997).

<table>
<thead>
<tr>
<th>Rice production system</th>
<th>Area (%)</th>
<th>Production (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tidal water (mangrove swamps, coastal plains)</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Deepwater or floating rice</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>Irrigated systems</td>
<td>12</td>
<td>28</td>
</tr>
<tr>
<td>Rainfed uplands</td>
<td>31</td>
<td>25</td>
</tr>
<tr>
<td>Rainfed lowlands</td>
<td>44</td>
<td>36</td>
</tr>
</tbody>
</table>

WARDA classification of rice production environments

WARDA (The Africa Rice Center) recognizes four major rice production systems in West Africa (Table 2):

- Tidal waters (mangrove swamps and coastal plains);
- Deepwater/flooding environments;
- Irrigated systems;
- Rainfed uplands;
- Rainfed lowlands.

Because the rainfed uplands, rainfed lowlands and irrigated systems account for the bulk of area and total production in western and central Africa, and because of their role in poverty reduction, priority was given to work in these three production systems. Relatively little direct attention was given to other systems such as mangrove and deepwater rice production, not because these systems were less important but merely because it was more resource-effective to concentrate on the three aforementioned production systems.

FAO classification

The FAO/World Bank Global Farming Systems Study recognizes eight different farming systems (Dixon and Gulliver, 2003):

- Irrigated smallholder farming systems;
- Wetland rice-based farming systems;
- Rainfed farming systems in humid areas;
- Rainfed farming systems in steep and highland areas;
- Rainfed farming systems in dry or cold areas;
- Dualistic farming systems with both large-scale commercial and smallholder farms;
- Coastal artisan fishing mixed farming systems;
- Urban-based farming systems.

The first three farming systems are relevant to rice–fish culture and coincide to a large extent with the three key environments selected for this workshop.

The IIA key environments

The classification used in the context of IIA development is:

- Irrigated systems (full water control);
- Floodplains;
- Inland valleys (no or partial water control).

This classification is thus based on a combination of geomorphology and water management considerations, as illustrated in Figure 1.

Irrigated systems

Irrigation can be described as the supply of land with water by means of artificial canals and ditches, to promote the growth of food crops. Irrigated systems are found in West Africa in inland basins, like the Senegal basin, the inner Niger delta, the Volta basin and along the floodplains of major rivers. Irrigation is about water supply on demand, independent of rainfall. Water retention by bunds without bringing in additional water, as often found in inland valleys, therefore cannot be considered as irrigation (Young, 1998).

Floodplains

A floodplain is a usually dry and relatively flat area of recent alluvial deposits alongside a stream or river and is subject to periodical inundation. Large floodplains are very suitable for irrigation, because they are more or less
Inland basins (extensive drainage depressions like the Niger, Nile and Congo basins and Lake Chad)

Floodplains (a wide and relatively flat plain of recent alluvial deposits bordering a river)

Inland valleys (the numerous flat-floored and relatively shallow valleys that occur extensively in the African landscape)

Full water control systems

Partial water control systems

Systems with no water control

**Geomorphology classification**

**Water management classification**

**IIA key environments:**
- Irrigated systems (full water control)
- Floodplains
- Inland valleys (no or partial water control)

Figure 1. Classification of integrated irrigation-aquaculture (IIA) environments based on a combination of geomorphology and water management considerations.

levelled, often fertile and close to a water source. Floodplain irrigation systems can be based on gravity, where water is delivered by a canal that runs upstream along the river to a point that allows water intake with sufficient pressure head. A disadvantage of these systems is that they depend on water level fluctuations in the river and intake may no longer be possible below a certain water level.

**Inland valleys**

Inland valleys are the upper reaches of river systems, in which alluvial sedimentation processes are almost or completely absent. Inland valleys include valley bottoms and minor colluvial floodplains, which may be submerged part of the year, their hydromorphic fringes and continuous upland slopes and crests extending over an area that contributes runoff and seepage to the valley bottom. The term partial water control is used for water retention by dikes or bunds in rainfed agriculture.

The classification chosen for IIA is pragmatic, as the three environments are not mutually exclusive. Full-control irrigation systems are often found in inland basins, but they are also encountered in floodplains or even in inland valleys. However, some confusion may arise regarding what to incorporate under the term "irrigation". While full water control is evident, the area of "partial water control" is less well-defined.

**Local classification of wetlands**

Every rural population has its own interpretation and its own words for areas of specific interest. Local names, also called vernacular or indigenous names, often don't correspond to a formal scientific classification because they are based on other criteria. So, a word of caution must be expressed on the use of indigenous nomenclature. These problems may arise in inventories that are based on interviews with farmers. Any question posed in a local language that is
related to a typology of the environment is likely to be answered with the vernacular name in the local language. Local names can provide important and unexpected information in site-specific studies, but if the objective is to relate the acquired information to a larger area, questionnaires should be designed to trace a category in a classification system and vernacular names should be used in such a way that they coincide with a unique category.

Some examples of indigenous wetland names

- **Inland valleys** (Anglophone West Africa). The term inland valley refers to the numerous flat-floored and relatively shallow valleys that occur in the extensive undulating plains and plateaus that make up most of the African landscape (Andriesse, 1986). The name was adopted by IVC because of its widespread use in Anglophone West Africa;
- **Bas–fonds** (Francophone West Africa). Strictly speaking, it is the valley bottom *per se* and not the inland valley. *Vallée Intérieure* refers to the valley as a whole, but the word bas–fond is more commonly used;
- **Boli lands** (Sierra Leone). Boli lands refer to a complex of seasonally-flooded wide and shallow depressions and low river terraces of negligible relief. Boli lands include inland valleys as well as floodplains;
- **Fadama** (Hausa) is a seasonally-flooded area. Fadamas comprise inland valleys as well as floodplains;
- **Dambo** (in Chichewa meaning valley meadow land). Dambos are periodically inundated depressions formed by weathering of the parent rock (Roberts, 1988). According to Mackel (1985), dambos are natural ecosystems occupying a shallow, seasonally-waterlogged depression at or near the head of a drainage network. This description coincides with that of an inland valley;
- **Mbuga** (in Swahili) is equal to dambo;
- **Matoro** (in Shona) is equal to dambo;
- **Vlei** (Afrikaans). An area of low marshy ground, especially one that feeds a stream. "Vlei" can be, but is not necessarily always, used to refer to an inland valley.

References


A REVIEW OF EXPERIENCE WITH AQUACULTURE INTEGRATION IN LARGE-SCALE IRRIGATION SYSTEMS

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Abstract

Irrigation systems do not only supply water to field crops but have many other productive and non-productive uses. Aquaculture is a productive, non-consumptive use of water that does not compete with irrigation. Theoretically, integration of aquaculture into irrigation systems may contribute to more efficient use of scarce freshwater resources. However, there is a need to study opportunities and constraints to integration of aquaculture in irrigation systems. Within formal, large-scale irrigation systems four functional subsystems can be distinguished: water source, delivery, use and disposal. While aquaculture may be integrated within any of these, this study focuses on canals and storage ponds within the delivery subsystem. Both floating cages and pens may be used to grow fish in these structures. Because of the great variability in conditions both within and between irrigation systems, conditions in storage structures must be evaluated carefully. Aquaculture is more demanding than irrigated crops in terms of continuity of water supply. Other points of attention are high loads of agrochemicals in return flows from agriculture fields, slow response times of water regulation in large irrigation systems, and the effect of aquaculture structures on water conveyance in the canals.

Introduction

It is generally acknowledged that since the 1960s technological advances in agriculture, collectively known as the “Green Revolution”, have provided the means for the developing world to feed its growing population. The dominant role of irrigation in promoting food security is also recognized. Irrigated agriculture in developing countries produces 40% of food and agricultural commodities and in Asia even 60% of total production. The corollary of this dependence on irrigated agriculture is that wherever irrigation is practised, it is one of the largest consumers of water. Globally 70% of all water extracted from rivers and underground aquifers is used for irrigation and in low-income countries the dominance is still greater, being 90% of total abstraction (Seckler et al., 1998). The distribution of irrigated land, however, is skewed towards a few countries and shows wide regional variations.

During the 1990s there was a dramatic shift in priorities for water resource allocation and development. Water scarcity has become a prominent issue with the result that irrigation is seen as both a profligate and a low-value user of water resources. There is great pressure to use water more effectively and often this involves reallocation of resources away from irrigation and in favour of municipal, industrial and environmental uses (Molden et al., 2001; Hamdy et al., 2003). Although this is not currently a major issue in sub-Saharan Africa, given projected population increases, it is expected that future food security depends upon rapid expansion of irrigated area and water scarcity will become a constraint (Gowing, 2003). This is leading to new perceptions of the need for proper understanding of the multiple uses of water within irrigation systems, for economic evaluation of non-irrigation uses (Meinzen-Dick and van der Hoek, 2001) and greater recognition of the linkages between water management activities and aquatic ecosystems (Bakker and Matsuno, 2001).

It is a common perception that irrigation systems supply water only to field crops, but the true picture is more complicated. Even within the agricultural sector, irrigation systems supply water not only for the main fields, but also for home garden cultivation and for livestock. Other productive uses may include
fishing, harvesting of aquatic plants and animals and a variety of other enterprises such as brick-making. Important environmental functions may include water supply to trees and other permanent vegetation, which provide an amenity to the local population and support biodiversity in plants, birds and other animals. Other non-productive uses may include laundry, bathing and domestic supply. Important implications for water management and policy arising from recognition of these multiple uses include considerations of: the valuation of water in irrigation systems, how systems are managed to maximize productivity and how water is allocated to alternative uses (Meinzen–Dick and Bakker, 2001).

The focus here is on fish production within irrigation systems and, in particular, opportunities for poor people to derive a livelihood benefit from this activity. It is evident that the extensive hydraulic engineering works associated with large-scale irrigation development have had a profound negative impact on many river ecosystems, which is reflected in a dramatic loss of biodiversity (Halls et al., 1999; Petr and Mitrofanov, 1998). Where this has resulted in loss of important subsistence fisheries, the impact of this change has generally been felt disproportionately by poor people. The opportunity may exist within the newly created irrigation systems to mitigate this negative impact by promoting complementary development of fish production, but this has generally been overlooked. Important fisheries do exist in irrigation canals in some countries, e.g. China (Tapiador et al., 1977), Pakistan (Javid, 1990), Egypt (Sadek and El Din, 1988), Sudan (Coates, 1984) and Thailand (Swingle, 1972), but little consideration has been given to the replacement of lost fishery potential through systematic development of aquaculture potential. Surprisingly little research evidence exists linking fish production to irrigation, either in terms of the impact on natural fisheries or the potential created for new managed fisheries. Furthermore, the linkages between fisheries management institutions and water management institutions are generally weak.

The irrigation environment

This paper is concerned with relatively large-scale irrigation systems providing full water control. There is no universally accepted classification, but irrigation systems can be defined in terms of their physical characteristics and also of their organizational characteristics. Size of the command area alone is not the distinguishing feature, since a 500 ha scheme may be classified as a “major” or “large-scale” scheme in one country, but be regarded as “minor” or “small-scale” in another. A more useful definition of the scope of this paper is that it concerns:

- formal hierarchies of open channels for controlled delivery of irrigation water and for removal of drainage water;
- formal organizational structures with a legally constituted management institution responsible for control of water allocation and delivery.

All formal large-scale irrigation systems comprise four functional subsystems: water source, water delivery, water use and water disposal. Figure 1 is a representation of these subsystems and their water flow linkages. A minority of irrigation systems include pipelines instead of open channels for part of their water delivery and/or water use subsystems, but open channel systems are more common.

As the size of command area may vary, so will the capacity and size of the primary and secondary canals. Typically, a primary canal may have a 5 to 50 m bed width and 1 to 5 m depth. In most circumstances, it will be designed to operate more or less continuously throughout the irrigation season. Design velocity depends on the nature of the bed material, whether it is lined or unlined, and whether it carries clear or sediment-laden water. Secondary and tertiary canals deliver water to progressively smaller sections of the command area and have accordingly smaller bed widths and depths. They are less likely to operate continuously.

Water storage structures provide operational flexibility in that they buffer differences between supply and demand. Distributed storage within the water delivery system is not always present; where it exists it may be provided as a buffer between primary and secondary canals or between secondary and tertiary canals. Storage may also exist within the water use subsystem as on-farm storage; either as farm ponds or as paddy basins. Important differences between storage structures are the duration and depth of storage, and the frequency and rate of variation.

It is sometimes reported that irrigation systems provide only a narrow range of habitats with much less diversity than natural
Fish in irrigation systems

Most irrigation systems probably sustain capture fisheries to some extent, although the practice is generally opportunistic. Usually, fish stocks are dependent upon fish entering the canal system from the source. Some species may form self-sustaining populations, but this is limited to those systems having favourable environmental conditions (Fernando and Halwart, 2000). A degree of management of fish stocks will be required to maintain a more productive and sustainable fishery. Such management may involve restocking and introduction of new species, but there is little recorded experience of such measures being adopted in canal systems, except where they have been primarily aimed at weed control through stocking of grass carp (e.g. Armellina et al., 1999).

Aquaculture offers greater control over production and access than is the case with capture fishery and even low-cost, semi-intensive systems can produce 1 500–2 000 kg/ha/year, which compares favourably with estimates for production from capture fisheries in canals. Cage-based aquaculture has been widely promoted in South and Southeast Asian countries (Beveridge and Muir, 1999) as a technology which can be easily adopted by resource-poor people. Cages can be made cheaply using widely available materials, such as bamboo (for frame) and plastic containers (for floats), but availability of suitable netting can be a constraint. Cages have the advantage for landless people that ownership is required only for the cage and its contents irrespective of the ownership status of the water body provided that access is assured.

An alternative is to produce fish in larger containment structures known as pens. Like cages, their sides are human-made, but an important difference is that the base is the canal substrate itself. This allows access to benthic organisms, providing an additional food source for the fish. At the same time it makes them less suitable than floating cages for canals with widely fluctuating water levels. Pens may be created by enclosing the full width of the canal, or may be aligned along the bank and occupy only part of the canal width (Beveridge, 1996; Haylor, 1993).
In parts of China and Southeast Asia, “integrated aquaculture” within the water use subsystem has existed for generations and its introduction into other countries has received considerable attention in recent years. Similarly, the potential for and constraints to harvesting and culturing fish within reservoirs of the water source subsystem are relatively well documented on the basis of experience in many countries. However, opportunities and constraints within the extensive engineered components of water delivery subsystems and water disposal subsystems have been largely neglected.

Case study of integrated aquaculture and irrigation

With this knowledge gap in mind, detailed interdisciplinary research was conducted between 1998 and 2002 at two sites in India and Sri Lanka to investigate potential for and constraints to integration of poverty-focused aquaculture within large-scale irrigation systems. Both sites lie within semi-arid environmental zones and both experience a tropical monsoon climate. Both experience water scarcity. Both are public irrigation schemes, which are managed by large bureaucratic organizations. At the time of the research, both were attempting to introduce institutional reform aimed at devolving some management responsibilities to water users.

Site 1

The Lower Bhavani Project (LBP) is located in Tamil Nadu state in southern India. Its water source is the Bhavani River, which rises in the Nilgiri Hills as a tributary of the Cauvery River. It is a typical valley-side system, comprising a 200 km contour canal serving a command area of 78,500 ha. Design capacity at the head of the system is 65 m$^3$/s with a canal bed width of 32 m and full supply depth around 3 m. In the tail reach, canal dimensions reduce to 4.5 m width and 1 m depth. The canal is unlined for most of its length with generally rocky bed and it carries a low sediment load. The system is about 50 years old.

Since the system experiences water scarcity, a “seasonal sluice turn system” applies. In the dry season of a calendar year (from 16 December to 15 April), water is rotationally released to the command area for raising irrigated dry crops. In the wet season (from 15 August to 15 December) water is “continuously” issued to the same zone for a rice crop. In the following year, this water allocation pattern is repeated for the other half of the command area.

Irrigation water in the LBP canal is used for livestock watering, laundry and bathing as well as irrigation. Groundwater recharge also depends to a large extent on irrigation. However, the statutes which govern the operation of the system do not recognize the water rights of other stakeholders and recent initiatives to devolve some management responsibilities to water users’ organizations have involved only irrigators.

Site 2

Mahaweli System H is situated in the North Central Province in the so-called “dry zone” of Sri Lanka. It was the first system developed under the Mahaweli Ganga Development Scheme and has been operational since 1978. System H lies within the Kala Oya basin and includes 14,200 ha of old irrigated areas and 28,750 ha of new land developed by the project. It incorporates three main reservoirs, whose limited storage is supplemented by transfers from the Mahaweli system.

There are two cultivation seasons in System H. Maha season (October to March) corresponds to the northeast monsoon and water supply is generally adequate for the full command area to be cultivated with rice. Yala season (April to September) corresponds to the Southwest Monsoon when water supply is limited and a “Bethma” system of cultivation is adopted, in which only 50% of the total area is brought under cultivation and “other food crops” (i.e. non–rice) dominate.

The feature of System H which is of particular interest is the large number of shallow reservoirs (known locally as tanks) distributed throughout the command area. These tanks existed prior to the development of System H. Originally they received runoff from local catchments (normally primary forest), but many are now connected to the new irrigation system by feeder canals, while others receive irrigation return flow in addition to catchment runoff.

Interdisciplinary research teams conducted extended fieldwork at these two sites on three key areas of research, as follows:

Socio-economic studies combined quantitative surveys at household level with qualitative studies based on PRA techniques in sample villages to investigate:
livelihood characteristics, strategies adopted by poor people and the importance of water; potential of aquaculture as an alternative or supplementary income-generating activity; potential for improved water use efficiency through integration of aquaculture/irrigation.

Engineering studies explored constraints to integrating cage-based aquaculture in irrigation canals and in secondary storage structures (tanks) within the irrigation distribution networks:

- secondary data sources allowed time series analysis in order to investigate duration and reliability of conditions suitable for aquaculture;
- primary data collection provided a basis for assessment of the impact of cages on flow in the canal and of cage anchorage and access issues;
- analysis of canal operating procedures in response to rainfall and of management of tank storage in combination with in-depth studies of water management provided a basis for considering whether multiple use management is compatible with a desire for efficiency.

Aquaculture studies began with in-depth consultations with primary stakeholders, which identified cage-based aquaculture as an appropriate technology. This led to:

- trials on cages at selected sites both in flowing canals and in tanks;
- investigations of the nature of the market for fish, particularly among rural consumers;
- investigations of attitudes of target beneficiaries to the proposed technology and requirements for its successful adoption.

Lessons for integrated aquaculture in large-scale systems

Opportunities

The aim of the intervention is to improve the livelihoods of the rural poor and to promote food security through improved food supply, employment and income. We are therefore seeking to introduce and promote appropriate technologies for aquaculture within irrigation systems where these are likely to provide livelihoods benefits to poor people without unacceptable impacts on other water users. A general framework for the assessment is shown in Figure 2. In the past, poor people have been largely bypassed in aquaculture development and their specific needs require careful consideration. It is by no means certain that the introduction of small-scale aquaculture technologies will contribute to the alleviation of poverty. There may be better ways for poor people to use their limited resources. A key question is:

- Is there potential for aquaculture activities to offer livelihoods benefits to poor people?

Having established that there may be potential demand amongst the target group, the next consideration is whether suitable mechanisms exist to introduce appropriate technologies to them. Within the wider context of agricultural development, there is frequent criticism of the traditional transfer of technology based on training and demonstrations. The alternative farmer first or participatory approach attempts to ensure the relevance of the technology by providing options and ideas and developing capacity to evaluate them and make informed decisions. A key question is:

- Do appropriate technologies exist and can they be made available to poor people?

The next requirement is to remove technical and institutional obstacles that may affect the successful adoption of appropriate technologies by the target group. This requires consideration of opportunities and constraints within the irrigation system. The aim is to identify favourable sites (niches) where the environment is suitable for aquaculture and its introduction will not have any adverse impact on the integrity of the irrigation system or on other water users. The key question is:

- Do suitable niches exist within the irrigation system where they can be introduced?

It is clear that the range of niches that may be available for aquaculture depends on the nature of the irrigation system and opportunities within each subsystem should be evaluated systematically. The situation can best be understood by considering the four component subsystems previously defined (Figure 1). We can then identify the possible niche opportunities for aquaculture that may exist in each subsystem, as summarized in Table 1.
This paper concentrates on niches within the water delivery system. In general, there will be greatest diversity within rice systems of tropical lowlands, but some niches can probably be identified in all irrigation systems. Conditions prevailing in the different niches must be considered carefully, since they can be expected to lead to different constraints. Key differences are:

- Stored water (ponds and reservoirs) versus flowing water (canals and drains);
- Upstream conditions (good water quality) versus downstream conditions (degraded quality);
- Individual control (private ownership) versus shared control (open access).
**Constraints**

Fish production poses a far greater challenge to system managers than irrigation in that continuity of supply must be guaranteed for the duration of the growing season. Whereas crops will suffer no yield penalty from a discontinuous supply because of buffer storage in the soil, fish will not survive any break in supply. In the case of LBP, the duration of the wet season (4 months) was sufficient to allow a short-cycle aquaculture crop, but reliability was a problem in 10 of the 12 seasons investigated (Li, Gowing and Mayilswami, 2005). Water supply reliability is a crucial constraint to integration of aquaculture and this is related to inherent difficulties in efficient operation of extensive canal systems under upstream control because:

- Long supply canals respond slowly to operational adjustments (more than 5 days response time at the tail of 200 km long LBP canal);
- Rainfall may vary significantly across an extensive command area leading to problems with interpreting available data and in determining appropriate action;
- Communications between operations staff may be a constraint and this is likely to be worse during critical periods of heavy rainfall.

Reliability of conditions suitable for aquaculture depends on design and operation decisions that influence continuity of supply and/or storage, such as:

- What type of regulator structure? (Overflow type is preferred) How closely spaced are regulators? What are their operating rules?
- Is secondary storage provided within the water delivery subsystem? Is it actively managed or does it simply receive drainage return flow? What are the operating rules?

Flow depth in irrigation canals is typically in the range 0 to 3 metres, while velocity is usually in the range 0.1 to 1.0 m/s. These factors may be important considerations for:

- fish survival and growth;
- access for feeding/managing/harvesting fish.

The desirable range of velocity depends upon the fish species and size. Good water exchange is essential for oxygen supply and removal of waste metabolites from fish. If velocity is too slow then this may be a problem. On the other hand, excessive velocities reduce fish growth rates and contribute to food losses. A range of 0.1 to 0.6 m/s is usually satisfactory, although the upper end of this range may create problems with anchorage of containment structures. If access depends on wading or swimming then the lower end of the range will be safer.

Where flow velocity is too high, it is possible to design the fish containment structure in such a way that velocity inside the structure is restricted (Li, Gowing and Mayilswami, 2005). The consequence of this action is that the dynamic loading on anchorages will be increased as will flow resistance. The limited documented experience of aquaculture in irrigation systems does include some cases of uncontrolled development interfering with canal performance. Careful consideration must therefore be given to:

- likely impact on canal conveyance capacity and operational performance;
- possible interference with maintenance activities.

<table>
<thead>
<tr>
<th>Sub-system</th>
<th>Niche</th>
<th>Aquaculture technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water source</td>
<td>Storage dam</td>
<td>Floating cages, stocked fishery</td>
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<td></td>
<td>Open wells</td>
<td>Stocking</td>
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<td>Water delivery</td>
<td>Primary canals</td>
<td>Pens, cages</td>
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<td></td>
<td>Secondary storage</td>
<td>Floating cages, stocked fishery</td>
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<tr>
<td>Water use</td>
<td>Farm ponds</td>
<td>Stocking</td>
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<td></td>
<td>Irrigated fields</td>
<td>Integrated rice-fish</td>
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<td>Water disposal</td>
<td>Primary drains</td>
<td>Pens, cages</td>
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<td></td>
<td>Evaporation ponds</td>
<td>Floating cages, stocked fishery</td>
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</tbody>
</table>
Any cage or pen introduces additional flow resistance and has a local effect on canal conveyance. The question is: does this represent a serious obstruction or can cages be designed and sited in such a way that they have negligible influence on canal water levels and discharge capacity? The hydraulic performance of any cage (or pen) is essentially the same. Water flowing through a mesh panel imposes a drag force on the panel, which results in a reduced velocity on the downstream side of the panel.

The desirable range of depth depends primarily on the type of fish containment structure. Pens and some cages are designed to sit on the bottom. The effective volume (and therefore stocking density) varies with flow depth and in general fixed structures are not appropriate if water depth varies. This is a particular problem if the structure is situated at the side of the canal and does not utilise the full depth. Depth variation is not important in floating cages, but access becomes difficult if depth exceeds 1.2 m and water depth should always exceed cage height.

Selection of the cage site can make a considerable difference to the influence on the canal and the recommended general approach is to regulate their installation and monitor their impact. Problems are likely to be more severe in a canal system on minimum slope as the effect of increased flow resistance will be to raise water levels upstream, which may affect performance of off-takes and/or lead to overtopping. For a canal built on a steeper alignment with drop structures at intervals to dissipate excess energy, then opportunity to install cages/pens without affecting performance will be greater. In either case, the increase in hydraulic resistance need not be any more severe than the recurrent problem of weed growth. Any site where this is known to be a particular problem and to affect canal performance should be excluded from consideration for installation of cages and/or pens.

Cages will normally be small relative to the canal width, but may be sited in mid-stream or close to the bank. Where a cage/pen occupies less than 25% of canal width and is sited close to the bank, the current will be partly deflected around the obstruction and its effect will be relatively small.

Any storage site within the irrigation system is likely to represent a potentially more favourable niche when compared to any canal site. Duration and reliability constraints are likely to be greatly reduced, thus making the enterprise less risky for target beneficiaries. At the same time, the impact on hydraulic performance is negligible, thus making the introduction of aquaculture less likely to create any problems for system managers. In this context, we are not concerned with any large reservoir that may exist within the water source subsystem. Rather we are interested in niche opportunities within any structures providing relatively short-term storage distributed throughout the water delivery subsystem. These may be:

- night storage reservoirs (typically 12–16 hours storage);
- secondary storage reservoirs (typically 10–20 days storage).

Work within the research project was focused on secondary storage reservoirs (known locally as “tanks”), which received water from the canal system as well as rainfall runoff from a local catchment and released supplies to a distinct downstream command area. Their key characteristics were found to be (Gowing, Li and Gunawardena, 2004):

- shallow depth (<3m);
- frequent and rapid water level fluctuations;
- short retention time (rapid turnover).

It can be assumed that any secondary storage structure will behave similarly, since its function is to buffer flow variations over a short time scale. The shallow depth of such reservoirs results in wide variations in water spread area as water level fluctuates, which introduces constraints on siting of cages/pens. Improved operating procedures can reduce this problem, but it cannot be avoided. At the same time, the turnover rate can be reduced, but retention time will always be quite short (typically 20 days) thus limiting primary productivity and therefore fishery potential.

Conclusions

It is a common perception that irrigation systems supply water only to field crops, but the true picture is more complicated. Growing recognition of the multiple uses of water within many established irrigation systems has revealed many other productive and non-productive uses. Aquaculture is a water-dependent activity, which is productive, but non-consumptive and therefore, in principle, not in competition with irrigation. However, opportunities for and constraints to its
integration within irrigation systems have received little attention.

Within formal, large-scale irrigation systems, we can identify four functional subsystems: water source, water delivery, water use and wastewater disposal. Opportunities may exist to incorporate aquaculture within any of these subsystems, but this paper has focused on canals and storage ponds within the delivery system and in particular on opportunities for the introduction of appropriate technologies targeted at the needs of poor people. The aim is to identify favourable sites (niches) where the environment is suitable for aquaculture and its introduction will not have any adverse impact on the integrity of the irrigation system or on other water users.

Conditions prevailing in the different niches must be evaluated carefully, since they can be expected to lead to different constraints. Formal, large-scale systems are generally considered to provide full water control, but aquaculture poses a far greater challenge to system managers than irrigation in that continuity of supply must be guaranteed for the duration of the growing season. Whereas crops will suffer no yield penalty from a discontinuous supply because of buffer storage in the soil, fish will not survive any break in supply. The requirement for strict continuity of supply may lead to lower water use efficiency, particularly during the rainy season. Any storage site within the irrigation system is likely to represent a potentially more favourable niche when compared to any canal site, but problems still remain.

Irrigation canals provide flowing conditions, which may present fewer problems with water quality than occur within storage ponds. However, water temperature and quality (turbidity, salinity etc.) may differ greatly from those occurring in natural channels. Return flows from agricultural fields may carry high loads of agrochemicals and in some cases industrial effluents may also cause significant water quality deterioration.

Local management institutions exist or are currently being created in many large-scale irrigation systems, but representation of non-irrigation water users is generally poor. Water rights, access and charging issues therefore require careful consideration in order to promote multiple use management of irrigation infrastructure.

Acknowledgement

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COMMUNITY-BASED FISH CULTURE IN SEASONAL FLOODPLAINS

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Abstract

During the rainy season in extensive river floodplains and deltaic lowlands, floods lasting several months render the land unavailable for crop production for several months each year. These waters are considerably underutilized in terms of managed aquatic productivity. This raises the opportunity to enclose parts of these floodwater areas to produce a crop of specifically stocked aquatic organisms aside from the naturally occurring "wild" species that are traditionally fished and are not affected by the culture activity, overall resulting in more high-quality, nutrient-dense food production and enhanced farm income for all stakeholders, notably the poor. The WorldFish Center and its national partners recently tested the concurrent rice-fish culture in the shallower flooded areas and the alternating rice-fish culture in the deep-flooded areas of Bangladesh and Viet Nam through a community-based management system. Results indicate that community-based fish culture in rice fields can increase fish production by about 600 kg/ha/year in shallow flooded areas and up to 1.5 tonnes/ha/year in deep-flooded areas, without reduction in rice yield and wild fish catch.

Introduction

The past decade has seen growing recognition of the crisis facing the world’s water resources and the need for concerted action to use these more efficiently. The efficiency of water use (or water productivity) can be increased by producing more output per unit of water used, or by reducing water losses, or by a combination of both. So far, strategies for increasing output have been limited to crop cultivation only. Water productivity at several organizational levels can be increased further by integrating fish and other living aquatic resources into the existing water use systems. Such opportunities of integration include community-based fish culture in irrigation schemes and seasonal floodplains.

A variety of studies show that reservoirs and canals of irrigation systems continue to yield substantial fish harvests, which are important sources of protein and livelihoods for the poor and landless households. Yet the current use of irrigation systems and floodplains for fish production falls far short of potential. In seasonal floodplains, fish production essentially emanates from capture activities by seasonal or part-time fisher-farmers where wild fish enter, reproduce and are harvested from the flooded fields. In Cambodian floodplains, the value of fish caught through trap ponds within rice fields reaches 37 to 42 percent of that of rice production (Gregory and Guttman, 1996; Guttman, 1999).

A number of studies have been conducted in the 1980s to test the technical feasibility of culturing fish in seasonally flooded rice fields in India (Roy et al., 1990; Das et al., 1990; Mukhopadhyay et al., 1991), Bangladesh (Ali et al., 1993, Ali et al., 1998), Cambodia (Gregory and Guttman, 1996; Guttman, 1999, 2000), and Viet Nam (Rothuis et al., 1998a; Rothuis et al., 1998b). These studies show that fish production can be increased by more than 1 tonne/ha/year by stocking flooded ricefields with fish (i.e. individual farmers fencing their plots and stocking fish during the flood season). In addition, the culture of fish within rice fields can increase rice yields, especially on poorer soils and in unfertilized crops where the fertilizing effect of fish is greatest (Halwart, 1998). Savings of pesticides and earnings from fish sales lead to increased yields and result in net incomes that are 7 to 65 percent higher than for rice monoculture (Halwart, 1998). But the adoption of this technology by farmers has
been very low due to the high cost of fencing individual plots.

Recently the WorldFish Center established a new approach in Bangladesh and Viet Nam, where fish is cultured communally during the flood season and the same land is cultivated with rice during the dry season individually. The results of initial trials show an additional 10 percent lower cost of rice production and a net return from fish production of 400 US$/ha in the Ganges and Meghna floodplains (Bangladesh), 340 US$/ha in the Red River Delta (Viet Nam), and 220 US$/ha in the Mekong Delta (Viet Nam). Significantly, these benefits were obtained with no reduction in the wild fish catch, composed mainly of small indigenous species (SIS). The returns from the sale of the produced fish were distributed among the group members according to a sharing arrangement that was pre-negotiated among group members at the beginning of the season. Gains to the landless were in form of cash income, which was significant as they did not have any alternative income generating opportunities.

There are many options for enhancing food production from fish in managed aquatic systems. The most appropriate technology will vary from country to country and site to site. Additionally, the social and economic conditions under which these technologies can be implemented need to be understood. Although our recent studies in Viet Nam and Bangladesh demonstrated the feasibility of the community-based fish culture systems, much more work is needed to understand the social and economic viability of these approaches under different socio-cultural and institutional environments, and to design appropriate institutional arrangements for different social settings. Similarly, the governance arrangements for fish culture in irrigation systems (canals, fields, reservoirs) also require detailed analyses if the full social value of these resources is to be harnessed.

At the ecosystem or basin level, water provides a wide range of goods and services, all of which need to be considered in broader analyses of the value obtained from water. Most of the previous studies of water productivity have concentrated on measuring the value of crop production only and excluded the existing and potential contributions by living aquatic resources. There is therefore a need not only to increase water productivity, but also to improve the methodologies for measuring water productivity.
Fig. 2.1. Farming System Evolution in Floodprone Areas (2/6)

Moderately Deep Flooding Land:
Rice followed by Deepwater Rice (1980s...)

Fig. 2.2. Farming System Evolution in Floodprone Areas (3/6)

Deep Flooding Land:
HYV - ‘Green Revolution’ followed by Fallow (1980s - 1990s)
Fig. 3.1. Farming System Evolution in Floodprone Areas (4/6)

Moderately Deep Flooding Land:
Rice followed by Deepwater Rice+Fish (2000s ...)

- Rice: 6-7 t/ha/yr
- Wild fish: 60-70 kg/ha/yr
- Stocked fish: 600 kg/ha/yr
- Income: ~770 $/ha/yr

Fig. 3.2. Farming System Evolution in Floodprone Areas (5/6)

Deep Flooding Land: Rice followed by Fish-only (2000s ...)

- Rice: 6 t/ha/yr
- Wild fish: 150-200 kg/ha/yr
- Stocked fish: 0.5-1.5 t/ha/yr
- Income: 1000 $/ha/yr
**Floodplain farming system evolution**

Farming practices in the flood-prone ecosystem are governed by a number of interacting physical factors, of which the chief ones are the flooding regime (onset, depth, recession, and variability), topography, rainfall pattern, soil texture and water management regime. Traditionally, farmers used to grow deepwater rice and capture fish during the rainy/flood season and subsequently cultivate a wide range of crops (such as pulses, oil seeds, and vegetables) during the post-flood dry season (Figure 1). In Gangetic floodplains (Bangladesh and eastern India), farmers used to get a maximum 2 tonnes of traditional rice and approximately 200 kg of wild fish per hectare per year with an average income of about US$ 300 per hectare per year.

During the last few decades, the flood-prone ecosystems in Asia have undergone some dramatic changes due to the establishment of deep wells (for example, in Bangladesh and eastern India) and construction of the Flood Control Drainage and Irrigation (FCDI) systems. With the availability of irrigation facilities, farmers grow high yielding varieties (HYV) of rice in the dry season under irrigated conditions. In Gangetic floodplains the dominant farming pattern in shallow flooded areas is irrigated HYV rice during the dry season followed by transplanted deepwater rice varieties during the rainy seasons (Figure 2.1), while the dominant pattern in deep flooded areas is single-crop irrigated HYV rice (Figure 2.2). Late harvest of HYV dry season (winter) rice does not allow timely establishment of a deepwater rice crop in the deep-flooded areas during the rainy season.

In shallow flooded areas in the Red River Delta (in northern Viet Nam), farmers generally grow high yielding irrigated rice during the dry season, and a tall-growing local or higher yielding variety during the rainy season. In the Mekong Delta of southern Viet Nam, where rice fields are also deeply flooded in the rainy season, two irrigated crops of high yielding rice varieties are grown with a flood fallow period in between. Although the introduction of irrigation-based “green revolution” technology has increased the total rice production in flood-prone areas (from about 2 tonnes/ha/year to about 6-7 tonnes/ha/year), the wild fish harvest from flooded rice fields has declined substantially (from 200 kg/ha/year to less than 100 kg/ha/year).

An opportunity for further increased production in the flood-prone ecosystem is the integration of fish culture with rice farming. The flood-prone areas are seasonally flooded during the monsoon and remain submerged from 4 to 6 months. In these flood-prone areas, land ownership is fixed according to tenure arrangements during the dry season. But during wet season floods, individual land holdings are not visible and waters are a community property granting all members access to fish in all areas of the community. Therefore, it is essential that the rice-fish culture activity in the flood-prone ecosystem is undertaken by the rural community under a group approach. The group should include the landless who have traditionally accessed the flooded areas for fishing, but would lose this essential resource if they were denied access because the areas are stocked with fish.

Generally, three types of rice-fish culture systems can be established in flood-prone areas: (i) concurrent culture of deepwater rice (with submergence tolerance) with stocked fish during the flood season followed by dry season rice in shallow flooded areas; (ii) concurrent culture of deepwater rice (with elongation ability) with stocked fish during the flood season, followed by dry season non-rice crops; and (iii) alternating culture of dry season rice followed by stocked fish only during the flood season (that is, without rice) in the enclosed area (for example, as in a fish pen). The WorldFish Center and its national partners recently tested the concurrent rice-fish culture (option i above; Figure 3.1) in the shallower flooded areas and the alternating rice and fish culture (option iii above; Figure 3.2) in the deep-flooded areas of Bangladesh and Viet Nam through a community-based management system. Results indicate that community-based fish culture in rice fields can increase fish production by about 600 kg/ha/year in shallow flooded areas and up to 1.5 t/ha/year in deep-flooded areas without reduction in rice yield and wild fish catch. These (as also shown in Figure 4) and other potential technical options need to be tested and validated in various floodplains of Asia and Africa under varying...

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1 Rice variety used in areas of shallow to moderate flooding depths, in which young plants tolerate total submergence of leaves for up to 10 (some varieties maximum 20) days, and after this period grow quickly and produce panicles.

2 Rice variety used in deepwater areas with longer flooding durations of up to 4 to 5 months in which the stems have the ability to elongate quickly, in response to increasing flooding depth.
institutional arrangements suitable for locally prevailing socio-cultural-economic and political conditions.

Conclusions from recently conducted trials

In the trials conducted over a three-year period in Bangladesh and northern and southern Viet Nam, the approach taken was that communities were encouraged to determine the management criteria and institutional arrangements which they considered suitable to their local conditions and social environment. Further details are provided in Dey and Prein (in press).

Institutional arrangements

Arrangements between stakeholders are necessary within the context that during the flooded season when individual plots are not discernable, the water body becomes a temporary common property, in contrast to the dry season when individual land holdings are clearly discernable and respected; this approach is needed to exploit the resource.

A group approach is used with around 20 households per group, comprising landowners, fishers of the community and landless labourers (with customary access rights for fishing in the flood season). Benefit arrangements are required to organize and consolidate the group. Landowners comprise participating (active) and non-participating (passive) persons. Landowners participating actively in the group activities receive an additional share of benefits for their role as group members (on top of the share they already receive through mere provision of their land).

It was found that existing social harmony among the groups before the introduction of the community-based fish culture approach was a requirement for its successful implementation. Artificial memberships based on previous linkages with facilitating organizations (e.g. NGOs) proved to have destabilizing effects or were even detrimental. The predisposition of the population to community-based activities in some countries also was an important determinant. For example, in southern Viet Nam farmers were highly averse to any form of group arrangements, even if these involved close relatives, and preferred individual management of smaller, individually owned and controlled...
areas. Further assessments on the attributes of successful group approaches and the reasons for spontaneous adoption and spread of the technology are planned in the near future.

Selection of concurrent versus alternating system

The selection is dependent upon the flooding pattern in the area and the preferences among the groups.

Selection of appropriate sites

The sites should be topographically suitable areas, and there is a need to include as much as possible existing embankments. Initially the number of suitable sites was perceived to be limited, however, "spontaneous adopters" fenced up to 75 percent of the perimeter (rest were existing embankments) at a comparatively high cost. Nevertheless, these sites still proved to be highly profitable.

Fish species, stocking densities, sizes

Recommendations were given on stocking densities of several fish species in a polyculture, preferably of larger sizes to avoid predation and to achieve greater sizes at harvest. However, these were not prescriptive packages (to avoid straightforward rejection), and the actually stocked numbers of individual fingerlings and species proportions depended on the local availability from hatcheries and other sources. Given the size of some of the enclosed areas, these were large numbers, far greater than the usual requirements for fish ponds, which together with the preference for larger sizes and several different species posed considerable logistical challenges (sourcing, transport) to the communities and the facilitating NGOs.

Market supply versus timing of harvests

Both the capture phase for wild fish and the harvest phase are bound to coincide as they depend on the flood duration, levels and recession pattern. However, the culture operation can be staged over a longer period through sequential harvests leading to thinning out of the standing fish stock for higher growth and greater returns. Further, deeper pits in the area can be used to keep fish beyond the normal capture season until fish prices increase and greater returns from markets can be achieved. This was done by some of the trial groups.

Financial management issues

In the first year the communities received financial support for the initial investment in fences. In subsequent years, communities were expected to re-invest a portion of their proceeds from the previous year's fish sales into the subsequent year's fish culture operation, e.g. for the purchase of fish fingerlings and the maintenance of the fences.

Effects on biodiversity (wild fish)

It was generally concluded that wild fish biodiversity and abundance was not affected by the culture operation, although no specific analyses were conducted as part of these early trials. The conclusion is based on comparisons of wild fish catch both in terms of biomass and species composition, which was essentially similar, except for predators such as snakehead (Channa sp.) and catfish (Clarias sp.), which were reduced. However, in some cases farmers observed that the biomass of small indigenous species was considerably higher than in neighboring unfenced areas, and few species which had previously been rare in their areas, had appeared again in their catches in the fenced areas. This was attributed to the strongly reduced abundance of predators within the fenced area. More detailed studies are required to validate that stocking fish into fenced areas of seasonally flooded waters has no negative effects as well as that the fences limit access of juvenile predatory fish into the fenced areas with the incoming/rising floods.

Beneficiaries and impact

Inland fishes in general have been characterized as the most threatened group of vertebrates used by humans, with a constant negative trend. These fish are of highest importance for the rural poor for income, nutrition and food security, but the demand is increasing which is reflected in constant price increases. Fish also have a high value for nutrition of the poor due to their nutrient density and quality (protein, lipids, micronutrients) that is in highly bio-available form in most small fish species.

Fish production from the fenced floodplain areas will be increased at least two to tenfold over the natural catch through the culture
activities, as shown from our previous work in Bangladesh and Viet Nam. Harvests are in bulk and therefore are sold on the market producing cash returns that are shared among group members, including the landless. Capture of non-stocked, small indigenous species by landless with traditional fishing methods within the culture areas during the culture period is specifically permitted by the groups, and thereby ensure their continued supply of protein and income over the culture season from the fenced areas. Cash income will increase for all involved, notably for the landless relative to their base income. We expect similar levels of benefits from group-based fish culture approaches in irrigation systems.

In the longer term, the approach aims at providing the rural populations in the floodplain areas and irrigation systems of the targeted basins with an equitable source of additional income and supply of fish, both from natural fish production, as well as from stocked culture species. This will directly benefit the members of the communities involved, but also fish consumers outside the culture areas due to increased supply on the markets, thereby countering the negative trend of inland fisheries production. Revenues from fish production can also be used to improve the maintenance and hence the sustainability of irrigation systems.

Extrapolation domains

The potential application areas for the community-based fish culture approach in floodplains and irrigation systems are considerable. These areas are usually densely populated, the seasonal floodwaters, however are underutilized.

The approach helps mitigate the trend of declining inland capture fisheries production, with increasing prices of fish, rendering these less affordable to the poor. For example, in Bangladesh alone, there are 3 million hectares of medium and deep flooded areas, out of which about 1.5 million hectares are estimated to be suitable for community-based fish culture. If this approach is adopted in only 50 percent of these areas, annual fish production will increase by 450 000 tonnes (additionally to presently produced 60 000 tonnes of wild fish caught in these areas) at an approximate value of US$ 340 million and will be of benefit to an estimated 6.7 million people (2.7 million of which are landless and/or functionally landless). Similar opportunities are seen for floodplain and deltaic systems in other countries in Asia and Africa.

In the Mekong river basin, 0.8 million hectares of medium and deep-flooded areas exist which could be utilized by the communities living in them for joint fish culture activities during the flood season, which is otherwise a fallow season with very low economic and agricultural activity. Of 5.2 million hectares of medium and deep flooded areas the Indo-Gangetic basin, 3 million hectares are in Bangladesh, wherein an estimated 27 million potential direct beneficiaries live. If only 25 percent of these adopt the approach, 6.7 million would benefit, of which 2.7 million persons are landless. Other seasonally flooding areas suitable for the approach in other basins in Asia are in Myanmar (1.2 million hectares), Thailand (0.7 million hectares), and the Red river delta in Viet Nam (0.1 million hectares).

In Africa, the potential for application of community-based fish culture is greatest in seasonal floodplains and in irrigation schemes. In West African floodplains, 470 000 hectares are used to grow deepwater rice (Catling, 1992) which could be used for concurrent deepwater rice and fish culture.

References


A REVIEW OF THE DEVELOPMENT OF INTEGRATED IRRIGATION AQUACULTURE (IIA), WITH SPECIAL REFERENCE TO WEST AFRICA

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Abstract

A review of the literature available on integrated irrigation aquaculture (IIA) activities in 13 countries of West Africa is presented. The concept of IIA has been the subject of some publications emphasizing the ‘theoretical’ potential and advantages of the practice. Other studies have tended to assess separately irrigation and aquaculture development/potential in these countries and have focussed on the technical aspects of each activity. Inland valley bottoms, floodplains and full-control irrigation systems have been identified as key environments to support the integration of irrigation and aquaculture. Background information is provided on the context and justification for the integration of irrigation and aquaculture activities, and specific IIA activities are detailed for each key environment based on documented case studies in West Africa. Issues identified as positively or negatively affecting the potential for integration include health concerns linked to the incidence of water-borne diseases, pest and weed management, wastewater recycling, mitigation of land salinisation, conservation of wetlands, demand for fish, marketing and processing, optimal allocation and pricing of irrigation water. It is emphasized that assessments of IIA potential should fully incorporate socio-economic and cultural factors as these deeply influence the ultimate adoption of new technologies. Despite a number of technical and socio-economic challenges to overcome, IIA activities should make a positive contribution to the livelihoods of operators and farmers, provided that they are given opportunities for private initiatives and that technologies are adapted to their needs.

Introduction

The preparation of this document was commissioned by the Inland Water Resources and Aquaculture Service of the FAO to serve as working paper for the FAO-WARDA Regional Workshop on Integrated Irrigation Aquaculture in Bamako, Mali, 4–7 November 2003. The geographical focus of the review is West Africa and includes Burkina Faso, Mali, Niger, Nigeria, Senegal, Ghana, Chad, Côte d’Ivoire as well as country members of the WARDA Inland Valley Consortium (IVC): Benin, Cameroon, Togo, Sierra Leone and Guinea.

The investigation of integrated irrigation-aquaculture development focuses on three key areas equipped for irrigation: inland valley bottoms, floodplains, full control irrigation systems, and includes rice-fish farming activities. IIA activities are reviewed in each key environment in West Africa, assessing potential, constraints, opportunities and other issues related to the future development of integrated irrigation-aquaculture in Africa and presenting recommendations on how to proceed with IIA development in each country and the region as a whole.

The first section of the document provides background information and rationale for developing IIA. Section 2 describes the key environments, aquaculture and irrigation systems covered by the study and includes case studies on integrated irrigation aquaculture activities carried out in floodplains, inland valley bottoms and full control irrigation systems in the countries under review. Other issues related to the development of IIA, such as health concerns, weed control, wastewater recycling, land salinisation, conservation of wetlands and irrigation water pricing are addressed in a third section. Challenges and opportunities for future integration are discussed in a fourth section in the light of the above information. The last section summarizes the findings and concludes.
Background and rationale for IIA

Irrigation: issues of water scarcity and water productivity

When 70 percent of the world's supplies of developed water are used by irrigation and overall withdrawals are forecast to increase, growing scarcity and competition for water adds a new dimension to the food security debate (Seckler et al., 1998). Problems related to irrigation are low water use efficiency, expensive exploitation of new water resources, resource degradation through water-logging, pollution and salinisation, which have a negative impact on drinking water supplies and health, and subsidies and distorted incentives which lead to further depletion and unequal benefits (Rosegrant, 1995). In the face of these challenges and to ensure increased food production and stable prices in forthcoming decades, investments and policy reforms have to be undertaken to improve water and irrigation management (Rosegrant and Cai, 2001).

Seckler et al. (1998) have classified countries according to calculated threat of water scarcity. None of the countries under study belonged to the group of currently water-scarce countries. However, Niger, Cameroon, Côte d'Ivoire, Nigeria, Ghana, Benin, Chad and Burkina Faso were classified as Group 2 countries in which conditions are often unfavourable for crop production and which must develop more than twice the amount of water they currently use to meet reasonable future needs. In these countries, it was recommended to put emphasis on expanding small-scale irrigation and supplemental irrigation to increase the productivity of rainfed agriculture. In Group 3, countries were Guinea, Senegal and Mali1, which need to increase their withdrawals by an average 48 percent to meet their water needs.

In the context of integrated uses, water productivity, i.e. the amount of food produced per unit volume of water used, is more informative than irrigation efficiency, the amount of water required for an intended purpose divided by total amount of water diverted to a spatial domain of interest (Guerra et al., 1998; Molden, 1997). As costs of developing new water resources increase, increasing productivity of existing resources, both irrigation and rainwater, becomes more attractive and can be achieved in four ways (Seckler et al., 1998):

- Reducing evaporation losses
- Reducing flows of usable water to sinks
- Controlling salinity and pollution
- Reallocating water from lower-valued to higher-valued crops.

A fifth way to increase water productivity is through the integration of a non-consumptive use of water (fish farming) within existing irrigation sources.

Aquaculture

Aquaculture is the fastest growing food producing industry in the world (FAO 2000a). Beyond some negative environmental impacts (usually specific to intensive marine or coastal aquaculture) inland fish farming has the potential to positively contribute to the livelihoods and food security of the poor (Ahmed and Loricav, 2002; Edwards, 2000; Halwart et al., 2003) and the emphasis is now on aquaculture for development, instead of solely aquaculture development (Friend and Funge-Smith, 2002). Living aquatic resources are however in a period of transition and face issues related to efficiency, in particular in post-harvest operations, equity, management, intensification and policy formulation (Williams, 1996). Improved water management satisfying both agriculture and aquatic resources can be a way by which water uses are optimised and local livelihoods enhanced but it calls for integrated policies that recognize the multiple uses of inland water bodies and the complexity of livelihoods to promote their sustainability.

Integrated farming systems

The concept of integrating fish production with other activities (crops, poultry, livestock) as part of complex farming systems is not new and its advantages have long been recognized (Pullin and Shehadeh, 1980; Little and Muir, 1987; FAO/ICLARM/IIRR, 2001). From a poverty reduction perspective, these systems contribute to improved livelihood outcomes through diversification of food production and household activities, income increases, nutrition improvements and spread of risk and uncertainty (FAO, 2000b; Prein, 2002). From an environmental perspective, they contribute to sustainable natural resource management.

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1 Togo and Sierra Leone were not part of the study.
through recycling/reuse of resources and nutrients, environment-friendly pest management, increased land and water use efficiency and waste management (ibid.).

While contribution of irrigation and aquaculture development to alleviating poverty have been separately assessed (Hussain and Biltonen, 2001 and Chambers, 1988 in the case of irrigation; Friend and Funge-Smith, 2002 and Edwards, 2000 in the case of aquaculture), the integration of both activities is relatively new, especially in Africa. Despite being referred to as a "drought-prone area", sub-Saharan Africa has under-exploited irrigation resources and infrastructures which would benefit from rehabilitation and modernisation (Alam, 1991) as well as from integrated approaches to water management to accommodate both irrigation and aquaculture.

**Integration of irrigation and aquaculture**

Much of the current literature recognizes the "theoretical" potential of the integration of irrigation and aquaculture. This potential is based on separate assessments of irrigation and aquaculture activities and potential for further development. While integrated systems such as rice-fish farming or cage culture in human-made (irrigation) reservoirs have been thoroughly studied, technical aspects of IIA in canals and management issues related to multiple water uses have been documented in very few studies (e.g. Li, 2002; Ingram et al., 2000). According to Fernando and Halwart (2000), harvesting fish in irrigation systems is a practice dating back at least two millennia. Although seldom recorded, it seems to have been widespread in the tropics and subtropics, especially in irrigated rice fields. Irrigation systems using stored or diverted water have increased exponentially over the past 50 years, but fish farming within these irrigated systems has not expanded equally and there is now a huge potential for this integrated enterprise (Fernando and Halwart, 2000).

Integrated irrigation–aquaculture is one aspect of the integration of agriculture and aquaculture. It is the practice of two technologies associated in the aim of increasing productivity per unit of water used. In the case of simultaneous irrigated rice and fish production, integration can be partial or complete depending on the spatial location of irrigation and aquaculture units: fish can be raised in a pond upstream or downstream of the paddy field, but also within the paddy field. In the case of irrigation conveyance systems, fish can also be raised in cages located in canals (Li et al., 2005; Ingram et al., 2000; Haylor, 1994). Other possible systems are detailed in the next section.

IIA presents a number of generic advantages, most of which stem from the benefits of integrated farming systems. Positive environmental impacts include (after Kabré 2000):

- In the case of fish ponds used for the provision of irrigation: fertilization of water and soil by fish excreta, accumulation of organic matter at the bottom of ponds which enhances the development of micro-flora and micro-fauna and improves pond productivity.
- In the case of rice-fish systems: fish species, in particular certain tilapia species, control weeds in paddy fields and fish movements prevent new growth. Fish act as biological control for rice parasites and mosquito larvae, against the spread of malaria and other water-borne diseases.

At the household level, positive impacts include enhanced food security, balanced nutrition and increased incomes (Moehl et al., 2001) through the production of a commodity (fish) readily available at times of necessity and the provision of supplementary irrigation for crops in the dry season (Little and Muir, 1987). Increases in income for the landless poor were also shown to be possible with the adoption of fish (Indian Major Carps) cages in irrigation canals (Brugère, 2003).

While the integration of aquaculture in irrigation systems is receiving increasing attention, technical constraints and opposition to the integration have hampered its development in some areas. In the case of large-scale reservoirs, cage/pen aquaculture can limit or alter the value of water in multiple uses by altering flow regimes, scenic value, disrupting spawning, interfering with navigation, preventing access and polluting water, especially when reservoirs are used as potable water supply (Haylor, 1994; Beveridge, 1987). In irrigation supply canals, cages, especially when fouled, can represent a barrier to flow and have encountered some opposition to their use (Costa-Pierce and Effendi, 1988 in the case of Indonesia; Jauncey and Stewart, 1987 in the case of Egypt). In addition, the integration of fish production in an irrigation scheme creates an extra burden on management, calling for a balance between the
needs and constraints of fish and crop production (Li et al., 2005; Haylor, 1994).

**Key environments and IIA development in West Africa**

It is necessary to determine which irrigation environments and which aquaculture systems are suitable for integration. Table 1 links each FAO-defined key environment (inland valley bottoms, floodplains and full control irrigation systems) and related water-engineered/irrigation systems to the aquaculture systems they can potentially support, as suggested by Haylor (1994). The following section reports case study analyses of such integration, with their potential and constraints, in West Africa.

**IIA development in West Africa**

Because of the specific focus of this study on integrated irrigation aquaculture, reviews of irrigation and aquaculture sectors at national levels are not reiterated. They have however been summarized in a table, which also includes potential of integrated irrigation-aquaculture by country, evaluated from feasibility studies and information from other sources (Annex 1).

Not many examples of practical initiatives have been reported in the context of West Africa and some aquaculture case studies do not mention the environment in which they took place. A notable exception is rice-fish integration. Following the FAO workshop for an African network on integrated irrigation and aquaculture (Moehl et al., 2001), case studies were carried out in Mali (Bamba and Kienta, 2000), Côte d’Ivoire (Coulibaly, 2000), and Burkina Faso (Kabré, 2000). These studies are amongst the most thorough studies available on IIA activities (usually trials or past activities) in Africa and describe the technical characteristics as well as some economic and social impacts of the systems developed. Sectorial approaches to development of each activity still prevail among practitioners and policy makers. Mention is rarely made of “integrated approaches” to management of irrigation water, taking into account other water uses, in particular fish production (fisheries or aquaculture) and domestic uses.

**Floodplains**

Floodplains play a fundamental role in supporting large human populations. Many activities they support depend on their hydrology (Thompson and Polet, 2000). The promotion of their management for fish production by extensive aquaculture techniques (e.g. ponds dug into the floodplain, dams which block drainage channels and dikes enclosing areas) is not new (Welcomme, 1976).

Floodplain resource use is usually synchronized with annual flood cycles as in the Hadejia-Nguru wetlands of North-eastern Nigeria (Thompson and Polet, 2000) where rice is cultivated in inundated areas, which are then planted with other crops after the floods recede. Fishing and cattle grazing intensity also varies with rising and falling water levels. The location of rice cultivation and small-scale irrigation is determined by water availability in the wet and dry seasons.

**Rice-fish**

In the Mopti region of Mali, rice-fish farming in the floodplain of the Niger River (Tiroguel area) was assessed in a case study analysis of a potential project (Bamba and Kienta, 2000). It was estimated that the project would benefit from the Special Programme on Food Security (SPFS) to allow floodplain dwellers to legally catch fish naturally caught in the floodplain irrigation network and enhance fish production in the irrigated floodplain area destined to deepwater rice cultivation. With the rehabilitation of a small-scale, community-managed irrigation area, a pond area of 10 ha would be created in the middle of a deepwater rice area of 13 ha. Water in the irrigated zone would accommodate both fish and rice simultaneously: a hole would be dug in the middle of the pond for fish to survive after drainage for the rice harvest. Management of both pond and rice would rely on involvement of all community members and harmonisation of management interests. Tilapias and *Clarias* spp. would be stocked in the pond using natural populations entering the floodplain and additional stocking. Fish feed will be made from organic fertilizers (on-farm waste recycling).

The financial analysis of this integration based on a number of production targets suggested positive net returns. Of all the impacts envisaged, nine could be positive, five negative, six potentially negative and two negligible. Benefits would relate to increases in social capital (community cohesion through communal management of rice and fish
<table>
<thead>
<tr>
<th>Key environment (as defined in FAOSTAT)</th>
<th>Water engineered-systems (after Haylor, 1994)</th>
<th>Status of fisheries (capture and enhanced) and aquaculture (after Haylor, 1994)</th>
<th>Aquaculture systems with potential for integration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full control irrigation systems (large scale)</td>
<td>Large reservoirs (dams) for storage/flood control</td>
<td>Large and increasing portion of fish production in many countries but only a recent innovation in Africa, in particular regarding reservoir-based aquaculture.</td>
<td>Cages/pens</td>
</tr>
<tr>
<td>Irrigation supply canals</td>
<td>Fish entering the system and self-sustaining populations are important in Asia. Stocked fish are used to control growth of aquatic plants and disease vectors.</td>
<td></td>
<td>Cages/pens (e.g. carp polyculture in China)</td>
</tr>
<tr>
<td>Water dispersion (drainage and wastewater)</td>
<td>No capture fishery. Aquaculture used to produce useful biomass from a controlled aquatic medium and treat wastewater.</td>
<td>Ponds, small reservoirs</td>
<td></td>
</tr>
<tr>
<td>Water transfer systems (conveyance schemes)</td>
<td>Fisheries not widely reported.</td>
<td></td>
<td>Cages/pens</td>
</tr>
<tr>
<td>Full control irrigation systems (small scale)</td>
<td>Farm sub-systems (= rice fields)</td>
<td>Capture fishery is as old as rice culture with yields around 135–175 kg/ha. Fish culture provides higher yields but this varies with field conditions.</td>
<td>Rice-fish (e.g. fingerling production in China)</td>
</tr>
<tr>
<td>Small-scale reservoirs (= farm dams, dual purpose reservoirs, tanks or irrigation reservoirs) for rain and flood water storage</td>
<td>Combination of fishery and aquaculture practices.</td>
<td>Cages/pens, rice-fish, coevolve with impoundments (e.g. fingerling production in China)</td>
<td></td>
</tr>
<tr>
<td>Groundwater irrigation (well, borehole, pump)</td>
<td>Extensive aquaculture in open wells but risk of conflict with other uses (human/livestock consumption).</td>
<td>Fish stocked in wells</td>
<td></td>
</tr>
<tr>
<td>On-farm reservoirs or ponds</td>
<td>Extensive to semi-intensive aquaculture.</td>
<td>Cages/pens, ponds</td>
<td></td>
</tr>
<tr>
<td>Inland valley bottoms / wetlands</td>
<td>Small-scale dammed reservoirs</td>
<td>Fish entering the system and self-sustained populations.</td>
<td>Cages/pens, ponds</td>
</tr>
<tr>
<td>Rice fields</td>
<td>Fish entering the system, sometimes stocked.</td>
<td>Rice-fish</td>
<td></td>
</tr>
<tr>
<td>Floodplains, including flood recession areas</td>
<td>Small-scale dammed reservoirs</td>
<td>Fish entering the system and self-sustained populations.</td>
<td>Cages/pens, ponds</td>
</tr>
<tr>
<td>Rice fields</td>
<td>Fish entering the system, sometimes stocked.</td>
<td>Rice-fish</td>
<td></td>
</tr>
</tbody>
</table>


production), transfer of resource management from the state to stakeholders, increased autonomy in decision-making, timely supply of fish when resources decline in the delta, with increased incomes for producers, in particular women, and improved diet.

Constraints to overcome would be linked to lack of institutional support and the single purpose management of water for irrigated rice areas, lack of funds for aquaculture activities in general, perception of aquaculture as a secondary activity by farmers, lack of water availability outside areas equipped for full control irrigation. Nevertheless, the potential for rice-fish integration was considered high and with adequate policy support, the example
of the Tiroguel area could be extended to all deepwater rice areas, ponds and inland valley bottoms of Mali.

In Burkina Faso, examples of direct rice-fish integration (fish growing in the paddy field) in the Kou Valley and indirect integration (fish pond upstream of paddy field) in the Bragué irrigation scheme were assessed (Kabré, 2000). The Kou Valley is a floodplain equipped for gravity irrigation while the Bragué irrigation scheme supplies water from canals linked to the Bragué dam reservoir. Despite partial success, the Kou Valley trial is more informative than the Bragué case study, which brings little insight into IIA (fish production was a secondary use of the pond, originally designed as a supplementary source of irrigation for rice; farmers did not participate in fish rearing and fish was not harvested). In the Kou Valley trial (1987-1988), rice plots were individually supplied by an irrigation canal. Sluices were fitted with grids to prevent stocked and wild fish populations to mix. A pond, constructed amidst the scheme to nurse tilapia fingerlings and fertilized with organic and mineral inputs, was communally managed by a group of fishers. A number of difficulties were faced in the set up and management of the operation: farmers were sceptical and fishers showed interest instead, conflicts arose over water allocation in the irrigated perimeter and a flash flood interrupted a second trial unexpectedly. In addition, the financial impact of the integrated activity on households' budget was limited and in-depth analysis showed that rice-fish farming was significantly determined by the availability of sufficient labour force in the household.

Other constraints to the widespread development of the activity, evaluated by Kabré and Zerbo (2001), are linked to the lack of direction from the government's Fisheries development agency and from research institutes in terms of aquaculture development and rice-fish culture in particular, lack of fingerlings, competition for feed resources, and lack of funds, land and water for IIA. However, during the trial, farmers started to recognize benefits of the integration of fish in paddy fields or in a pond used to irrigate paddy. It is estimated that their attitude could be easily changed by extension efforts and awareness raising on nutrient recycling, technical knowledge on IIA management and some forms of co-operative saving to fund and develop new IIA activities. This would be supported by the existing demand for fish and the possibility for post-harvest activities (e.g. fish smoking) involving women.

Ponds

In Nigeria, the development of a fish pond in the floodplain of the Hadejia-Ngura Wetlands was reported in Thomas (1994). This study highlighted a common characteristic of many aquaculture projects in Africa: the failure to consider economic and social aspects to ensure the success of technical developments. The project purpose was to increase fish production from seasonal ponds to compensate for decreases in capture fisheries. Techniques used involved deepening ponds and controlling the outflow of water after flood recession, fertilizing with cow manure, and increasing the natural fish density with wild-caught fingerlings of Clarias lazera and tilapia (Sarotherodon galilaeus). The depression chosen was a community pond and thus was community-managed. A nearby pond was left unmanaged and used as control. Fingerlings were provided by fishers and manure collected from camps of Fulani (nomadic pastoralists).

Thirteen kg of fish were harvested from the unmanaged pond after 4 months and 35 kg were harvested from the managed pond after 8 months. However, economic analysis of the trial showed lower returns to labour in the case of the managed pond (5.19 Naira per person-hour) compared to the unmanaged pond (6.04 Naira per person-hour), although labour surpluses available in the dry season at the time of fish harvest and possibility to sell fish in the "lean" period could offset the lower returns.

Despite encouraging results, community participation and technology adoption were low because of the following factors:

- Community organisation and traditional individual management of fishing activities in the floodplain, which made the concept of "community-managed" activities new;
- Low levels of education which hampered record keeping and made fishers reluctant to provide the required fingerlings for stocking the pond;
- Customs and rights of access over the stocked pond and floodplain fishery (some groups saw the project as a threat to their rights);
- Tense ethnic relations and suspicion of theft;
- Micro-economics of the activity: while fishing can provide instantaneous benefits, aquaculture has to be envisaged over
several months and a change in income flow can have many repercussions for household survival.

Inland valley bottoms

Rice-fish

Oswald et al. (1996) showed positive interactions and returns from the combination of fish farming (mainly Oreochromis niloticus) carried out in ponds adjacent to lowland rice fields in peri-urban zones of Côte d'Ivoire. The activity was a suitable farm diversification strategy and benefited from the proximity of markets.

In Senegal, the rice-fish farming potential was assessed in the Senegal River valley (north of the country) and in inland valley bottoms and floodplains (south in the Casamance area) (Sanni, 2002). In the Senegal River valley, rice is intensively farmed and water managed to suit its growth requirements (including periods of low water or dry land) which would limit the growth of fish stocked in rice plots. However, potential is higher in the Casamance area where rice is grown extensively and some form of rice-fish integration already exists and could be easily improved. Despite farmers' interest in IIA, in particular rice-fish, and existing irrigation management knowledge, high demand for fresh fish in remote inland areas, fry and fingerlings availability, a number of constraints have been noted.

Some of these constraints are common to IIA activities in general as practised elsewhere (see also contributions by Peterson et al., this volume). Local environment (e.g. proximity to the Delta where fish is plentiful) and ethnic origin were also considered as influencing factors in the potential of IIA. While these analyses showed potential, Sanni (2002) acknowledged the need for socio-economic assessments to be carried out, in particular in the context of intensive rice-fish farming in the Senegal River valley.

Full control irrigation systems

Dams/reservoirs

Diallo (1995) reported encouraging results from the semi-intensive rearing of Tilapia guineensis and Sarotherodon melanotheron in pens in dammed valleys of Casamance, Senegal, as a method to cover the gap of protein demand after habitat loss and diminution of catches.

In Kainji Lake, Nigeria, an experiment was carried out using six wooden-framed, poultry mesh cages measuring 1 m³ stocked with specimens of Tilapia galilaeae, T. zillii and Oreochromis niloticus together and T. galilaeae separately (Ita, 1976). The cages were suspended from nylon ropes into the water and the ropes tied to the float of a landing pier a few meters from Kainji Dam. Fish were fed daily with pellets prepared by mixing dried fish, roasted or fresh groundnuts, guinea-corn bran, yam flour and commercial vitamin premix or blood meal together. Results showed that growth of T. galilaeae over 164 days was higher than in the case of polyculture over 171 days. Improving cage design to reduce feed wastage and cost of construction were suggested to improve the economic viability of the operation.

Canals

In Senegal, Sanni (2002) assessed the potential of several forms of IIA. In primary canals, trials were unsuccessful because of theft, bird predation, and lack of participation by target group but showed some potential. Low depth and easy predation constituted constraints in secondary and tertiary canals. Large-scale reservoirs located within irrigation systems offered the most potential for fish to be intensively grown in cages. Drainage areas were not suitable because of the presence of harmful pesticides in the water.

Rice-fish

In Côte d'Ivoire, a case study analysis of IIA (rice-fish) trials was carried out in the valley bottom village of Luenoufla in the Daloa region (Coulibaly, 2000). The trials, initially set up under the Projet Piscicole Centre Ouest (PPCO) in 1992, were followed up by the APDRA-CI (Association Pisciculture et Développement Rural en Afrique tropicale humide - Côte d'Ivoire) and have shown positive results. Areas where fish-fish cultivation was carried out are usually cascade systems, with rice plots upstream and downstream of a small dammed reservoir where fish were grown. A nursing pond was built as part of the irrigation system, which was also designed to accommodate organic dike cropping (vegetables) and cattle drinking. Polyculture of tilapia, Hemichromis fasciatus, Heterotis niloticus and grass carp (Ctenopharyngodon idella) was practised.

In economic terms, it was shown that the fish activity contributed to 20 percent of the total value of production (rice, vegetables and maize) and increased the value of the valley bottom equipped for irrigation. However,
returns to labour were lower than returns to the land. Benefits at the household level included changes in decision-making regarding land exploitation, with a switch from upland cultivation to irrigated valley bottom exploitation, increased returns to labour compared to rice farming only, improved diet, increases in subsistence consumption, household budgeting with income from fish buffering against larger expenses, and more independence for women through dike cropping and aquaculture post-harvest activities. At the village level, increased year-round human activity around the reservoir was a sign of overall improved water management. In addition, employment creation, strengthening of social and human capital (group collaboration, women’s involvement) along with market opportunities for fresh fish were other positive impacts of the project.

Rice-fish culture trials were conducted on test plots in a large irrigation scheme in the Upper East Region of Ghana (Kumah et al., 1996). Two different systems, both with refuge ponds on one side of the rice field, were evaluated. One had a lateral trench around the entire rice field. The other had only a single central trench. After 105 days, rice yields ranged from 1.6 to 4.1 tonnes per hectare. Lateral trenches prevented rat infestation of the rice crop, thereby increasing yields. Over the same period, fish production ranged from 133 to 142 kg per hectare. Results encouraged farmers to embark on trials on their own irrigation plots.

**Issues and benefits related to IIA development**

Issues raised in this section are not specific to West Africa, although, reference to countries under review was made when possible. Experiences from other areas can however inform the development process of IIA in the region. The list of examples is not exhaustive but rather meant to illustrate the issues.

**Human health issues**

There are various strands to the debate on health-related issues in the development of aquaculture in tropical countries. Some argue that water retention in ponds or other water bodies destined for aquaculture increases the incidence of water-borne diseases (West, 1996). Others say that larvivorous and mollusci-vorus fishes stocked in fish ponds and other water bodies, in combination with other agents, can be used as biological controls and increase fish production (Chiotha, 1995; Fletcher et al., 1993).

The development of fish farming in inland water bodies constructed for the activity can be accompanied by a surge in water-borne diseases. Fish ponds have been found to host higher numbers of bilharzia snails than the streams and canals that feed them, in particular when these ponds have weedy edges, increasing the risk of infection (Chiotha and Jenya, 1991). Similar findings were reported in Slootweg et al. (1993) in Cameroon where the introduction of irrigation (work in irrigated paddy and creation of permanent water reservoirs near the village) increased exposure to schistosomiasis. The situation was similar in the area of the WeiJa reservoir in Ghana, where the combination of environmental (proliferation of water weeds, changes in flow rates of water) and social (migration of infected farmers and fishers, flawed resettlement programmes) had contributed to increased incidence of schistosomiasis (Ampofo and Zuta, 1995).

However, the introduction of aquaculture offers an alternative approach in dealing with a vector-borne disease problem created by the construction of irrigation works (Slootweg, 1991; example of Cameroon). Selecting appropriate fish species, such as Trematocranus anaphyrims, *T. placodon* and *Astotilapia callistera*, which are molluscivorous fish, could serve the dual purpose of controlling snail vectors of bilharzia and increasing pond productivity through occupation of empty niches (Chiotha, 1995). Similarly for malaria, Fletcher et al. (1992) showed that stocking an indigenous cyprinodontid fish, *Aphanius dispar*, in all types of water storage containers in Assab in Ethiopia, was a successful and well-accepted method to control mosquito larvae, with monthly stocking necessary to maintain adequate levels of control. In an assessment on the role of fish as biocontrol agents, Halwart (2001) concluded that well-maintained aquaculture operations did not increase but rather contributed, often significantly, to the quality and diversity of the ecosystem.

It is also often pointed out that organochlorine insecticides, in particular DDT and HCT, used to control mosquito populations and to contain the spread of other diseases, have accumulated in trophic chains and the environment (D’Amato et al., 2002) and have increased water pollution, making it potentially...
unsuitable for aquaculture (Dua et al., 1996). Aquaculture development was hampered in the irrigation canals of the Gezira Scheme (Sudan) because of the use of harmful insecticides, larvicides and molluscicides and the lack of coordinated administrative and technical measures to cope with pollution in these canals (George, 1976). The presence of pollutants, especially pesticides leaching from fields into irrigation and drainage channels can have negative impacts of pesticides on fish growth, although methods are available to minimize them (Haylor, 1994). Aerial application of insecticides to control blackflies (transmitting onchocerciasis or river blindness) in heavily infected areas and water bodies did not have significant impacts on fish and aquatic invertebrate populations (Biney et al., 1994; FAO, 1996).

**Pest, disease and weed control**

The uncontrolled proliferation of aquatic weeds (*Salvinia molesta* and *Eichhoma crassipes*) in African irrigation systems and waterways has been a growing concern but adapted management of these plants could benefit fish stocks in inland waters and be used in aquaculture (Petr, 1992). In the South Chad and Baga irrigation projects, in Nigeria, where aquatic weeds were spreading in canals and drains, the introduction of herbivorous fish such as grass carp (*Ctenopharyngodon idella*) was considered a suitable biological alternative to expensive weed control treatments, while increasing overall fish production (Okafor, 1986). However, preference should generally be given to the use of indigenous fish species before the introduction of an alien species is considered.

In rice-fish systems, fewer agricultural pests, reduced incidence of weeds or less damage caused by pests and diseases in the presence of fish is reported (Halwart, 2001). However, it has also been reported that some fish species damaged rice plants in the floodplain of the central delta of the Niger in Mali (Matthes, 1978). While few fish were found to attack rice predominantly for food (*Tilapia zillii*, *Alestes* spp. and *Distichodus* spp.), other species (e.g. *O. niloticus*) only attacked rice when other foods were scarce, or damaged plants during other activities (e.g. *Heterotis* and *Clarias*). This can however be reverted by using local varieties (e.g. *Oryza glaberrima*) or deepwater, late-flowering “floating rice” varieties (Matthes, 1978). In addition, periphyton on rice stems can be a significant source of fish food and the nibbling of fish on the rice stems is sometimes mistakenly interpreted as feeding on the rice plant itself (M. Halwart, personal communication, 2003).

**Wastewater management**

Wastewater management and recycling should be taken into account when aiming to increase water productivity. Aquaculture both produces and transforms waste, and as such, widens the scope of IIA by encompassing environmental and multiple water use considerations.

Wastewater recycling

Wastewater stabilisation ponds can be used simultaneously to polish the treatment of municipal wastewater (Metcalfe, 1995) and support fish production. Nutrient-rich effluents from wastewater fish ponds were then shown to be suitable for irrigation applications (Shereif et al., 1995) and sludges from oxidation ponds for land fertilization (Hosetti and Frost, 1995). Aquaculture in wastewater ponds contributes to eutrophication and water quality control while providing direct economic benefits through the sale of fish (Yan and Zhang, 1994). Health risks associated with the utilisation of wastewater for fish production have been extensively documented and all studies concur in recognizing fish produced in municipal (Slabbert et al., 1989) and mixed domestic/industrial (Sandbank and Nupen, 1984) effluents and from primary and secondary treated wastewater (Khalil and Hussein, 1997) as microbiologically safe for consumption.

Waste-fed ponds

Integrated fish pond systems are often a means to recycle otherwise wasted nutrients through the use of pond sediments and water to fertilize and irrigate adjacent crops (Little and Muir, 1987). Animal waste is extensively used to fertilize fish ponds throughout Asia as part of integrated livestock-fish (pig, duck, cow, chicken) systems (ibid; Edwards and Little, 2003; Yan et al., 1998). Fish pond water used to irrigate vegetable plots in South Africa has been shown to increase yields (Prinsloo and Schoonbee, 1987). Whilst these examples focused on fish pond water irrigation, Prinsloo et al.'s (2000) water efficiency assessment used effluents from a fish pond in combination with micro and flood irrigation technologies. They showed that nutrient-enriched water use
efficiency was higher when applied with the former (drum-drip irrigation) to vegetables and maize than with flood irrigation. This illustrates how the gap between water-saving irrigation technologies (e.g. micro-irrigation) and IIA technology, which a-priori, could not be carried out without flood/irrigation water storage devices, could be bridged.

In the floodplains of West Africa, which have been shown to be deficient in essential crop nutrients (N, P and K) (Buri et al., 1999), the use of effluents from aquaculture operations could be used to “fertigate” crops in dry seasons (Valencia et al. 2001, example of forage crops in the U.S. Virgin Islands). According to Edwards (1998), the best prospect for the implementation of wastewater aquaculture systems is in arid and semi-arid countries where there is increasing pressure to reuse water.

Mitigation of land salinisation

Salinisation is one of the many problems faced by irrigation systems around the world and is partly caused by an excessive use of water (Agnew and Anderson, 1992). In West-Africa, salt-related soil degradation due to irrigation activities is a major threat to the sustainability of rice cropping under semi-arid conditions (van Asten et al., 2003). Using saline water for irrigation affects yields but measures to rehabilitate saline land or reduce irrigation water salinity levels are often too costly for smallholders. When combined with water logging and overall lack of water availability to irrigate, this leads to poorer lands left uncultivated (J. Gowing, personal communication, 2003).

However, enhancing food production will necessitate the conversion of marginal lands to other appropriate land uses with technologies increasing nutrient use efficiency through integrated nutrient management and recycling mechanisms as well as improving water use efficiency through the development and adoption of water harvesting, recycling and irrigation (Lal, 2000). It has been suggested that the opportunity cost of digging an on-farm reservoir (or pond) on cultivable land was lower than using the same land for agricultural purposes (Brugere and Little, 1999). Opportunity cost of saline uncultivated land would be a fortiori lower. This concurs to support that productivity of degraded areas by salinity could be enhanced through stocking of salt-resistant freshwater species in ponds and use pond water to irrigate crops with higher salt resistance (e.g. sorghum, groundnut, pearl millets). In Egypt, reclaimed salt-affected land was taken under cultivation with continuous flooding and fish production and later converted to rice culture (Halwart, 1998).

Conservation and sustainable use of wetlands

Wetlands across the world provide a wide range of valuable functions and benefits but are threatened by over-exploitation and unwise developments, the most important being dam construction and equipment of wetlands for intensive modern irrigation (Holli et al., 1988). There is growing evidence that large-scale irrigation schemes are often less efficient than traditional extensive systems supporting cropping, grazing and fishing activities, as shown in the comparison of water productivity in the natural floodplain of the Niger inner delta and the irrigated rice scheme of the Office du Niger in Mali (Drijver and Marchand, 1985; cited in Holli et al., 1988). It is therefore possible that the extensively equipped wetlands may provide a more adapted environment for the development of adapted small-scale IIA activities, which should also be in tune with principles of wetland conservation and sustainable use, as defined in the Ramsar Convention.

Demand, markets and fish processing

Processing and marketing aspects of a commodity to be produced in larger quantities are significant factors in the success and development of IIA activities. In Burkina Faso, where dried fish is frequently added to meal preparations, changes in diet composition have been reported, with a switch from traditional to marketed products (Lykke et al., 2002). This suggests that fish products, in particular from aquaculture, should keep up with raising demand for transformed products with post-harvest value added (the bulk of small-scale aquaculture production in Africa is sold fresh, in contrast to capture fisheries which are subjected to post-harvest transformation such as smoking, roasting, or drying (Chimatiro, 1998). However, such transformations are the cause of health hazards as no handling standards are in place or enforced (ibid.) and species such as catfish may not be protected from dermestid beetles solely through sun-drying (Lal and Sastawa, 1996).
Improvements in processing infrastructure was shown to improve the handling, marketing and development of demand for fish products in Ghana (Mensah, 1990). In addition, the role of the private sector in fish processing and of women as marketing agents of aquaculture production should be emphasized (Jaffee, 1995; Gladwin, 1980). This would be particularly important in the promotion and take off of IIA and the creation of a sustained demand for fish. However, Hecht and de Moor (undated) stressed that the findings of past and location-specific fish marketing and preference studies should not be interpreted as applicable to the whole of sub-Saharan Africa and that consumers' preferences should be investigated where aquaculture is promoted, and farming practices and species choices be modified accordingly.

**Optimal allocation and pricing of irrigation water**

A distinction has to be made between optimal use and allocation of water among users, based on socio-economic trade-off analysis - to which IIA belong and water pricing, a policy instrument for demand management and cost recovery (Hellegers, 2002). Another distinction relates to efficient allocation and optimal allocation (ibid.), as reflected in the two core, yet antagonistic, principles of water management: efficiency, i.e. the amount of wealth generated by a given resource, and equity, the fairness of allocation across economically disparate groups (Dinar et al. undated). Irrigation water is a special case because, in comparison with alternative uses, it has high opportunity costs, and yet, the ability to pay for irrigation water is limited, particularly in resource-poor agriculture and irrigation-dependent areas (Hellegers, 2002).

Demand-led approaches have been advocated to provide households with the water provision services they want and are willing to pay for (Whittington et al., 1998). Charging for quantities of irrigation water has been envisaged in irrigation management (World Bank, 2003), with advocacy for a shift from charges per area of land under irrigation, to charges per volume of water used (Rosegrant, 1997; Rosegrant and Perez, 1997). This process is however faced with difficulties in terms of implementation, enforcement, user acceptance as well as overall legitimacy in developing countries (Molle, 2001; Perry, 2001), especially as fisheries and aquaculture activities tend not to be taken into account in future water demand and management scenarios (see Rosegrant et al., 2002; Rosegrant and Ringer, 1999). The status of fisheries and aquaculture as non-water consumers would indeed complicate charging issues further.

**Challenges for future IIA development**

Haylor (1994: 92) suggests that: "in order to assess situation specific feasibility, it is necessary to quantify how appropriate it is to integrate the principal objectives of fish production with the primary objective of each system (e.g. water conveyancing in irrigation supply canals). Consideration should be given to the major characteristics of the system, costs and benefits of integration, to the type of fish species that might be appropriate, the potential fish producers (operators) and the scale of investment." However, achieving this will not be without overcoming a number of challenges.

**Technical challenges**

There are more technical challenges to overcome for the integration of irrigation and aquaculture in the case of full-control, engineered irrigation systems because of the lack of flexibility in the management of these systems, in particular if large-scale. Water supply reliability is a crucial constraint to integration of aquaculture because of the slow response of long supply canals to operational adjustments, variations in rainfall across extensive command areas and poor communications between operation staff resulting in difficulties to co-ordinate management actions to ensure adequate water provision to sustain fish populations. In addition, the reliability of conditions suitable for aquaculture depends on design and operation decisions that influence continuity of supply and/or storage.

When cages are used in irrigation canals, engineering aspects such as velocity inside cages and its impact on fish growth, drag forces and impacts on canal flow, impact on canal conveyance capacity and operational performance and possible interference with maintenance activities should also be taken into account. Adapted cage designs to prevalent hydraulic conditions is likely to be necessary (Li
et al., 2005). Morphology and slope of canals will influence cage site selection.

In principle, the provision of secondary storage should reduce water inequity between head and tail sections of irrigation systems (Brugere and Lingard, 2003), whilst providing opportunities for aquaculture development in comparison to large-scale irrigation systems without storage (Li et al., 2005). However, this will only be achieved if operating procedures reduce rapid fluctuations in water storage, as were observed in Sri Lanka, as this does not increase irrigation efficiency and constitutes a serious barrier to integrating fish farming in storage structures (Gowing et al., 2004). Even to satisfy non-consumptive uses of water, multi-purpose management is complex and difficult. Efficiency and equity goals are often irreconcilable. Aquaculture adds a further variable into the equation (Brugere, 2002).

Which IIA technologies to promote and where?

Emphasis should be placed on IIA development in small-scale irrigation systems as they require minor modifications to incorporate fish production. These modifications can be undertaken by farmers themselves and are more easily sustained than important large-scale changes (Haylor, 1994). In this context, rice-fish farming in inland valley bottoms and floodplains appears to be the most easily and readily achievable activity. Construction of fish ponds in inland valley bottoms, floodplains and full-control irrigation systems, may also be relatively easy, although by requiring more substantial investments and land transformations, it may be out of the reach of individual, resource-limited farmers. Large-scale irrigation systems present a high "theoretical" potential, with the advantage of being accessible to those without land. However, promoting the integration of aquaculture in such systems will require collaborations between user groups and water managing institutions (fisheries and irrigation authorities) to ensure the multi-purpose management of water, as well as improvements in the aquaculture technology.

Technology adoption

Technology adoption revolves around the assessment of two distinct, yet related, issues. The first is who to target as a suitable group to ensure the long-term success and spread of the activity. The second is why some interventions are adopted, while others are not. Paris (2002), in reviewing the reasons for the success and failure of improved integrated crop-animal technologies, underlined the paucity of information related to the socio-economic impacts of such interventions on rural communities. Her reasons for low adoption can also be applied to aquaculture:

- Lack of seed materials;
- Shortage or high opportunity cost of male family labour;
- Lack of capital and poor access to formal credit to make the initial investment;
- Increased competition between animal husbandry and other activities;
- Weak research and extension services;
- Lack of training.

To these have to be added local knowledge and water availability constraints, as well as in the context of Africa, the legacy of previous aquaculture experiences, national economic situations, marketing channels, households' perceptions of scarcity and security, and forms of land tenure and security of tenure, in particular for women (Harrison, 1991). Others, typically associated with all types of fish farming, e.g. fish mortality and escapees, high feed costs, poaching of cages, distance from the water body, lack of co-operation among family members or groups of aquaculturists, have contributed to disinterest and abandonment of fish culture (Bulcock and Brugere, 2000).

Tackling only technical constraints may be insufficient as adoption rates are also explained by the characteristics of the decision-making unit and the actors (belonging to the household or not) involved (Solano et al., 2001). Low interest and adoption of aquaculture technology may result from inadequate consideration or neglect of women's role in household decision-making and income generation as well as technology poorly adapted to their needs and quickly appropriated by men (Suwanrangsi, 2001).

For ponds constructed in full-control irrigation systems in Zambia and Tanzania, Van der Mheen (1999) suggested a method to analyse and monitor farmers' perceptions and criteria of adoption of the activity. While physical and environmental criteria influenced participation and uptake, other factors linked to the pursuit of the activity (household labour availability, inputs, information), innovation adoption (relative advantage, compatibility,
complexity, triability and observability) and farmers' needs (for protein, diversification and flexible water allocation) were paramount in the success of the IIA. He showed that suitable conditions increased adoption rates but that unfavourable topography did not affect participation as much as often assumed: farmers constructed ponds even on steep slopes. However, the compatibility of fish farming in irrigation schemes subject to water shortages, the complexity of the technology and the difficulty to try the activity independently and on a small-scale restricted the integration of ponds in water distribution systems and lead to a preference for independent fish ponds. Adoption rates increased in areas where at least two of the assessed needs (protein, diversification and flexible water allocation) were moderately or strongly felt by farmers and their households. From farmers' point of view, benefits brought about by an independent source of water outweighed benefits in the form of fish and income. However, this attitude should not be seen as impeding the development of aquaculture in irrigation structures, as fish still provide a "plus" to households. As with "saving pond fish for emergencies" rather than increasing pond productivity (Harrison 1991), long-term technology uptake will have more chances of succeeding when farmers decide which technology they would like to use, regardless of its productivity compared to other activities (Brummett and Noble, 1995).

Socio-economic challenges

Many socio-economic challenges are linked to the making the right decisions, at the outset of initiatives, on who to target with the activity. As mentioned above, this is also a key determinant of future adoption rates. These decisions are however confounded by political choices and their implications at macro levels, in particular in relation national development priorities and policies a country wishes to put in place.

Who to target?

The very poor or the wealthier?
The aim of increasing water productivity may only be partially achieved if its benefits are not shared by the very poor or other disadvantaged groups. However, targeting aquaculture development efforts to the poorest has been questioned (A. Coche, personal communication, 2003; Hecht, 2002; Wijkstrom, 2001). This does not mean that the poorest are to be excluded from aquaculture and irrigation development processes as they may initially benefit indirectly through increased and cheaper fish supply. But the high costs of irrigation development, even small-scale, and high risk associated with some IIA technologies (e.g. fish cages in canals) may make IIA initially unattractive to poorer groups (Brugere, 2003). However, as the technology is improved and adapted to local irrigation systems, and its cost reduces over time with wider uptake by wealthier households, it will become an alternative activity to the resource-poor, provided their access to the necessary irrigation structures and aquaculture inputs is ensured.

Landless or landowners?

Large-scale irrigation schemes serve only a minority of the world’s farmers (Haylor, 1994). The accessibility of large-scale irrigation schemes is a serious constraint for the landless poor people to participate in aquaculture activities. Although the extent of landlessness may not be as important in Africa as it is in other parts of the world (A. Coche, personal communication 2003), the premise of rice-fish culture is that rice fields are available, excluding the landless from the activity. Similar constraints apply to fish pond construction with the additional requirement of accessing and affording a source of water (e.g. pumps or wells). These limitations, which do not apply in the same way to large-scale irrigation systems, which the landless can access and use for other purposes than irrigation, reduce the potential of aquaculture as an entry point for poverty alleviation amongst this group.

Men or women?

So far, most aquaculture and irrigation development have targeted men, disguising the fact that women play a considerable role in the management of both activities, in particular small-scale aquaculture for home consumption (Harrison, 1991). Targeting men or women has implications for training as extension agents are usually males (ibid.). Working with women may result in the quicker adoption of a new activity where the nonchalance of men may slow down the process, as shown during the implementation of South-South co-operation of the Special Programme for Food Security in Senegal (FAO, 2002c).
### Table 2. Trade-offs in development of aquaculture within irrigation systems (Brugere, 2003).

<table>
<thead>
<tr>
<th>Dry season water supply / livelihoods improvements</th>
<th>versus</th>
<th>Groundwater depletion (environmental damage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfed crops adapted to water shortages and grown for subsistence</td>
<td>versus</td>
<td>Irrigated cash crops for exports and national income</td>
</tr>
<tr>
<td>Adoption of aquaculture by richer households and targeting aquaculture to areas where support networks exist, i.e. promoting 'commercial'-scale aquaculture</td>
<td>versus</td>
<td>Narrowing of gap between rich and poor, creating opportunities for the poorest of the poor, i.e. sustaining the &quot;poverty focus&quot; of international development</td>
</tr>
<tr>
<td>Provision of assistance (subsidies)</td>
<td>versus</td>
<td>Entrepreneurship incentives (credit)</td>
</tr>
<tr>
<td>Fish production for local markets and improved nutrition</td>
<td>versus</td>
<td>Value-adding activities and higher prices for urban dwellers</td>
</tr>
</tbody>
</table>

Fishing or land-based households?
Traditional aquaculture development has focused on crop farmers and land-based operations such as fish ponds. Fishers may be closer to "hunter-gatherers" and have unique attributes that require careful consideration if they are targeted by aquaculture activities in irrigation reservoirs for example (Balarin et al., 1998). If aquaculture, and in particular integrated irrigation aquaculture, is recognized as a branch of farming and not fishing activities, this also has implications for extension as in sub-Saharan Africa, most programmes rely on agents with capture fisheries background and little knowledge of farming systems (Harrison, 1991).

Micro or macro-priorities?
With the promotion of any form of integrated irrigation-aquaculture, decision-makers will be faced with a policy dilemma. At the micro-level, the first challenge is to address the usual lack of coincidence of all necessary resources, such as water, land, and labour availability, in particular for poorer households. The second challenge relates to the contribution of the activity to improved incomes, nutrition and well-being. At the macro-level, donors and governments alike will be faced with difficult trade-offs and choices related to prioritization of interventions at the grass root level and implementation of policy instruments at the national level (Table 2). Aquaculture in irrigation systems can be an attractive activity and priority for poverty alleviation. But overcoming the trade-offs involved in its promotion will be crucial in improving water use efficiency and equity and successfully reducing the vulnerability of the rural poor. Much ultimately depends on governments and development agencies' decisions.

### Conclusion

**Summary of findings**

Potential for the integration of irrigation and aquaculture exists throughout West Africa. Many of the constraints identified are common to all countries and are usually linked to limitations in the development of either irrigation or aquaculture. They are ranked hereafter by decreasing order of importance, according to their frequency of mention in Annex 1:

1. Lack of extension/technical support - conflict/competition over (water) resources; 
2. Low credit availability; 
3. Lack of information - government support/direction - high irrigation development costs - presence of pesticides in waterways - unfavourable climatic/hydrographic conditions - socio-economic factors; 
4. Lack of fingerlings and fish feed; 
5. Lack of aquaculture and rice-fish farming experience - lack of funding from international donors.

Some issues, each affecting positively or negatively the potential for IIA development in Africa, were reviewed. Health concerns arising
from water-borne diseases in irrigation systems could be limited by the right combination of fish species used as bio-control agents of disease vectors. Assessments of the presence of pollutants in water sources used for irrigation should be carried out prior the introduction of aquaculture. Positive impacts of fish raised in paddy fields outweigh negative ones. The design of fields can be changed relatively easily to accommodate and retain fish stocks including the use of a pond upstream or downstream of the field for aquaculture. Wastewater can be used for both irrigation and aquaculture after minor treatment. This may be a suitable option in more urban areas (water for gardens and fish production).

The human and environmental impacts associated with dam building have slowed down the pace of irrigation development through large irrigation schemes, which may constitute a constraint to the potential for IIA. Priority is given to the rehabilitation of existing schemes or enhancement of small-scale ones (Alam, 1991), which are in fact more suitable for the implementation of integrated irrigation aquaculture activities and wetland conservation principles.

Marketing and processing of cultured fish production is an area deserving attention to ensure the safe handling of fish for consumers' safety and the maintenance or enhancement of benefits drawn from those involved in post-harvest activities, i.e. women, as fish production and market supply increase. Deserving as much attention, from a broader perspective, is the issue of irrigation water pricing which could become even more complex with the introduction of a non-consumptive, yet water-dependent, activity and which could slow down the adoption and promotion of IIA by national governments.

Opportunities for the development of IIA activities thus exist but are country-specific. In general, they appear to prevail in small-scale, community or farmer-managed irrigation (existing or rehabilitated) which offer the flexibility required for multi-purpose water management and favour local stakeholders' participation. The relative technical simplicity of rice-fish farming and the familiarity of most farmers with rice, irrigation and wild fish populations are strengths to build on. This type of integration could present an advantage over more complex integrated systems such as fish cages in canals, which require higher technical inputs and are risky ventures.

It is important however that, from a research perspective, no IIA options be left out while others are promoted in priority based solely on "simplicity" criteria as many other factors influence the success of technical interventions. Among these factors are social, cultural and economic dimensions. Most of the case studies showed that lack of consideration given to either of these dimensions resulted in failure, results below expectations or low technology adoption. Although limited, a search of the literature has provided an insight into technical aspects linked to the field implementation of IIA activities. The socio-economic impacts of the activity, where it has been tested, have however been scarcely studied or reported. Bearing in mind that the sum of (irrigation+aquaculture) potential does not equal integrated irrigation-aquaculture potential, more research is needed to cover these issues, along with livelihood impacts, technology adoption, gender and marketing aspects related to the introduction of IIA.

Concluding comments

Replicating lessons and experiences from Asia has not always proved successful on the African continent with its cultural diversity and environmental specificities. Moving from donor-driven aquaculture development to private, individual interventions based on farmers' initiatives and resources will help avoid activity planning on false assumptions of labour and resource availability, production for home consumption and easiness of fish farming (FAO, 2000b). With more flexibility and time given for changes and farmers' initiatives to take place, sustainability and adoption of IIA activities may be more successful than past aquaculture development projects.

However, IIA should not be seen as an entirely new paradigm. It has been happening "naturally", in simpler forms (a pond naturally retaining a few fish, used to water the garden), in many parts of Africa and in the world at large. If objectives are set for developing and strengthening the activity, they should initially focus on the consolidation of the knowledge-base on integrated aquaculture and irrigation. This is more important in terms of technology adoption than, for example, a larger number of ponds or higher fish production figures, as it will contribute to the outlasting of the activity after departure of donor assistance (Harrison, 1991).
References


Fletcher, M., Teklehaimanot, A. & Yemane, G. 1992. Control of mosquito larvae in the port city of Assab by an indigenous larvivorous fish,


International Institute of Rural Reconstruction, Silang, Cavite, Philippines, pp. 70-75.


Metacliffe, M.R. 1995. Investing in aquacultural waste-water techniques for improved water-


## Appendix 1. Country review of irrigation, aquaculture, IIA activities and potential

### TABLES A–N.

#### A: BENIN

<table>
<thead>
<tr>
<th>Source</th>
<th>Irrigation potential (ha)</th>
<th>Large irrigation schemes (ha)</th>
<th>Medium scale (ha)</th>
<th>Small-holder / small-scale schemes (ha)</th>
<th>Irrigated areas (ha)</th>
<th>Dominant type of irrigation / main environment</th>
<th>Rate of irrigation development (ha/year over 1985-1997)</th>
<th>Main irrigated crops</th>
<th>Constraints to irrigation development</th>
<th>Constraints to aquaculture development</th>
<th>IIA activities carried out</th>
<th>Potential sites for developing IIA</th>
<th>Constraints to IIA development</th>
<th>IIA research carried out</th>
<th>IIA potential (current strengths)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sources: Kay (2001), FAO (1995), République Populaire du Bénin (1976)</td>
<td>86 000 (1982); 300 000 (1994)</td>
<td>7 556 (1994)</td>
<td>192 (1994)</td>
<td>1 038 (1994)</td>
<td>22 000 (1982); 17 224 under fully controlled irrigation in 1994</td>
<td>River floodplains and hill irrigation (SH), surface irrigation (40% of areas under controlled irrigation in 1994)</td>
<td>1 167</td>
<td>1. Rice (93% of irrigated crops), 2. Onion (5%) (1993)</td>
<td>N/A</td>
<td>N/A</td>
<td>Some holes, or canals/channels, dug to raise fish in the floodplain of the Ouémé and Sô rivers were reported in the late 1970s.</td>
<td>N/A</td>
<td>In the late 1970s, the Ouémé River valley (floodplain) irrigation project was managed for crop cultivation leaving little scope for fish production, even integrated with rice. Heavy pesticide use was also a constraint.</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

#### B: BURKINA FASO

<table>
<thead>
<tr>
<th>Source</th>
<th>Irrigation potential (ha)</th>
<th>Large irrigation schemes &gt;500ha (ha)</th>
<th>Medium scale (ha)</th>
<th>Small-holder / small-scale schemes &lt;100ha (ha)</th>
<th>Irrigated areas (ha)</th>
<th>Dominant type of irrigation / main environment</th>
<th>Rate of irrigation development (ha/year over 1985-1997)</th>
<th>Main irrigated crops</th>
<th>Constraints to irrigation development</th>
<th>Constraints to aquaculture development</th>
<th>IIA activities carried out</th>
<th>Potential sites for developing IIA</th>
<th>Constraints to IIA development</th>
<th>IIA research carried out</th>
<th>IIA potential (current strengths)</th>
</tr>
</thead>
</table>

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2 NB – Discrepancies among figures may be attributed to the various sources and their methods of assessment.
### B: BURKINA FASO

(continued)

| - Indirect rice-fish integration in the Bragué irrigation scheme.  
| - Several proposals made for the Sourou irrigation scheme but no implementation.  
| - Small-water bodies fisheries enhancement practised for several years.  
| - In dam reservoirs of Tanguiga, Goudri and Ramitenga  
| - Integrated with vegetables upstream from dams. |

| Potential sites for developing IIA | - Fully controlled irrigation: Kou, Banzon and Sourou valleys  
| - Inland valley bottom, e.g. Comoé River  
| - Rainfed areas  
| - Integrated fish-livestock projects |

| Constraints to IIA development | - Lack of rice-fish farming experience  
| - Lack of fingerlings  
| - Competition for on-farm resources, conflict over water allocation  
| - Poor communication networks  
| - Lack of funding (international agencies)  
| - Lack of government direction in rice-fish development  
| - Poor extension |

| IIA research carried out | - Rice-fish with different rice varieties in combination with mono/polyculture of fish  
| - Breeding programmes to stock ponds and reservoirs  
| - Duck-fish systems |

| IIA potential (current strengths) | - 16 000ha currently under irrigation, priority to rice  
| - Many small reservoirs  
| - Good fisheries management  
| - Supportive institutional and policy frameworks.  
| - High demand for fish and possibility to develop post-harvest value-adding activities |

### C: CAMEROON


| Irrigation potential (ha) | 240 000 (1985) |
| Large irrigation schemes (ha) | 11 000 (1982) |
| Medium scale (ha) | N/A |
| Small-holder / small-scale schemes (ha) | 9 000 (1982) |
| Irrigated areas (ha) | 20 000 (1982); 20 970 under controlled irrigation (1987) |
| Dominant type of irrigation / main environment | River floodplains (SH), hill irrigation (SH) |
| Rate of irrigation development (ha/year over 1985-1997) | 0 |
| Small water bodies | 10 000 (<3ha) |
| Perennial reservoirs (ha) | N/A |
| Main irrigated crops | 1. Rice (77%) 2. Vegetables (19%) 3. Banana (4%) |
| Constraints to irrigation development | - N/A |
### C: CAMEROON (continued)

<table>
<thead>
<tr>
<th>Constraints to aquaculture development</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Lack of co-operation between research institutions and government agencies (development)</td>
</tr>
<tr>
<td>- Lack of coherent aquaculture development policy and targeted funding</td>
</tr>
<tr>
<td>- Lack of credit facilities for fish farmers and low availability of fingerlings</td>
</tr>
<tr>
<td>- Poor management of aquaculture and breeding labs</td>
</tr>
<tr>
<td>- Lack of socio-economic considerations related to aquaculture development, incl. lack of economic performance indicators</td>
</tr>
<tr>
<td>- Lack of extension</td>
</tr>
<tr>
<td>- Difficulties linked to land tenure</td>
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<table>
<thead>
<tr>
<th>IIA activities carried out</th>
<th>N/A</th>
</tr>
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<tbody>
<tr>
<td>Potential sites for developing IIA</td>
<td>N/A</td>
</tr>
<tr>
<td>Constraints to IIA development</td>
<td>- Deteriorating irrigation infrastructures</td>
</tr>
<tr>
<td>IIA research carried out</td>
<td>N/A</td>
</tr>
<tr>
<td>IIA potential (current strengths)</td>
<td>N/A</td>
</tr>
</tbody>
</table>

### D: CHAD

<table>
<thead>
<tr>
<th>Sources: Kay (2001), FAO (1995)</th>
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<tbody>
<tr>
<td>Irrigation potential (ha)</td>
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<tr>
<td>Large irrigation schemes &gt;500ha (ha)</td>
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<tr>
<td>Medium scale (ha)</td>
</tr>
<tr>
<td>Small-holder / small-scale schemes &lt;100ha (ha)</td>
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<tr>
<td>Irrigated areas (ha)</td>
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<tr>
<td>Dominant type of irrigation / main environment</td>
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<tr>
<td>Rate of irrigation development (ha/year over 1985-1997)</td>
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<tr>
<td>Main irrigated crops</td>
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<td>Constraints to irrigation development</td>
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<td></td>
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<tr>
<td>Constraints to aquaculture development</td>
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<tr>
<td>IIA research carried out</td>
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<tr>
<td>IIA potential (current strengths)</td>
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</tbody>
</table>

³ This figure does not take into account environmental constraints (in particular linked to the decreasing water levels of Lake Chad), nor consideration related to the sharing of water resources among riverine countries of the Logone River and Lake Chad.
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Irrigation potential (ha)</td>
<td>130 000 (1982), 475 000 (1994)</td>
</tr>
<tr>
<td>Large irrigation schemes &gt;500ha (ha)</td>
<td>42 000 (1982)</td>
</tr>
<tr>
<td>Medium scale (ha)</td>
<td>N/A</td>
</tr>
<tr>
<td>Small-holder / small-scale schemes &lt;100ha (ha)</td>
<td>10 000 (1982)</td>
</tr>
<tr>
<td>Irrigated areas (ha)</td>
<td>89 000 under controlled irrigation in 1994; 72 000 (2001).</td>
</tr>
<tr>
<td>Dominant type of irrigation / main environment</td>
<td>Fully controlled irrigation (54%) and equipped valley bottoms (28%) in 1994. River flood plains (SH)</td>
</tr>
<tr>
<td>Rate of irrigation development (ha/year over 1985-1997)</td>
<td>1 583</td>
</tr>
<tr>
<td>Small-holder / small-scale schemes &gt;100ha (ha)</td>
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</tr>
<tr>
<td>Rate of irrigation development (ha/year over 1985-1997)</td>
<td>1 583</td>
</tr>
<tr>
<td>Perennial dam reservoirs (ha)</td>
<td>N/A</td>
</tr>
<tr>
<td>Main irrigated crops</td>
<td>1. Rice (gravity, mainly in inland valley bottoms) 2. Sugarcane (sprinkler) 3. Plantain (sprinkler) 4. Vegetables (gravity)</td>
</tr>
<tr>
<td>Constraints to irrigation development</td>
<td>In 1994, irrigated agriculture has a minor role compared to rainfed agriculture.</td>
</tr>
<tr>
<td>Constraints to aquaculture development</td>
<td>Despite aquaculture development supported by adequate research facilities and government support (extension, credit and subsidies),</td>
</tr>
<tr>
<td>IIA activities carried out</td>
<td>- Enhanced fisheries in small reservoirs - Rice-fish: within, upstream and upstream of paddy fields. &quot;Projet d'appui à la Profession Piscicole du Centre Ouest&quot; in Doloa Region (farm-based but no dissemination of results) - Fish in ponds adjacent to lowland rice fields in peri-urban zones</td>
</tr>
<tr>
<td>Potential sites for developing IIA</td>
<td>South and West of the country (Zone de Forêt): perennial streams and higher rainfall.</td>
</tr>
<tr>
<td>Constraints to IIA development</td>
<td>- Lack of institutional support and funding supporting integrated activities. - Lack of information and high irrigation costs which small farmers and women cannot afford. No credit. - Pesticide use in agriculture. - Insufficient extension and technical support. - Droughts and conflicts among water users.</td>
</tr>
<tr>
<td>IIA research carried out</td>
<td>N/A</td>
</tr>
<tr>
<td>IIA potential (current strengths)</td>
<td>- Irrigated rice areas should increase by 34 000 ha between 1992 and 2015 - Inland valley bottoms and coastal swamps are favourable to irrigated rice culture (equivalent to 275 000ha) but remains under-exploited</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Large irrigation schemes (ha)</td>
<td>4 720 (1994)</td>
</tr>
<tr>
<td>Medium scale (ha)</td>
<td>1 204 (1994)</td>
</tr>
<tr>
<td>Small-holder / small-scale schemes (ha)</td>
<td>450 (1994)</td>
</tr>
</tbody>
</table>
### F: GHANA (continued)

<table>
<thead>
<tr>
<th><strong>Irrigated areas (ha)</strong></th>
<th>10 000 (80% gravity) to be increased to 100 000 by 2020.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dominant type of irrigation / main environment</strong></td>
<td>Surface (90%, including SH gravity irrigation schemes based on diversion of water stored in small dams), river floodplains (SH) and inland valley swamps.</td>
</tr>
<tr>
<td><strong>Rate of irrigation development (ha/year over 1985-1997)</strong></td>
<td>333</td>
</tr>
<tr>
<td><strong>Main irrigated crops</strong></td>
<td>1. Rice (floodplains) 2. Cash crops (veg., fruits, flowers)</td>
</tr>
</tbody>
</table>
| **Constraints to irrigation development** | - High capital investment for irrigation infrastructure  
- Poor management of government funds  
- Lack of consistent policies for both small and large-scale projects  
- Land tenure system that constraints individual involvement  
- Limited capability to identify and formulate projects adapted to local land and water resources (topography)  
- Failure to take into account gender issues in the design of irrigation schemes for rice production. |
| **Constraints to aquaculture development** | - Modest success of aquaculture extension |
| **IIA activities carried out** | Early promotion of aquaculture and culture-based fisheries in irrigation systems:  
- on-farm pond aquaculture  
- enhanced fisheries in dam reservoirs  
- conversion of 5% of irrigated area in ponds  
- rice-fish trials in large-scale irrigation schemes in the Upper East Region. |
| **Potential sites for developing IIA** | - Tono, Vea and Dawhenya irrigation schemes (rice-fish)  
- Mampong Valley (vegetable-fish) and inland valley bottoms |
| **Constraints to IIA development** | - Inadequate extension  
- Lack of fish seed, feed, capital and information for farmers  
- High investment for irrigation development  
- Socio-cultural factors |
| **IIA research carried out** | - Rice-fish  
- Vegetable-fish (Institute of Renewable Natural Resources) |
| **IIA potential (current strengths)** | - Breeding and fingerling production  
- Adequate distribution and marketing support  
- Existence of an integration policy  
- Inland valley swamps identified as a cheaper alternative to large-scale irrigation schemes but, if developed for rice, sedimentation and siltation will have to be controlled by improved tillage |

### G: GUINEA

| **Sources:** Agro-Ind. (2002), FAO (2002e), Kay (2001), FAO (1995) |
|--------------------------|------------------------------------------------------------------|
| **Irrigation potential (ha)** | 150 000 (1982), 520 000 (1994) |
| **Large irrigation schemes (ha)** | 8 233 (1994) |
| **Medium scale (ha)** | N/A |
| **Small-holder / small-scale schemes (ha)** | 7 308 (1994) |
| **Irrigated areas (ha)** | 45 000 (1982); 99 148 (1994) |
| **Dominant type of irrigation / main environment** | Fully controlled irrigation (16% of total area under irrigation, incl. surface (90%), inland valley bottoms (swamps) (78%) and river floodplains (SH)) |
| **Rate of irrigation development (ha/year over 1985-1997)** | 417 |
| **Main irrigated crops** | N/A |
| **Constraints to irrigation development** | N/A |
### G: GUINEA (continued)

| Constraint to aquaculture development | [assumed to be similar to those constraining inland capture fisheries development:  
- lack of equipment  
- limited access to credit  
- isolation and remoteness of villages, poor access to internal markets  
- lack of processing infrastructures (preservation of fish)] |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>IIA activities carried out</td>
<td>N/A</td>
</tr>
<tr>
<td>Potential sites for developing IIA</td>
<td>N/A</td>
</tr>
<tr>
<td>Constraints to IIA development</td>
<td>[Inadequate land tenure in irrigation schemes]</td>
</tr>
<tr>
<td>IIA research carried out</td>
<td>N/A</td>
</tr>
<tr>
<td>IIA potential (current strengths)</td>
<td>- Mangrove management is oriented towards integrated production systems (rice, fish, salt etc.)</td>
</tr>
</tbody>
</table>

### H: MALI

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigation potential (ha)</td>
<td>560 000 (1992); 1 100 000</td>
</tr>
<tr>
<td>Large irrigation schemes (ha)</td>
<td>63 119 (1994)</td>
</tr>
<tr>
<td>Small-holder / small-scale schemes (ha)</td>
<td>15 501 (1994)</td>
</tr>
<tr>
<td>Irrigated areas (ha)</td>
<td>191 469 (1994); 200 000. Segou is the largest area equipped for irrigation.</td>
</tr>
<tr>
<td>Dominant type of irrigation / main environment</td>
<td>Surface (100% in fully controlled large-scale irrigation schemes), floodplains of rivers Niger and Bani (SH), inland valley bottoms in SW part of the country. Flood recession cropping area constitutes 57% of total area under irrigation.</td>
</tr>
<tr>
<td>Rate of irrigation development (ha/year over 1985-1997)</td>
<td>2 167</td>
</tr>
<tr>
<td>Main irrigated crops</td>
<td>1. Rice (80%) 2. Sorghum 3. Sugarcane 4. Tea</td>
</tr>
</tbody>
</table>
| Constraints to irrigation development                                | - Limited irrigation research  
- Under-exploitation of irrigated areas  
- Unfavourable climatic conditions (important evaporation, irregular rainfall) and uneven distribution of water resources in the country.  
- High infrastructure costs (reservoir building)  
- No farmers' organisations and too many irrigation extension officers (lack of extension cohesion). |
| Constraints to aquaculture development                               | - Focus on fish biology, feed formulation, pond fertilisation and artificial breeding.  
- Lack of consideration given to the socio-economic aspects of the activity (land access, appropriation of techniques, competition between fish farming and capture fisheries). |
| IIA activities carried out                                           | Several types of integration of aquaculture in large-scale irrigation schemes have been tried but are currently dominated by rice-fish activities. Rice-fish is promoted in Segou (demonstration pond in community-managed irrigation scheme, as part of SPFS) and Mopti (floodplain) areas. |
| Potential sites for developing IIA                                    | Mopti, Ségou and Sélingué areas. High potential for improved rice-fish ponds in partial control large-scale irrigation schemes in the Delta Central of the Niger River (>80,000ha at Mopti and Segou, deepwater rice areas). |
### H: MALI (continued)

<table>
<thead>
<tr>
<th>Constraints to IIA development</th>
<th>Little potential for IIA in flood-dependent irrigation schemes (e.g. Niger River) due to reduced peak floods. Constraints mainly linked to aquaculture development:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>- Lack of extension officers and limited promotion of the activity among rural populations</td>
</tr>
<tr>
<td></td>
<td>- Limited access to credit for the activity</td>
</tr>
<tr>
<td></td>
<td>- Limited institutional support (Chambres d’Agriculture)</td>
</tr>
<tr>
<td></td>
<td>- Seasonal water availability</td>
</tr>
<tr>
<td></td>
<td>- Use of pesticides in agriculture</td>
</tr>
<tr>
<td></td>
<td>- Lack of institutional support and funds for aquaculture development</td>
</tr>
<tr>
<td></td>
<td>- Single purpose management of irrigated rice areas</td>
</tr>
<tr>
<td></td>
<td>- Low priority amongst farmers</td>
</tr>
</tbody>
</table>

| IIA research carried out | Rice-fish trials |

| IIA potential (current strengths) | May be limited due to lack of water availability but current irrigation infrastructures are being rehabilitated and private sector initiative in irrigation development promoted. Emphasis is placed on stakeholders' involvement in water management and infrastructure maintenance [which could stimulate the creation of a favourable context for IIA development] |

### J: NIGER

<table>
<thead>
<tr>
<th>Sources: Kay (2001), FAO (1995)</th>
<th></th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Irrigation potential (ha)</th>
<th>100 000 (1982); 270 000 (1990)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large irrigation schemes (ha)</td>
<td>10 000 (1982)</td>
</tr>
<tr>
<td>Medium scale (ha)</td>
<td>N/A</td>
</tr>
<tr>
<td>Small-holder / small-scale schemes (ha)</td>
<td>20 000 (1982)</td>
</tr>
<tr>
<td>Dominant type of irrigation / main environment</td>
<td>Full + partial control irrigation (85% of total irrigated area), flood recession cropping area (15%), River Niger floodplain (SH). Dry-season irrigation widespread (vegetables) but supplementary irrigation in the wet season is not.</td>
</tr>
<tr>
<td>Rate of irrigation development (ha/year over 1985-1997)</td>
<td>3 000</td>
</tr>
<tr>
<td>Main irrigated crops</td>
<td>1. Rice 2. Cotton 3. Wheat</td>
</tr>
<tr>
<td>Constraints to irrigation development</td>
<td>- Farmers see irrigation as a means to diversify crop production, not to increase productivity</td>
</tr>
<tr>
<td></td>
<td>- Limited farmers’ participation in irrigation planning</td>
</tr>
<tr>
<td></td>
<td>- Lack of irrigation infrastructures and high irrigation costs, in particular in remote areas</td>
</tr>
<tr>
<td></td>
<td>- Priority given to rainfed agriculture</td>
</tr>
<tr>
<td>Constraints to aquaculture development</td>
<td>N/A</td>
</tr>
<tr>
<td>IIA activities carried out</td>
<td>N/A</td>
</tr>
<tr>
<td>Potential sites for developing IIA</td>
<td>N/A</td>
</tr>
<tr>
<td>Constraints to IIA development</td>
<td>N/A</td>
</tr>
<tr>
<td>IIA research carried out</td>
<td>N/A</td>
</tr>
<tr>
<td>IIA potential (current strengths)</td>
<td>N/A</td>
</tr>
</tbody>
</table>
## K. NIGERIA

<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Irrigation potential (ha)</strong></td>
</tr>
<tr>
<td><strong>Large irrigation schemes (ha)</strong></td>
</tr>
<tr>
<td><strong>Medium scale (ha)</strong></td>
</tr>
<tr>
<td><strong>Small-holder / small-scale schemes (ha)</strong></td>
</tr>
<tr>
<td><strong>Irrigated areas (ha)</strong></td>
</tr>
<tr>
<td><strong>Dominant type of irrigation / main environment</strong></td>
</tr>
<tr>
<td><strong>Rate of irrigation development (ha/year over 1985-1997)</strong></td>
</tr>
<tr>
<td><strong>Perennial dam reservoirs (ha)</strong></td>
</tr>
<tr>
<td><strong>Main irrigated crops</strong></td>
</tr>
<tr>
<td><strong>Constraints to irrigation development</strong></td>
</tr>
<tr>
<td><strong>Constraints to aquaculture development</strong></td>
</tr>
<tr>
<td><strong>IIA activities carried out</strong></td>
</tr>
<tr>
<td><strong>Potential sites for developing IIA</strong></td>
</tr>
<tr>
<td><strong>Constraints to IIA development</strong></td>
</tr>
<tr>
<td><strong>IIA research carried out</strong></td>
</tr>
<tr>
<td><strong>IIA potential (current strengths)</strong></td>
</tr>
</tbody>
</table>
### L. SENEGAL

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigation potential (ha)</td>
<td>180 000 (1982), average 400 000 (1994)</td>
</tr>
<tr>
<td>Large irrigation schemes (ha)</td>
<td>23 135 (1994)</td>
</tr>
<tr>
<td>Medium scale (ha)</td>
<td>4 265 (1994)</td>
</tr>
<tr>
<td>Small-holder / small-scale schemes (ha)</td>
<td>44 000 (1994)</td>
</tr>
<tr>
<td>Irrigated areas (ha)</td>
<td>100 000 (1982); 141 400 (1994) including 71 400 under full/partial control irrigation; over 155 000 (2002).</td>
</tr>
<tr>
<td>Dominant type of irrigation / main environment</td>
<td>Full/partial control irrigation (50% of total area under irrigation), inland valley bottoms (26%) and flood recession areas (23%). River Senegal floodplain and inland valley bottoms (swamp irrigation) (SH). Irrigated mangrove rice in Casamance. Rice irrigation divided in 3 types: large-scale schemes (grands périmètres), small-scale private/individual systems (périmètres d'irrigation privée) and village irrigation schemes (périmètres irrigués villageois).</td>
</tr>
<tr>
<td>Rate of irrigation development (ha/yr over 1985-1997)</td>
<td>- Agro-technical constraints (poor management of irrigated crops) - Socio-economic constraints (farmers' dependency on state, credit defaulting, problems related to water allocation) - Institutional constraints (traditional irrigation practices remain dominant, crop diversification rather than intensification)</td>
</tr>
<tr>
<td>Main irrigated crops</td>
<td>1. Rice (95% of irrigated areas) 2. Sugarcane (6% of irrigated areas) 3. Vegetables, fruits, maize.</td>
</tr>
<tr>
<td>Constraints to irrigation development</td>
<td>Fish culture is limited following unsatisfactory results from internationally-funded projects on intensive pond culture, cage culture, extensive culture and rice-fish farming due to, in Senegal River valley:  - Environmental constraints (variations in hydrological regime, soil porosity, high water turbidity, low temperature and mineral content, low consultation regarding water management policies)  - Technological and institutional constraints (poor site selection, lack of research-development co-ordination, lack of fingerlings, extension staff, poor project management and premature technology transfer to farmers)  - Socio-economic constraints (high costs of equipment for aquaculture, competition with marine fish and other on-farm resources, including labour, inadequate choice of target groups). In Casamance, poor results were caused by inadequate pond management and feeding, predation, high maintenance and labour costs.</td>
</tr>
<tr>
<td>Constraints to aquaculture development</td>
<td>IIA activities carried out  - Rice-fish culture: research (USAID + Chinese support) in Ndiarème dyu Wallo and Guidakhar, NGO support to development in Fatick (Ndjaye Ndiaye, Ndjosmon, Sanghai) and Kédougou (Fadiga pond) regions (part of SPFS).  - Community-managed fish culture in large-scale irrigation system of Vélingra (Anambe basin).  - Pens in dammed valleys of Casamance (1994).  - Fish stocked in irrigation canals and large-scale reservoirs.</td>
</tr>
<tr>
<td>Potential sites for developing IIA</td>
<td>River Senegal floodplain is being developed (as part of a national development plan to 2015) and existing irrigation systems are being rehabilitated. IIA already exists in the inland valleys of Casamance and systems could be improved there.</td>
</tr>
<tr>
<td>Constraints to IIA development</td>
<td>- Lack of experience in aquaculture, and IIA in particular - Land tenure and high cost of irrigation equipment - Single purpose or low water management efficiency - Lack of credit for aquaculture activities and of extension support</td>
</tr>
<tr>
<td>IIA research carried out</td>
<td>N/A</td>
</tr>
</tbody>
</table>
**L. SENEGAL (continued)**

| IIA potential (current strengths) | - Rehabilitation of current schemes and development of the River Senegal floodplain, provided that aquaculture is taken into account as an additional and complementary use to planned uses (flood recession crops, irrigated cash crops, vegetables and hydro-power)  
- Rice-fish farming in floodplains holds highest potential, especially in community and individually managed small-scale irrigation systems  
- Potential in large-scale full control irrigation systems is not as high due to institutional difficulties related to water management and low demand for fish in these areas  
- High demand for fish  
- Availability of fingerlings |

**M: SIERRA LEONE**

| Irrigation potential (ha) | 100 000 (1982); 807 000 (1981) |
| Large irrigation schemes (ha) | 5 000 (1982) |
| Medium scale (ha) | N/A |
| Small-holder / small-scale schemes (ha) | 50 000 (1982) |
| Irrigated areas (ha) | 55 000 (1982); 155 360 (1992) |
| Dominant type of irrigation / main environment | Inland valley swamps and mangrove swamps (81% of total area under irrigation) and river floodplains (SH). |
| Rate of irrigation development (ha/year over 1985-1997) | 83 |
| Main irrigated crops | Rice (155 000 ha in 1991) |
| Constraints to irrigation development | - Rainfed upland rice dominates agricultural production and is grown by 96% of farmers  
- Irrigation development primarily related to a return to political stability |
| Constraints to aquaculture development | - Deficient socio-economic and infrastructural conditions constrain the development of large-scale aquaculture but small-scale projects have shown potential |
| IIA activities carried out | N/A |
| Potential sites for developing IIA | N/A |
| Constraints to IIA development | N/A |
| IIA research carried out | N/A |
| IIA potential (current strengths) | - Considerable potential for development of small-scale hydro-electric schemes that could be designed to accommodate irrigation [and aquaculture.]  
- Swamps considered as the most promising land to increase rice production [which could then be integrated to aquaculture]  
- Use of rice fields for rice-fish farming holds promises (with 10 percent of fields used for IIA, 8 000 tons of fish could be produced per year. |
<table>
<thead>
<tr>
<th><strong>N: TOGO</strong></th>
<th>Sources: Kay (2001), FAO (1995), Kusiaku (1976)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigation potential (ha)</td>
<td>86 000 (1982), 180 000 (1990)</td>
</tr>
<tr>
<td>Large irrigation schemes (ha)</td>
<td>900 (1990)</td>
</tr>
<tr>
<td>Medium scale (ha)</td>
<td>772 (1990)</td>
</tr>
<tr>
<td>Small-holder / small-scale schemes (ha)</td>
<td>336 (1990)</td>
</tr>
<tr>
<td>Irrigated areas (ha)</td>
<td>13 000 (1982); 7 008 (1990)</td>
</tr>
<tr>
<td>Dominant type of irrigation / main environment</td>
<td>Inland valley bottoms (71% of total area under irrigation), full/partial control irrigation (28%, of which 72% use surface irrigation). Small to medium-sized earth dams commanding downstream areas by channels and river floodplain (SH)</td>
</tr>
<tr>
<td>Rate of irrigation development (ha/year over 1985-1997)</td>
<td>0</td>
</tr>
<tr>
<td>Main irrigated crops</td>
<td>1. Sugarcane (45% of irrigated crops) 2. Rice/vegetables (28%) 3. Fruits (23%)</td>
</tr>
<tr>
<td>Constraints to irrigation development</td>
<td>More than 1 000 ha under full/partial control irrigation are under-exploited or even abandoned due to: - Management problems - Lack of market opportunities for agricultural outputs. - Irrigation not a priority in the country's development planning.</td>
</tr>
<tr>
<td>Constraints to aquaculture development</td>
<td>Lack of confidence given to aquaculture extension initiatives by farmers.</td>
</tr>
<tr>
<td>IIA activities carried out</td>
<td>N/A</td>
</tr>
<tr>
<td>Potential sites for developing IIA</td>
<td>- Largest irrigation scheme is Anié.</td>
</tr>
<tr>
<td>Constraints to IIA development</td>
<td>N/A</td>
</tr>
<tr>
<td>IIA research carried out</td>
<td>N/A</td>
</tr>
<tr>
<td>IIA potential (current strengths)</td>
<td>- Rehabilitation of existing schemes could stimulate irrigation development [especially if aquaculture is a new activity integrated in these] - Equipment of inland valley bottoms for irrigation has been a priority since the early 1990s</td>
</tr>
</tbody>
</table>
THE POTENTIAL FOR DEVELOPMENT OF AQUACULTURE AND ITS INTEGRATION WITH IRRIGATION WITHIN THE CONTEXT OF THE FAO SPECIAL PROGRAMME FOR FOOD SECURITY IN THE SAHEL

Jim Miller
Aquaculture and Inland Fisheries Project
FAO – National Special Programme for Food Security Office, Abuja, Nigeria


Abstract

Integrated aquaculture may help produce more fish and at the same time use water more efficiently in West Africa. In this paper, the potential for enhanced fish production in Burkina Faso, Mali, Niger and Senegal is assessed. Systems examined include floodplains, irrigation systems, lakes, wetlands and other water bodies. Floodplains form the basis of inland fisheries in Senegal, Mali and Niger. In Burkina Faso, the fisheries are based mainly on lakes and ponds. Floodplain fisheries yields are affected mainly by droughts and by upstream development of dams and irrigation schemes. Niger and Burkina Faso have benefited considerably from the development of small dams and other water bodies. Of the four countries, Senegal has experienced most development of fish pond aquaculture. Traditional marsh aquaculture exists in all four countries and involves keeping fish alive during the dry season in wells or holes in the wetlands. Methods used include collecting, holding, transporting and stocking fingerlings, combined with composting and some feeding. This artisanal aquaculture extends the availability of fish during the dry season and provides fish for restocking the wetlands when the rains return. Apart from some attempts at developing integrated rice-fish farming, most recent aquaculture development efforts have focused on more intensive technology involving raceways or cage culture. A number of environmental, socio-cultural, institutional, financial and technical constraints to aquaculture development in the Sahel region are discussed. The main opportunity for development lies in extensive, integrated systems using low-cost, locally available inputs over large land areas as found in irrigation schemes. These are presently underutilized and through their integration with aquaculture, rice and fish production can be increased. More attention is also needed for developing traditional forms of aquaculture. Recommendations for training and institutional strengthening conclude the paper.

Introduction

With decreasing fish catch across West Africa in contrast with growing populations and increasing demand for food, aquaculture can play a role in helping increase fish production in the Sahel region. However, water is a limiting resource and effective optimization of water use is a critical issue to be resolved. Integrated irrigation-aquaculture (IIA) has been proposed as a way of increasing the efficiency of water use and producing much-needed animal protein for human consumption. In the past, aquaculture development in the Sahel has been attempted in “large steps”, resulting in costly failures of intensive tilapia farming in raceways (e.g., Burkina Faso) and cages (e.g., Niger). Major undertakings have been tried in extensive and semi-intensive fish farming as well, but today, aquaculture remains limited to monocultures with little integration. One of the lessons of the past is that there is a clear need for integrated aquaculture.

In 1997, the FAO proposed an IIA Network for Ghana, Côte d’Ivoire, Mali, Burkina Faso and Zambia (Coche, 1998). The FAO’s Action Plan for Aquaculture Research in sub-Saharan Africa (Coche et al., 1994) had recommended eight priority research programmes including “Aquaculture in irrigation schemes” and “Small Water Body Fisheries Enhancement”. These programmes were to operate as part of the IIA network for comparative studies among the various countries as recommended at the IIA Workshop in Accra, Ghana in September 1999 (Moehl et al., 2001). The core of the network
Table 1. General information on Sénégal, Mali, Niger and Burkina Faso, January 2000. Sources: EIU (2005); aquaculture & fisheries strategy reports for Mali, Niger and Burkina Faso; FAO (2005).

<table>
<thead>
<tr>
<th>Information</th>
<th>Burkina Faso</th>
<th>Mali</th>
<th>Niger</th>
<th>Sénégal</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>General information</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area of country (km²)</td>
<td>274 000</td>
<td>1 240 190</td>
<td>1 267 000</td>
<td>196 720</td>
</tr>
<tr>
<td>Total population (inhabitants)</td>
<td>11 400 000</td>
<td>9 790 000</td>
<td>10 100 000</td>
<td>9 000 000</td>
</tr>
<tr>
<td>Population density (inhabitants/km²)</td>
<td>42</td>
<td>8</td>
<td>8</td>
<td>45</td>
</tr>
<tr>
<td>Rural population (%)</td>
<td>73</td>
<td>83</td>
<td>81</td>
<td>60</td>
</tr>
<tr>
<td>GDP/person ($US)</td>
<td>217</td>
<td>272</td>
<td>336</td>
<td>520</td>
</tr>
<tr>
<td><strong>Rainfall</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average annual (mm)</td>
<td>844</td>
<td>334</td>
<td>north 180</td>
<td>742</td>
</tr>
<tr>
<td>Range annual (mm)</td>
<td></td>
<td></td>
<td>south 300</td>
<td></td>
</tr>
<tr>
<td>• north</td>
<td>300</td>
<td>100</td>
<td>0</td>
<td>300</td>
</tr>
<tr>
<td>• south</td>
<td>1300</td>
<td>1400</td>
<td>800</td>
<td>1800</td>
</tr>
<tr>
<td><strong>Marine sector</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marine fishery production (tonnes)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>450 000</td>
</tr>
<tr>
<td>No. marine fishermen</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• industrial</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>10 000</td>
</tr>
<tr>
<td>• artisanal</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>45 000</td>
</tr>
<tr>
<td><strong>Inland fishery sector</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inland fishery production (tonnes)</td>
<td>6 000-8 000</td>
<td>100 000</td>
<td>6 000</td>
<td>14 000</td>
</tr>
<tr>
<td>- of which from rivers (%)</td>
<td>27</td>
<td>80</td>
<td>65</td>
<td>0.05</td>
</tr>
<tr>
<td>- of which from lakes (%)</td>
<td>73</td>
<td>20</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>Potential fish production (tonnes)</td>
<td>12 500</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of inland fishermen</td>
<td>8 000</td>
<td>70 000</td>
<td>2 000-3 000</td>
<td>2 500</td>
</tr>
<tr>
<td>Aquaculture production (tonnes)</td>
<td>80</td>
<td>100</td>
<td>(est.) 30</td>
<td>(est.) 40</td>
</tr>
<tr>
<td>Total area of inland lakes (ha)</td>
<td>55 400</td>
<td>22 000</td>
<td>10 000</td>
<td></td>
</tr>
<tr>
<td>Potential exploitable inland water (ha)</td>
<td>200 000</td>
<td>560 000</td>
<td>270 000</td>
<td>400 000</td>
</tr>
<tr>
<td>Total area floodplain (ha)</td>
<td>2 000 000</td>
<td>400 000</td>
<td>1 000 000</td>
<td></td>
</tr>
<tr>
<td><strong>Economic impact</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fisheries %GDP</td>
<td>1</td>
<td>4.2</td>
<td>insignificant</td>
<td>4</td>
</tr>
<tr>
<td><strong>Animal protein consumption</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fish (kg/capita/y)</td>
<td>1.5</td>
<td>10.5</td>
<td>0.3 – 0.5</td>
<td>37</td>
</tr>
<tr>
<td>Meat (kg/capita/y)</td>
<td>–</td>
<td>7.8</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td><strong>Irrigation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full/partial control (ha)</td>
<td>15 430</td>
<td>85 620</td>
<td>66 324</td>
<td>69 286</td>
</tr>
<tr>
<td>Total irrigated land (ha)</td>
<td>45 730</td>
<td>200 000</td>
<td>81 000</td>
<td>141 400</td>
</tr>
<tr>
<td>Gravity irrigation (ha)</td>
<td>3 917</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irrigated rice (ha)</td>
<td>30 900</td>
<td>193 000</td>
<td>30 000</td>
<td>32 000</td>
</tr>
</tbody>
</table>

would be formed by a number of research and development institutions in each country. This would encourage collaboration and exchange of information, improved data collection, improved communications, capacity building and technology development with a focus on optimization in water management practices. The network would be linked with other regional groups including the Africa Rice Center (WARDA, for rice farming), the International Institute of Tropical Agriculture (IITA), the WorldFish Center (previously ICLARM), the Food and Agriculture Organization (FAO) and its Special Programme for Food Security (SPFS) and others.

The Special Programme for Food Security (SPFS) is FAO’s flagship initiative for reaching the goal of halving the number of hungry in the world by 2015. Currently there are 852 million food insecure people in the world. Of these, 86 percent live in the 102 countries participating in the SPFS. The SPFS promotes effective,
tangible solutions to the elimination of hunger, undernourishment and poverty. It was launched in 1994 with the goal of achieving sustainable increases in food production through dissemination of existing and proven agricultural technology. To maximize the impact of its work, the SPFS strongly promotes national ownership and local empowerment in the countries in which it operates. The SPFS has entered its second phase for diversification of activities in many countries. This offers opportunities for integration of aquaculture into irrigation schemes. Many constraints exist for agricultural development and the SPFS uses on-farm contact and small-scale demonstrations as entry points for identifying effective actions for removal of existing constraints faced by farmers. The SPFS strives to create an enabling environment conducive to the success and widespread adoption of improved agricultural techniques. Through participatory methodologies and partnerships with village organizations and farmer groups, the SPFS is increasing vegetable and grain production, improving small animal production, as well as improving management of water in irrigation schemes. Each country has a management committee to oversee implementation of the SPFS programme, monitor progress and assure adherence to the principles of partnership. In general, activities are focused on basic production including rice, maize and other cereals, vegetables, cowpeas and small animal husbandries. A major thrust of the programme is the management of water resources in valleys and irrigation schemes.

With such a broad range of activities, many possibilities exist for integration of aquaculture with crops, animals and irrigation schemes. Extensive aquaculture has already been incorporated in the activities in all four countries as with small dam construction and stocking small water bodies by fishermen. As the SPFS enters Phase II for diversification and expansion of activities, the integration of aquaculture into ongoing activities and irrigation schemes offers potential to improve the use of farm resources and water for an increase in production and revenues. In addition to integration of aquaculture, other SPFS activities could include encouragement for rural credit and savings and an increased focus on reduction of post harvest losses, through demonstration and training in using improved fish smoking technology.

In this paper, the current situation and potential for enhanced fish production is assessed in four Sahelian countries: Burkina Faso, Mali, Niger and Senegal. Systems examined include floodplains, irrigation systems, lakes, marshes, ponds and other bodies of water (locally, the French word mare is used for wetland pools). The paper particularly focuses on the potential for increasing fish production and aquaculture within the context of the Special Programme for Food Security (SPFS) and evaluates past and present aquaculture efforts. Recommendations for integration of aquaculture in ongoing programmes (including the SPFS) are made. The information on which the paper is based was collected during a mission of the author to the four countries between December 1999 and January 2000, during which discussions with government officials and other experts in local institutions and development projects were held, relevant documents were reviewed and visits to sites with aquaculture and culture-based fisheries were made.

Aquatic resources in the Sahel

Sahelian countries experience a harsh, deteriorating environmental situation of cyclical drought, causing increased desertification, diminishing surface waters, losses in agriculture and diminished fish catch. This is in contrast with growing populations in need of more food, including animal proteins. In view of this situation, it is urgent to seek methods to optimize the use of available water for food production. Africa has considerable potential to develop aquaculture but has not exploited this technology significantly. Less than 5% of Africa’s potential in aquaculture has been tapped (Kapetsky, 1994; FAO, 1996). The 1.39 million ha of irrigated land in the four countries under review have been exploited for rice and cereal production without consideration for integration, which offers more efficient use of water. Presently, the large area of irrigated lands are under-exploited and offer an opportunity to include integrated aquaculture as a diversification in irrigation schemes.

One of the constraints is the lack of statistics in fisheries and aquaculture. All countries in this study lacked data or had questionable information. Available reports sometimes presented conflicting data on fish production, and even basic quantitative information such as the number of ponds, lakes and even rainfall was missing. Clearly, there is a need to gather information in a systematic...
Table 2. Significant rivers and floodplains in Senegal, Mali, Niger and Burkina Faso. Sources: Britannica (2005); EIU (2005); Country fisheries reports.

<table>
<thead>
<tr>
<th>Country</th>
<th>River</th>
<th>Length (km)</th>
<th>Floodplain area low water (ha)</th>
<th>Floodplain area high water (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Senegal</td>
<td>Senegal</td>
<td>1641</td>
<td>78 700</td>
<td>1 295 000</td>
</tr>
<tr>
<td></td>
<td>Gambia</td>
<td>1120</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Casamance</td>
<td>322</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Saloum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Falémé</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mali</td>
<td>Niger</td>
<td>700</td>
<td>2 000 000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Senegal</td>
<td>368</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Niger</td>
<td>Niger</td>
<td>550</td>
<td>25 000</td>
<td>400 000</td>
</tr>
<tr>
<td>Burkina Faso</td>
<td>Komoé (Black Volta)</td>
<td>750</td>
<td></td>
<td>78 000</td>
</tr>
<tr>
<td></td>
<td>Mouhoun (Black Volta)</td>
<td>1 160</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nazinbé (White Volta)</td>
<td>640</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Léraba</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sourou</td>
<td></td>
<td></td>
<td>10 000</td>
</tr>
</tbody>
</table>

manner and to update information from the field. To accomplish this, local capacity needs to be improved through training and better organization.

Rainfall

Agriculture and fishing are held hostage to limited rainfall, which determines planting season, volume flow of the rivers and recharge of the underground aquifers. The past thirty years have witnessed unpredictable and decreased rainfall as well as decreased water flow in streams and rivers in the four countries under study. The cumulative rainfall deficit was 7% in the 1960s, but amounted to 16% in the 1980s. Rainfall has increased in recent years, but the region has experienced repeated, exceptionally low water flows in rivers and earlier drying of temporary water bodies (IRD, 1999). Although all four countries have experienced diminished water flows in streams and rivers over the past thirty years, a report from Niger indicates that underground aquifers appear to be unaffected by decreased surface waters). Rainfall in Niger averaged 650 mm between 1950 and 1970, but decreased significantly to less than 400 mm from 1971 to 1990 causing Lake Tchad’s portion in Niger to dry up completely. However, increased rainfall in recent years has generally returned Lake Tchad to its normal levels, including 310 000 ha in Niger. Rainfall comparisons among the four countries are presented in Table 1.

Rivers and floodplains

Some data on rivers and floodplains in the four countries is presented in Table 2. A number of rivers contribute to the hydrogeography of the four countries in this study. Two major rivers traverse sub-Saharan Africa, the Senegal with a total length of 1 641 km and the Niger with 4 200 km. Both of these rivers as well as the Gambia (1 120 km) originate in mountainous, forested areas with relatively high rainfall supplying a huge region with a well-developed hydrographic system flowing through desertic, arid zones as in northern Senegal, Mali and Niger. Thus, waters originating in humid tropical areas flow through arid areas, affording a much greater production potential than the arid zone would normally support on its own. This represents a significant transfer of productivity to the Sahel.

Floodplains form the basis of inland fisheries in Senegal, Mali and Niger. In Burkina Faso the fisheries are based mainly on lakes and ponds. Floodplain fisheries are subjected to great fluctuations caused by droughts. An example is the Niger floodplain in Mali, which produced only 40 000 metric tonnes during a drought in 1990 but in 1999 had yields surpassing 100 000 tonnes (Table 1).
Table 3. Small water bodies (1-100 ha), lakes and dams, and village fish ponds in four countries of the Sahel region. Source: personal communication, field workers in each country.

<table>
<thead>
<tr>
<th>Country</th>
<th>Location</th>
<th>Number</th>
<th>Area (ha)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>small water bodies</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Senegal</td>
<td>no data</td>
<td>–</td>
<td>–</td>
<td></td>
</tr>
<tr>
<td>Mali</td>
<td>no data</td>
<td>–</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Niger</td>
<td>1 023</td>
<td>10 000–27 000</td>
<td>175 permanent</td>
<td></td>
</tr>
<tr>
<td>Burkina Faso</td>
<td>2 100</td>
<td>200 000</td>
<td>400 permanent</td>
<td></td>
</tr>
<tr>
<td><strong>lakes and artificial water bodies</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Senegal</td>
<td>Guiers</td>
<td>17 000–30 000</td>
<td>1 000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Niaudouba</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Anambé</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mali</td>
<td>Manantali</td>
<td>50 000</td>
<td>40 900</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sélingué</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Niger</td>
<td>Tchad</td>
<td>310 000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Burkina Faso</td>
<td>Bam</td>
<td>1 200–20 000</td>
<td>10 000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sourou</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bagré</td>
<td>25 000</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kompiembiga</td>
<td>20 000</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>village fish ponds</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Senegal</td>
<td>Basse Casamance</td>
<td>236</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>elsewhere</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mali</td>
<td>Niono, Segou, San</td>
<td>273</td>
<td>12.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 borrow pits</td>
<td></td>
<td>9.6</td>
<td></td>
</tr>
<tr>
<td>Niger</td>
<td>scattered</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Burkina Faso</td>
<td>southwest</td>
<td>500</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The Senegal River has some 1.295 million ha of floodplains, which used to produce 32 000 mt per year of fish prior to the drought. The combined effects of damming of the Senegal, droughts and installation of many irrigation schemes in floodplain areas have severely impacted this once highly productive floodplain fishery. Similar developments have affected the Niger River in Mali and Niger. The drought and development on the Senegal River caused fish catch to drop drastically from 32 000 to 14 000 tonnes (Diop, 1999); other sources estimate inland catch to have dropped to 2 000 tonnes. Such information is much debated in Senegal, as inland fisheries statistics have not been collected for 20 years. Nevertheless, poor inland fishermen have experienced tremendous decreases in fish catch, causing many of them to relocate. The number of fishermen decreased from some 10 000 to around 2 500 during this period of diminishing catch (Diop, 1999). Fishermen in Mali and Niger have also decreased in number, but have also actively sought to diversify into culture based fisheries or agriculture. A number have moved to other countries, especially Côte d’Ivoire and Ghana.

Small water bodies, lakes and fish ponds

Information on small water bodies, lakes and fish ponds is summarized in Table 3. Niger and Burkina Faso have benefited considerably from projects focused on the development of small dams and other water bodies. Both countries have programmes for stocking such temporary and permanent water bodies, involving participation of fishermen in the capture, holding, transport and stocking of fingerlings. Species caught include tilapias (*Oreochromis niloticus* and *Sarotherodon melanotheron*) and catfish species (*Clarias gariepinus*, *Synodontis* spp., *Heterobranchus* spp. and *Chrysichthys nigrodigitatus*) as well as some *Alestes* sp.

The four countries under study have a number of lakes and sizeable artificial bodies of water. As a result of the Government
Table 4. Status of irrigation in Senegal, Mali, Niger and Burkina Faso (FAO, 2005).

<table>
<thead>
<tr>
<th>Item</th>
<th>Senegal</th>
<th>Mali</th>
<th>Niger</th>
<th>Burkina Faso</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>− Status of irrigation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface water irrigation (ha)</td>
<td>–</td>
<td>78 520</td>
<td>–</td>
<td>11 530</td>
<td></td>
</tr>
<tr>
<td>Pumped irrigation water (ha)</td>
<td>71 400</td>
<td>100</td>
<td>66 480</td>
<td>3 900</td>
<td></td>
</tr>
<tr>
<td>Equipped valleys/irrigation (ha)</td>
<td>37 000</td>
<td>3 826</td>
<td>–</td>
<td>8 900</td>
<td></td>
</tr>
<tr>
<td>Other valleys (ha)</td>
<td>37 000</td>
<td>109 023</td>
<td>12 000</td>
<td>21 400</td>
<td></td>
</tr>
<tr>
<td>Total irrigated lands (ha)</td>
<td>141 400</td>
<td>191 469</td>
<td>78 480</td>
<td>45 730</td>
<td></td>
</tr>
<tr>
<td>Irrigated rice fields (ha)</td>
<td>32 000</td>
<td>193 000</td>
<td>29 000</td>
<td>30 900</td>
<td>284 900</td>
</tr>
<tr>
<td>− Potential for rice-fish farming</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total irrigation potential (ha)</td>
<td>400 000</td>
<td>560 000</td>
<td>270 000</td>
<td>164 460</td>
<td>1 394 460</td>
</tr>
<tr>
<td>15% of irrigated rice (ha)</td>
<td>4 800</td>
<td>28 950</td>
<td>4 350</td>
<td>4 635</td>
<td>42 735</td>
</tr>
<tr>
<td>Potential fish production at 0.25 tonnes/ha (tonnes)²</td>
<td>1 200</td>
<td>7 237</td>
<td>1 087</td>
<td>1 159</td>
<td>10 683</td>
</tr>
</tbody>
</table>

¹Total of 4 countries = 42 735 ha of irrigated rice (15% of the total irrigated rice fields)
²Total potential fish production = 10 683 tonnes

decentralization programme, fishermen are being permitted concessions for fishing a number of water bodies in Niger, Senegal and Burkina Faso. Irrigation schemes are associated with most of these lakes.

Of the four countries, Senegal experienced the most significant effort at developing village fish farming. In the 1970s and 1980s some 788 small (100–300 m²) fish ponds were built. Today only some 30% of these remain active. Little importance appeared to be given to record keeping, as no mention of fish ponds was made in any of the documentation obtained for the four countries (including national fisheries strategies and other important documents).

Irrigation

Table 4 presents the status of irrigation in each of the four countries under review. Farmers using irrigation schemes are often poorly organized. They are sometimes disadvantaged with the management of certain irrigation schemes, which may charge up to CFA160 000 equivalent to US$246 per hectare per year (exchange rate 1 US$ = 651 CFA Franc in 2000) for frequently unreliable water delivery which sometimes cannot prevent crop failures.

Aquaculture development in the Sahel

Africa uses less than 5% of its potential for aquaculture (Kapetsky, 1994). Despite many constraints, the Sahel region does have potential for aquaculture development and tapping into this can contribute to increased fish production, employment and revenues for farmers. International aquaculture projects in the Sahel region have often failed to recognize the existence of aquaculture in the Sahel long before international assistance arrived on the scene.

Traditional extensive aquaculture

Extensive aquaculture in pools and ponds (mares) occurred in response to harsh droughts, which dried up ponds and shallow lakes near villages, threatening the loss of fish to the fishing communities. In an effort to maintain a stock of fish for their pond or marsh, villagers caught fish and held them in wells or holes dug in the bottom of the marshes. Fish were kept alive with some feeding and were restocked in the pond or marsh when the rains returned. This "artisanal marsh aquaculture" has been practiced for many decades and was mentioned by villagers in each of the four countries visited. Methods used include collecting, holding, transporting and stocking fingerlings, combined with composting and some feeding of fish in ponds and small lakes. Species used include *Clarias* sp., *Heterobranchus* sp., *Synodontus* sp., tilapias and others. This culture system effectively extends fish availability for nearby communities into the dry season and demonstrates a unique case of fishermen becoming involved in fish husbandry, a shift rarely seen as successful.
The “ownership” of fisheries by the fishermen represents much progress from the past. Much of this has come about through institutional decentralization and government’s efforts to empower fishermen for community-based management of fisheries resources. In Niger, fishermen have taken an active role in artisanal marsh aquaculture and today, some 100 ponds are stocked and exploited extensively for fish farming by fishermen in collaboration with the local villagers. In some areas of Mali, Niger and Burkina Faso, such ponds or small lakes are being leased to fishermen. In Senegal, similar activities have occurred with Vietnamese technical assistance in isolated areas of the country, like e.g. Kédougou.

A unique problem is the increased soil salinity of coastal areas once used for rice farming in the Casamance region in the south of Senegal. Here, over 50,000 ha of farmland have been lost to increased salinity from encroachment of the Casamance River during high tides. This river has become little more than an arm of the ocean. To combat this problem, farmers have established rice paddies on higher ground, using the freshwater overflow into the saline fields, which have been converted into fish ponds. This integrated effort has three goals: 1) production of rice; 2) production of fish; and 3) desalination of the fish ponds and their eventual recuperation for rice production.

**Rice-fish farming**

Rice-fish farming has been attempted in all four countries. Most of these efforts unfortunately ended abruptly during floods with loss of fish and rice in some cases. Nevertheless, results from a few conclusive studies in Mali (Malengi-Ma, 1988; 1989) and Niger (Olivier et al., 1998) offer promise, as rice production was somewhat greater (up to 6-7 tonnes/ha/year) with the presence of fish which yielded between 130 and 190 kg/ha/year.

**Village fish farming**

In the past, a variety of aquaculture projects were initiated and several small fish stations were built, often with international assistance. Although the use of some village fish ponds continues in all four countries, most of the fish stations and ponds have since been abandoned. Senegal has a variety of limited aquaculture activities including the culture of fish, shrimp and oysters. However, in spite of years of research and ongoing efforts in these activities, no commercially viable aquaculture enterprise is ongoing (Diop, 1999). With its large exodus from rural areas, Senegal has labor shortages in rural areas. Labour availability was also identified as a problem in the SPFS programme. All countries have plans for further aquaculture projects including a large commercial fish farm in northern Senegal with Chinese technical assistance and mixed involvement of both the private sector and government. Aquaculture activities are also being planned for the Zinder region of Niger with FED assistance.

**Intensive fish farming**

Two notable intensive aquaculture projects, supported by French assistance, have failed in Burkina Faso and Niger. A highly intensive and costly tilapia raceway farm system was attempted in Burkina Faso, but failed for technical reasons and lack of economic viability. Similar results were obtained with an intensive tilapia cage culture system in Niger. Fish were reared in cages in the Niger River and efforts were made to extend this technology to the private sector before the technology was proven to be economically viable. It was discovered that water temperatures dropped too low for acceptable growth during the winter period and it was only possible to carry out one production cycle per year. Both of these projects relied on costly imported inputs, forming the basis of their failure from inception. These efforts used complicated, costly technology to resolve basic problems of increasing fish production in a difficult environment.

**Discussion: constraints and opportunities for aquaculture in the Sahel region**

A number of commonalities among the four countries can be noted. Efforts to improve fish production could be focused on these common activities in all countries. The commonalities are:

- Similar history of aquaculture;
Table 5. Constraints to aquaculture development in the Sahel region.

<table>
<thead>
<tr>
<th>Type of constraint</th>
<th>Details</th>
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</table>
| Environmental      | • harsh climatic conditions (heat, high evaporation, wide temperature swings)  
                      • water shortages |
| Social/cultural    | • extension efforts have lacked the participatory approach and lack of involvement of the beneficiaries in decision making  
                      • lack of public awareness  
                      • difficulties in finding labor in some rural areas (e.g., Senegal) |
| Institutional      | • overemphasis on infrastructure (fish stations)  
                      • lack of reliable statistics and general information on fish production  
                      • poorly trained field and senior technicians, many of whom were also involved in repressive activities, incompatible with aquaculture extension  
                      • lack of involvement of universities and research institutions  
                      • lack of coordination within and between countries  
                      • lack of an established framework or strategy for advancement |
| Financial          | • insufficient financial resources  
                      • lack of clear demonstration of economic viability |
| Technical          | • inputs for fingerlings and fish feed components limited, costly or unavailable  
                      • theft and predation of fish  
                      • lack of good pond construction  
                      • lack of good pond management |

• Capture fisheries-based traditional aquaculture in ponds and small water bodies;
• A common need to increase fish production;
• Presence of large irrigation schemes for production of cereals and rice;
• Farming of animals suitable for integration with fish farming;
• High post-harvest losses of fish;
• Lack of trained personnel and need for training and capacity building;
• Weak organization and communications in countries and between countries;
• Limited availability of rural credit and savings programmes.

The SPFS is active in all countries with activities in fisheries and aquaculture, although the programmes are not identical.

Constraints

The main constraints to aquaculture development in the Sahel are summarized in Table 5. Institutional and human capacity limitations exist in all countries, calling for training especially at the field technician level for transfer of aquaculture technology to farmers and individual investors. Support for universities and research institutions has also been limited or lacking. Other constraints include lack of coordination of activities both within and between countries. Technicians in each of the countries could benefit and learn from each other’s experiences, mistakes and successes.

Opportunities

The opportunity for aquaculture in the Sahel, lies not in intensive systems focused on maximizing production through capital intensive, hi-tech systems using the smallest area with the least labor and costs, but in extensive application of aquaculture using low-cost, locally available inputs for extensive, integrated systems over large land areas as found in irrigation schemes. These irrigation schemes are presently underutilized and through their diversification and integration with aquaculture, rice as well as fish production can be increased. This could improve the use of farm resources and water as well as increase overall farm output. Considering the large water areas involved, fish production could be significantly increased, thus strengthening food security in each country. Such aquaculture can also increase employment in rural areas and contribute to maintaining food security.

Aquaculture offers farmers more flexibility than other types of agriculture. This helps insure food security, as harvest of fish does not have to occur at a fixed time because fish can
be harvested over time. Marketing of fish can be combined with other farm products in terms of transport and access to consumers. In many cases, fish in ponds serve as savings banks to farmers, who harvest their fish when financial emergencies arise. Technical details of this integration remain to be resolved in the particular context of the Sahel region for the benefit of farmers.

Table 6 provides an overview of the potential increased fish production with rice-fish aquaculture if 15% of the irrigated rice area would be integrated with aquaculture (42 735 ha) at an average production of 250 kg of fish/ha. At a value of only CFAF400/kg, increased revenues would amount to CFAF4.3 billion, or US$6.5 million. More than 10 500 tonnes could be added to the region’s fish production. This is significant as it would increase fish production in each country by 7 to 12%. Increased employment could be more than the estimated 5 340 jobs, as this was calculated at only 1 person per 8 ha of rice.

The diversified approach taken by the SPFS programme orients the farmers to focus on integration of farming activities, benefiting from synergies and combined activities. Extensive aquaculture responds well to this integration and would contribute to more efficient use of water. The SPFS programme can serve as a springboard for integrating aquaculture with a number of ongoing activities including irrigation, various cultures and animal husbandries. Support can also be given to artisanal marsh aquaculture for training and basic equipment as well as follow-up data collection. The SPFS could involve research institutions in training and applied research in the field (see Table 7).

Conclusions and recommendations

Aquaculture technology

- Future efforts in aquaculture development should be oriented towards extensive fish production with low-cost, locally available inputs. High cost intensive aquaculture, such as cage fish farming and raceway farming, are inappropriate and uneconomical in conditions found in the Sahel and should be discouraged.

- Traditional forms of aquaculture should be strengthened and integrated into irrigation schemes. Only extensive methods of fish farming should be used as they are low-cost, use only inexpensive, locally available inputs and are not complicated to manage. Demonstrations of artisanal marsh aquaculture should be launched in each country, using fishermen for collecting fingerlings from the wild, to stock ponds and small lakes. Training is needed to strengthen local capacity for assuring quality fish production.

- Integration with crops and animal husbandry should be developed. Several programmes, including the SPFS, are working on improving small animal husbandry with chickens, sheep and goats. In some areas, pigs are grown and could also be used. Integrations create synergies, like easily available water to small animals and sources of feed for the fish, and help reduce labour costs.

- Post-harvest losses should be reduced. Fish are smoked in all four countries under study and loss due to spoilage and infestation with insects may be as high as 50%. This can be greatly improved through training in improved fish smoking techniques, to achieve a reduction in the use of firewood, reduction in fire outbreaks and a greatly improved product with a longer shelf life. Women need training in this
Table 7. Institutions for collaboration on the Integrated Irrigation Aquaculture network.

<table>
<thead>
<tr>
<th>Country</th>
<th>Institution</th>
<th>Acronym</th>
</tr>
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<tbody>
<tr>
<td>Senegal</td>
<td>Centre de Recherches Oceanogra-Phiques de Dakar-Thiaroye</td>
<td>CRODT</td>
</tr>
<tr>
<td></td>
<td>Société d'Amenagement des Eaux du Delta</td>
<td>SAED</td>
</tr>
<tr>
<td></td>
<td>Institute de Recherche pour le Développement</td>
<td>IRD</td>
</tr>
<tr>
<td></td>
<td>Comité d’Action pour le Développement du Fogny</td>
<td>CADEF</td>
</tr>
<tr>
<td></td>
<td>Association Sénégalaise pour la Promotion de Petits Projets de Développement de Base</td>
<td>ASPRODEB</td>
</tr>
<tr>
<td></td>
<td>Union des Jeunes Agriculteurs du Koyli Wirndé</td>
<td>UJAK</td>
</tr>
<tr>
<td></td>
<td>Departement Eaux et Forets</td>
<td>DEF</td>
</tr>
<tr>
<td></td>
<td>West African Rice Development Agency</td>
<td>WARDA</td>
</tr>
<tr>
<td></td>
<td>Université Cheikh Anta Diop</td>
<td>UCAD</td>
</tr>
<tr>
<td></td>
<td>Institut Sénégalais de Recherche Agricole</td>
<td>ISRA</td>
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<tr>
<td>Mali</td>
<td>Ministry of Rural Development &amp; Environment</td>
<td>MDRE</td>
</tr>
<tr>
<td></td>
<td>Directorate Support to Rural Populations</td>
<td>DNAMR</td>
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<tr>
<td></td>
<td>Chambers of Agriculture of Mali</td>
<td>CAM</td>
</tr>
<tr>
<td></td>
<td>Institute for Training &amp; Applied Research</td>
<td>IFRA</td>
</tr>
<tr>
<td></td>
<td>Institute for Rural Economics</td>
<td>IER</td>
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<tr>
<td></td>
<td>Fishermen’s organizations</td>
<td>−</td>
</tr>
<tr>
<td>Niger</td>
<td>Ministère Hydraulique et de l’Environnement</td>
<td>MH/E</td>
</tr>
<tr>
<td></td>
<td>Direction Faune, Pêches et Pisciculture</td>
<td>DFPP</td>
</tr>
<tr>
<td></td>
<td>Ministère de l’Agriculture et d’Elevage</td>
<td>MA/E</td>
</tr>
<tr>
<td></td>
<td>Institut National de Recherche Agronomique du Niger</td>
<td>INRAN</td>
</tr>
<tr>
<td></td>
<td>Association des Aquaculteurs</td>
<td>ADA</td>
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<tr>
<td></td>
<td>Fishermen’s organisations</td>
<td>−</td>
</tr>
<tr>
<td>Burkina Faso</td>
<td>Ministry of Environment &amp; Water Department of Fisheries &amp; Fish Farming</td>
<td>MEW</td>
</tr>
<tr>
<td></td>
<td>Université Bobo Dioulasso’s Institute of Rural Development</td>
<td>IDR</td>
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<tr>
<td></td>
<td>National Institute for Environment &amp; Agricultural Research</td>
<td>INERA</td>
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<td></td>
<td>Office for Dams and Hydraulics</td>
<td>ONBAH</td>
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<td></td>
<td>Sourou Valley Development Authority</td>
<td>AMVS</td>
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<td>German Fisheries Project for the SW</td>
<td>GTZ</td>
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<td>Kou Valley farmers</td>
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<td></td>
<td>Fishermen’s organisations</td>
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technology and access to rural credit and savings programmes.

- Divestment is recommended for much of the unutilized infrastructure (fish stations) built during the 70s and 80s. Policies that encourage private sector initiatives should be developed. Fish stations retained by the government should become multi-purpose agricultural centers which focus on integrated animal husbandry, rice-fish farming and provision of fish fingerlings.
Training

Training needs include:

- Training in integrated irrigation-aquaculture, stocking of fish in irrigation reservoirs, capturing overflow from irrigation plots for fish ponds and building ponds in adjacent water-logged or saline areas unsuitable for crops. Other integrations include rice-fish farming and integration with animal husbandries such as poultry, sheep, goats and pigs.
- Training in artisanal marsh aquaculture, including training of technicians and fishermen in fish fingerling collection, sorting, holding and transport and stocking in different bodies of water. Niger or Burkina Faso would be good choices for hosting such training programs.
- Training in reduction of post-harvest loss with improved fish smoking techniques which produce quality products with longer shelf-life with much less wood and greatly lowered costs.
- Training of trainers. This could be carried out in one country with study tours furnished to participants from other countries. Regional meetings should also be supported.
- A regional coordinator should assist in organizing and coordinating activities for regional training and other means of sharing experiences among the participating countries.

Institutional support

- A subregional programme should address short-term needs for support of IIA development. A coordinated strategy should be developed and implemented for conducting needs assessment meetings and site evaluations with farmers and carrying out training courses for field technicians and farmers. Innovations in IIA must be seen as a process with a series of actions. An enabling environment must be created with resources to support adoption of the integrated technology. Farmers need to see their farming as a series of integrated, rather than as individual activities. This latter view tends to digress towards competition for use of land, water and labor. Through a participatory approach, farmers need to be involved in planning for activities in their area, especially in the context of irrigation schemes and artisanal marsh aquaculture.
- The IIA network should be further developed. Mali and Burkina Faso are already members of the planned IIA network, and Niger should be considered for inclusion. Special consideration should be given to Senegal.
- Access to rural credit and savings should be improved. If effective rural credit programmes are in place, training on the use of credit for fish processing could be provided to women and to the fishermen involved in collecting fingerlings for artisanal marsh aquaculture.
- Logistical support should be funded for strengthening aquaculture-related activities in each country.
- A South-South cooperation programme should provide assistance in developing integrated irrigation aquaculture. Successful rice-fish farming technology from Madagascar could be of great benefit to farmers in the Sahel.
- Communications programmes on radio and television should increase public awareness of aquaculture and options for its integration. Programmes could include, e.g., success stories from fish farmers.

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A FEASIBILITY STUDY OF RICE-FISH FARMING IN WESTERN AFRICA

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Abstract

The paper presents the executive summary of results of a mission to Mali, Senegal, Ivory Coast and Ghana to evaluate past experience and current activities in rice-fish farming and assess the potential for further development. The main finding of the mission was that rice-fish culture is feasible in the West African subregion. The extensive form of rice-fish farming which is already practiced is worth improving to obtain higher fish yields. Intensive rice-fish culture should be introduced to rice farming in West Africa because it can provide additional income to rice farmers. The main immediate constraint is the need for technology training at local level. Recommendations include introduction of intensive rice-fish farming in rice plots with totally controlled irrigation; improved water management in low lying areas, especially for flood control; assessment of the feasibility of extensive rice-fish farming in ponds along rivers; assessment of the feasibility of extensive rice-fish culture in mangrove areas, with due recognition of environmental considerations; and integrated pest management for rice-fish farming.

Introduction

Aquaculture integrated into irrigated plots has been considered a suitable way to increase the fishery production in sub-Saharan Africa. Since the early 1990s, the Food and Agriculture Organization of the United Nations (FAO) has worked to help implementing these recommendations. In September 1999, FAO organized a workshop in Accra to consider the opportunity of setting up an Integrated Irrigation-Aquaculture Network (IIA) in the western Africa subregion (Moehl et al. 2001). Two missions were fielded between October 1999 and July 2000 to assess the potential for IIA integration. At the same time, FAO proposed a regional programme to develop integrated inland water resources management in areas prone to recurrent drought in western Africa. Within this regional programme, rice-fish farming can be considered a part of the IIA component. Following the conclusions of the two missions, the Committee for Inland Fisheries of Africa (CIFA), during its meeting in Abuja (Nigeria) in October 2000, recommended to look more closely at the feasibility of rice-fish farming in western Africa.

IIA in sub-Saharan Africa, and more specifically rice-fish farming, should be seen in the context of:

- the enormous availability of water and irrigable lands;
- the progressive depletion of marine and inland fisheries;
- increasing poverty;
- the progressive implementation of the Special Programme for Food Security (SPFS) in many countries of the sub-region since 1995. The SPFS includes a water management component aimed at developing and demonstrating suitable irrigation technologies and a diversification component including aquaculture.

This report is based on a mission to Niger, Mali, Senegal, Ivory Coast and Ghana during March and April 2001. In each country, the authors evaluated past experiments and the current status of rice-fish farming and assessed its potential and the availability of know-how and other resources such as rice varieties, fish seeds and farmers’ expectations about rice-fish culture.
**Results**

The main finding of the mission was that rice-fish culture is feasible in the West African subregion. All sites visited by the team provided a good idea of rice farming practices and revealed that rice-fish farming can be implemented successfully in western Africa. The West African subregion has great infrastructure potential for irrigated rice culture. Both irrigated rice crops under total water management, and rice crops with controlled flooding in low-lying areas or swamps can be integrated with fish farming.

In all countries visited, rice farming irrigation projects have been planned or are being implemented. Because existing rice areas were not designed for rice-fish farming, the height of the dikes is often insufficient for rice-fish farming. Some of the pumping systems used to irrigate these rice fields may not be sufficient to supply the water requirements of rice-fish farming, particularly during the dry season when most motors are switched off or run at low capacity to save energy.

Water management is the most important factor for success of rice-fish culture in low lying areas. Water supply can be either too high, with floods washing away the fish, or insufficient with fields drying up too early in the season.

The same rice varieties are used almost everywhere. These varieties are distributed by WARDA through its research networks or through the Inland Valley Consortium. The average duration of the rice production cycle is 120 days. Some varieties have local names. In irrigated rice culture, large amounts of fertilizers as well as herbicides and pesticides are used to assure higher yields. Only in Ivory Coast and Ghana, the use of chemicals has been reduced after training on integrated pest management. This is positive for rice-fish culture. The aquatic fern *Azolla* can be found nearly everywhere, but it is not formally farmed and farmers often ignore its properties and use. Nonetheless, irrigated rice culture techniques are generally well known and mastered in all the sites visited. Problems in water management sometimes arise due to overlapping activities with other crops in the culture calendar.

In the immediate vicinity of the sites visited the availability of fingerlings, especially of Nile tilapia (*Oreochromis niloticus*), is not a problem either because there are streams nearby or (sometimes privately run) fish farms.

Traditional extensive rice-fish farming is still practiced in Niger, Senegal and Mali, where river floods and rising tides pour fingerlings into rice plots where they grow until harvest. Human intervention in this system is mainly concerned with the infrastructure and not with fish because water regulation is needed to increase rice production.

Experiments on intensive or classic rice culture have been carried out in each of the countries visited. These experiments had a strong research focus and few or no farmers were involved; the results, whether positive or negative, were often not available. Because of the increasing interest in rice-fish farming, intensive rice-fish culture projects have been planned in these five countries and are awaiting funds to revive research in this field. A rice-fish farming project has been planned at the Private Agriculture Institute of Mianzan in Adzope, Ivory Coast.

During discussions with farmers and technicians it became clear that rice-fish farming is viewed as a potentially important technology in the struggle for food security. Various issues related to the problem were raised, such as lack of technological knowledge and need for training, use of fertilizers and pesticides, expensive supplementary food, mangrove fish, drying up of low lying areas, fish size at harvest, contributions the farmers have to provide, the starting date of such a venture, etc. Farmers expressed a strong interest in this technology.

In all countries, experience in rice culture exists and experience in aquaculture is growing. Innovation is stimulated by the implementation of water management and diversification of the SPFS programmes. Whereas experience in the management of traditional rice-fish farming systems also exists (although improvements are needed), knowledge on intensive rice-fish culture is lacking everywhere. There are a few technicians who had the opportunity to deal with rice-fish culture during a training course in Asia or even in their home country (as e.g. in Dawhenya, Ghana), but they never had the opportunity to exploit their skills. Farmers generally know nothing about rice-fish culture but are curious to discover. Some farmers followed the training in Dawhenya, Ghana and know the technology but, for the time being, cannot put their knowledge into practice because of predators.
Unfortunately, the yield data on past rice-fish culture experiments are often unavailable. However, farmers intuitively grasp that they will harvest fish as well as rice in the same field where only rice was previously harvested. The Niger Office in Niono (Mali) reported rice yields from one rice-fish plot of 9 tonnes/ha, considerably higher than the average 7 tonnes/ha usually obtained from regular rice plots. Results of fish production were not considered in this experiment because of predators.

It is concluded that rice-fish farming has good prospects also in financial terms but not under all scenarios and conditions. For example, it is still not clear if the additional fish crop will compensate for the additional water pumping. This cannot be answered at the moment and further research should be carried out in this direction.

For “intensive” rice-fish farming to succeed, it must be practised at individual farmer or farming household level, where everybody contributes to rice-fish culture management.

Conclusions and recommendations

On the basis of the above findings, the mission came to the conclusion that both extensive and intensive forms of rice-fish farming are feasible in western Africa. The extensive form which is already practiced is worth improving to obtain higher fish yields. Intensive rice-fish culture should be introduced to rice farming in West Africa because it can provide additional income to rice farmers.

The mission also recognized constraints to development of rice-fish farming. The main immediate constraint is the need for technology training at local level. Rice-fish development in Africa will only happen if the following issues are addressed:

1. Introduction of intensive rice-fish farming in rice plots with totally controlled irrigation;
2. Improved water management in low lying areas, especially for flood control;
3. Assessment of the feasibility of extensive rice-fish farming in ponds along rivers with a view to intensification;
4. Assessment of the feasibility of extensive rice-fish culture in mangrove areas, with a view to intensification but due recognition of environmental considerations; and
5. Integrated pest management for rice-fish farming.

It is recommended that a development strategy for rice-fish farming in Africa be focused on three main themes: training, experimentation, and implementation.

In support of this strategy, it is recommended that Technical Co-operation Programmes be implemented in each country and that FAO’s Telefood projects be planned to give assistance to the pilot rice-fish farmers who could further serve in the technological promotion. Further to these programmes in each country, it is suggested that complementary action be taken for fisheries and water management. On a regional scale, active participation of countries in an IIA network to which they will contribute with the results of their activities is recommended. These countries should also start collaborating with international research institutes, particularly with WARDA which has an important role in the research on rice varieties used in different ecological conditions and farming systems. Finally, exchange within the South-South cooperation programmes should also be considered.

References

THE POTENTIAL FOR INTEGRATED IRRIGATION–AQUACULTURE IN MALI

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\textsuperscript{b}FAO Regional Office for Africa, Accra, Ghana


Abstract

The paper provides an analysis of the potential for integrated irrigation–aquaculture in Mali. It is based on general information available from workshops and meetings facilitated by FAO in 1999 and 2000 as well as field reports from several missions to Mali by experts in agronomy, aquaculture and socio-economics between December 2000 and March 2002. There are environmental, institutional, technical and socio-economic constraints, and recommendations are presented for the Direction Nationale d’Aménagement et Equipement Rural (DNAER) of the Ministry of Rural Development of Mali on how to alleviate these. It is concluded that Mali has all of the essential resources necessary to produce large quantities of fish in irrigation systems. At the same time, the opportunity costs associated with the use of these resources need to be weighed carefully. The development of fish production in short cycle systems, using locally available, low cost techniques is considered the most feasible way forward.

Introduction

Located in the heart of West Africa, the northern half of Mali is situated in the Sahara desert, in an arid, sparsely populated zone unsuited to many economic endeavours. Fortunately, Mali is blessed with two large rivers, the Niger and tributaries of the Senegal, which travel over 1 000 kilometers within the country. Mali’s fisheries production is the largest in the Sahel, and represents 40 percent of West Africa’s freshwater fish production. Annual fisheries production varies from an estimated 70 000 to 150 000 tonnes annually, depending on rainfall and flooding. An estimated 10 to 20% of freshwater fish production is exported regionally. These important water resources also provide irrigation for the production of cotton (which makes up almost 40% of Mali’s exports), millet, rice, maize, groundnuts, vegetables, cattle, sheep and goats. Per capita fish consumption is estimated at 10.5 kg/year (compared to meat consumption of 7.8 kg/year), although fish consumption among fishing families is probably much higher.

As a result of the importance of water resources to the country and the unpredictable availability of fish, representatives from the Government of Mali have been working with the Food and Agriculture Organization of the United Nations (FAO) on a number of different fisheries initiatives, including efforts to develop pilot integrated irrigation and aquaculture (IIA) activities. This included two separate missions of an aquaculture expert who visited Mali to assess aquaculture opportunities in the region (Miller, 2000), and a team of irrigation and rice production specialists who evaluated the potential to develop aquaculture in rice production systems (Sanni and Juanich, 2001). Mali has also expressed interest in participating in a regional IIA network during regional workshops and meetings of international irrigation and fisheries staff (Moehl et al., 2001).

This report presents the results of a third mission by a socio-economist and an aquaculture specialist who visited Mali in December 2001 to evaluate additional opportunities for the development of IIA activities in the country. In Mali, the team spent several days working with a representative from the Direction Nationale de l’Aménagement et de l’Equipement Rural (DNAER), evaluating potential opportunities for and constraints to the development of IIA activities in the country. This was done on the basis of (i) review of available documents; (ii) meetings with the FAO Programme Officer, the FAO Special Programme for Food Security (SPFS) Coordinator, and DNAER staff; and (iii) field visits to Baguimenda, Niono/Ségou and Sélingué.
History and context of IIA

The integration of irrigation and aquaculture (IIA) is as old as aquaculture itself. In most countries, water used to produce fish is also used to irrigate gardens, bathe children, wash clothes and nourish animals. Integrated systems can be more or less complex, depending on the general layout of the irrigated plots and the fishpond. Fishponds can be located above irrigated plots (in this case, the plot is fertilized with water from the fish pond, and the pond functions as a water storage device as well as a fish production system), on the same plot (either at the same time or in a relay cropping system), or below the irrigated plot (where fishponds benefit from and capture drainage water from irrigated plots). Integration can be both temporal (with production occurring at the same time, in the same season) and spatial (with production occurring on the same plot of land). Integration generally implies an intensification of water use, but not necessarily increased water use. In some cases, water is simply used more efficiently in integrated systems. By stocking holding ponds, dams and seasonal ponds with fish, no additional water is used but additional production is generated.

It is the development of these types of efficiently integrated systems which FAO has been encouraging for the past 10 years, through various workshops, missions and pilot projects (Coche, 1998; Moehl et al., 2001; PSSA, 2000; SPFS, 2000; Van der Mheen, 1996; 1997; 1999).

Past, present and planned IIA activities

The main difference this IIA team noted from previous visits was the organization of fisheries activities within the Ministry of Rural Development and Environment (MDRE). While fisheries activities previously were under the direction of the National Direction for Support to Rural Populations (DNAMR), the team found fisheries activities housed in the Direction National d'Aménagement et Equipement Rural (DNAER). Many of the same opportunities and constraints to the development of IIA activities exist as those elicited by Miller (2000) and Sanni and Juanich (2001). Mali continues to have significant potential for the development of IIA activities, especially in irrigated rice systems, seasonal ponds, and recessional flood plains. However, the benefits of such integration have yet to be tested or proven at the field level in Mali, and remain hypothetical at the national level.

Government activities

In the late 1980s, the government in collaboration with international donors funded two aquaculture projects - Projet de Développement de la Pisciculture et de Rationalisation de la Pêche (Fish Culture and Fishing Development Project - FAO/PNUD Projet MLI/86/001) and Projet Mali (funded by the African Union). Although neither project explicitly promoted the integration of irrigation and aquaculture activities, both projects promoted the development of aquaculture in existing irrigation schemes and seasonal ponds. In addition, the former project conducted rice-fish farming trials which produced between 6 to 7 tonnes of rice along with 125 kg of fish per ha. According to Miller (2001), even unstocked and unmanaged rice fields produced 73 kg of fish, implying that some form of rice-fish farming is already practiced on a traditional level.

The only aquaculture activities reportedly supported by government are the activities undertaken by the staff at the Molodo fish station, which at one time assisted 66 villages and 525 fish farmers. However, during the time of this visit, the station was in a complete state of disrepair, and only two of the 12 ponds were functional. No future IIA activities are being planned by the government, however, it was mentioned that IIA activities would fit quite well into the Sustainable Livelihoods Programme being implemented by DFID and FAO in 25 countries in the sub-region.

The Special Programme for Food Security (SPFS)

The Special Programme for Food Security (SPFS) was launched by FAO in May 1994. The goal of the programme is to increase food production through dissemination of existing and proven agricultural technologies. The programme has four components: water management; intensification of agricultural production; diversification of production; and analysis of constraints. The programme targets low income food deficit countries in Africa, Latin America and Asia.

In Mali, SPFS activities officially began in 1998 and have been implemented in three regions – Mopti in the east, Koulikoro in the central region and Kayes in the west. Activities included the development of low-cost water management systems, the intensification of rice
and maize production systems, the development of animal fattening activities, gardening activities, and beekeeping. Fish culture activities have been implemented in the Mopti area, in association with local NGOs. At the time of this mission there were five Chinese specialists including one aquaculture expert implementing SPFS activities on the development of post harvest technologies, rice culture, beekeeping and animal husbandry.

**Donor and non-governmental organization (NGO) activities**

In the early 1980s Africare and Peace Corps implemented aquaculture activities in San, which included the construction of an experimental fish station. The station was later abandoned due to technical difficulties associated with water access. These activities were funded by USAID.

In the late 1980s the French Association of Volunteers for Progress (AFVP) promoted the integration of fish ponds and gardening in large irrigated perimeters in the Niono area. This project resulted in the construction of 200 village fish ponds using heavy equipment. Ponds were integrated with vegetable gardens, rice and cereal production. Unfortunately, some ponds could not be drained, ponds were poorly managed, and fish production was low.

No other current or planned IIA activities funded or implemented by NGOs were uncovered by the team during this mission. However, few NGOs were contacted due to the timing (during Ramadan) and duration of the mission. Past, present and planned IIA activities are further detailed in Table 1.

**IIA potential and fit into local farming systems**

**Agro-ecological zones**

The main agro-ecological zones found in Mali, their farming systems, and potential for IIA development are summarized in Table 2. The most important farming activities in the country are rice and maize production, vegetable gardening, beekeeping, chicken rearing, fishing and animal husbandry. Generally speaking, a household will practice as many different agricultural activities as possible in order to maximize production and income, and decrease risk (Kone and Sangono, 2000).

**Irrigation systems in Mali**

The main types of irrigation systems found in Mali include:

- Parastatal/government-managed agricultural irrigation schemes
- Village irrigation schemes
- Private irrigation schemes
- Small-scale micro-dams
- Marshes, seasonal ponds and borrow pits
- Recessional flood plains

Of the 242 298 ha of irrigated farmland in Mali, 144 605 (equivalent to 60%) are irrigated by one of three irrigation schemes: dams in Segou (35 415 ha), the Office of Niger (60 000 ha) and Mopti (49 190 ha). Mali has the largest area of controlled irrigation in the West African Sahel, and most of it is controlled by gravity rather than the pumps used in Senegal (Miller, 2000). The benefits and constraints to the integration of aquaculture activities with existing irrigation systems in Mali are summarized in Table 3.

**Aquaculture and inland fisheries systems**

There are three principal fish production zones in Mali: the Central Delta of the Niger River, and two artificial lakes – Lake Sélingué and Lake Manantali. The central delta is a vast floodplain between Markala and Timbuktu. Floodwaters from both the Niger and Bani rivers feed this floodplain. In Mopti, which marks the confluence of the Niger and the Bani, the high water period is generally in October. During this time, the floodplains can cover over 20 000 km². The low water mark generally occurs in May (DNAER, 2001). The Central Delta floodplain produces an estimated 70 000 to 150 000 tonnes of fish per year. In addition, the Senegal River produces an estimated 2 000 tonnes per year from 45 000 ha of floodplains (Miller, 2000).

Lake Sélingué is located 140 km south of Bamako, and was built in 1980. The dam provides both hydroelectric power and irrigation and is managed by the Office for the Exploitation of Hydraulic Resources of the Upper Niger (OERHN). The dam is 348 m long, and the lake covers 409 km² and holds 2.2 billion m³ of water. However, the maximum depth does not exceed 20 m (DNAER, 2001). Lake Sélingué produces an estimated 4 000 tonnes of fish per year (Miller, 2000).
Lake Manan tali was constructed in the valley of the Bafing River. It was built in 1987 and provides both hydroelectric power and irrigation. The dam is 208 m long, and holds 11 billion m$^3$ of water, with a surface area of up to 500 km$^2$. The average depth is 20 m, with a maximum depth of 50 m at the dam (DNAER, 2001). The lake produces an estimated 1500 tonnes of fish per year (Miller, 2000).

In addition to these large water bodies, fish are also produced in the Office of Niger Irrigation Scheme, which includes the Markala dam with its 60 000 ha of irrigated fields; seasonal ponds (mares), borrow pits (land where soil has been removed for infrastructure development projects) and bancotières (land where soil has been removed for making bricks). Farmers have been stocking these small natural water bodies for more than 20 years, and in some cases fish are fed rice bran and kitchen waste. Production from these seasonal ponds has been estimated at 542 to 650 kg/ha/year (Kienta, 2001).

Most capture fishing occurs from November to March. Fishermen use nets, buckets, canoes and local tools to capture fish, day and night. The money generated from fisheries production is often used by families to pay for supplies required to migrate to other countries in the region. A tax of CFAF7.50/kg is imposed on local fish producers for certifying fish quality. This money is used to finance fisheries activities in the country (Seydou Coulibaly, pers. comm.). See Table 4 for a summary of fishing activities and seasons.

Over 130 species of fish have been identified in the middle Niger, which have been divided into two main groups: migrating species and opportunistic species. Some of the most important commercial species include *Lates niloticus*, *Heterotis niloticus*, *Bagrus bajad*, *Alestes dentes*, *Brycinus leuciscus*, *Clarias anguillaris*, *Hydracynus brevis*, *Sarotherodon galilaeus* and *Oreochromis niloticus* (DNAER, 2001).

The mission was told that DNAER would like to develop the culture of catfish (*silure*), *Lates* spp. and *Hydrocynus* spp. in the country. Currently, most production consists of tilapias, *Clarias* spp. and *Heterotis* spp. *Lates* spp. sell for CFAF2 000/kg, *Hydrocynus* spp. for CFAF1 500/kg, tilapias for CFAF1 000/kg and *Clarias* and *Heterotis* spp. for CFAF600/kg. However, dried *Lates* and *Hydrocynus* spp. are worth CFAF3 000-4 000/kg (Seydou Coulibaly, pers. comm.).

**Labour**

Mali has over 70 000 active fishermen and fishing families, including full-time professional fishermen (generally from Bozo or Somono ethnic groups), part-time fishermen/farmers (Rimaïbé, Bambara, Marka and Songhai), and migrant fishermen (also Bozo) (Miller, 2000). Some of these fishermen have formed associations, such as the Association of Fish Farmers of the Office du Niger. This association includes 150 fish farmers in 25 villages in the zone of N’débougou. They use small (less than 500 m$^2$) fish ponds built by the World Bank in irrigated perimeters, and borrow pits created by brick makers. The role of the association is to defend the interest of its members, participate at harvests, and source funding.

Women are often active in fish processing, as well as the stocking and production of seasonal ponds. This team found that women also were interested in aquaculture, specifically in Niono, Sikasso and Kadiolo. A women's association which practices gardening activities built a 500 m$^2$ fish pond. They are interested in pursuing aquaculture as a secondary activity, after vegetable gardening (which takes up approximately 80% of their time).

Local government agents reported that almost 90% of all fishing activities in the country are managed by women. They are involved in all aspects of harvesting, processing, transport and marketing of fish. Although men know how to trap fish, women know what fish characteristics and qualities other women want for cooking and home consumption. Women are the head of the family in fishing communities. Men hand their fish catch to women, who decide what to do with it. In polygamous marriages, men compare the capacity of women to manage and profit from their fish harvest. In the past, this has made credit programmes for fishermen difficult to manage, because credit was given to men, but women managed the profits of fish harvests (Seydou Coulibaly, pers. comm.).
Table 1. Past, current and planned IIA activities in Mali.

<table>
<thead>
<tr>
<th>Institution</th>
<th>Years</th>
<th>Target zone</th>
<th>Type of IIA system</th>
<th>Objectives</th>
<th>Constraints/lessons learned</th>
</tr>
</thead>
<tbody>
<tr>
<td>USAID/ Africare/ US Peace Corps/ Cie. malienne de développement des textiles</td>
<td>1979-1982</td>
<td>San/ Ségou</td>
<td>Aquaculture in irrigated cotton-producing systems, pumped water</td>
<td>Construct experimental fish station in San; produce and distribute fingerlings; do applied research using local fish species; extend and disseminate aquaculture practices</td>
<td>Activities ceased and station abandoned in 1982 due to lack of water and cost of pumping water</td>
</tr>
<tr>
<td>French Association of Volunteers for Progress (AFVP)</td>
<td>1987</td>
<td>Niono/ Ségou</td>
<td>Integration of fish ponds and gardening in large irrigated perimeters, gravity fed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Projet Mali/ Organisation de l'unité africaine (OUA)</td>
<td>1986-1990</td>
<td>Ségou, Kayes, Timbuktu, Sikasso</td>
<td>Integration of aquaculture with seasonal ponds</td>
<td>Develop extensive aquaculture by improving seasonal ponds and valleys (bas fonds); provide equipment and supplies for construction of individual and collective ponds; provide water pumping materials (solar power)</td>
<td></td>
</tr>
<tr>
<td>Projet de développement de la pisciculture et de rationalisation de la pêche (FAO/PNUD Projet MLI/86/001)</td>
<td>1987–1992</td>
<td>Niono/ Office du Niger et Sélingue</td>
<td>Integration of fish ponds with large irrigated perimeters</td>
<td>Promote family fish farming; improve fishing in lakes, irrigation canals and seasonal ponds; distribute fingerlings, train farmers, disseminate techniques. Create three fingerling stations and one national training center.</td>
<td>Biggest problem was the complete dependence of fish farmers on the project for all inputs and supplies. Additional problems: predation and theft, incomplete pond drainage, the lack of participation of farmers in maintenance of irrigation infrastructure.</td>
</tr>
<tr>
<td>FAO/Special Programme for Food Security (SPFS)</td>
<td>1996-2002</td>
<td>Mopti</td>
<td>Integration of aquaculture with seasonal ponds and borrow pits; production of fish and animal fodder (Echinochloa stagnina)</td>
<td>Disseminate proven technologies; engage farmers in dialogue; demonstrate technologies and practices to stabilize production and promote diversification; provide a platform for policy dialogue and institutional support.</td>
<td>Potential exists for integrated irrigation and aquaculture in the Mopti region through NGOs and farmer groups, and in rice-fish culture systems in the Office du Niger.</td>
</tr>
<tr>
<td>PUFS (Swiss NGO)</td>
<td>unknown</td>
<td>Sikasso and Kadiolo</td>
<td>Integration of aquaculture with small dams and seasonal ponds; animal husbandry-gardening-fish culture</td>
<td>Promote community management of seasonal ponds and dams</td>
<td>Difficulty in managing and controlling fishing access at night</td>
</tr>
</tbody>
</table>
Table 2. Agroecological zones in Mali (source: SPFS, 1999).

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>ZONE I: Saharan Zone</th>
<th>ZONE II: Sahelian Zone</th>
<th>ZONE III: Sudanian Zone</th>
<th>ZONE IV: Sudano-Guinean Zone</th>
<th>ZONE V: Central Niger River Delta</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Includes the northern part of the country (53%). The desert occupies the region of Kidal, ¾ of Timbuktu, and a large part of the region of Gao.</td>
<td>Includes the middle and lower northern portions of the country (low rainfall zones), including Mopti, Ségué, and the remaining portion of Timbuktu.</td>
<td>Includes the regions of Kayes, Koulikoro and parts of Sikasso and Bamako</td>
<td>Includes the region of Bamako, and portions of Koulikoro, Kayes and Sikasso</td>
<td>Includes certain parts of Ségué, Mopti, and Timbuktu. It is further subdivided into the actual delta, the middle Bani-Niger, the old delta and the lake zone.</td>
</tr>
<tr>
<td>Size (km²)</td>
<td>632 000</td>
<td>281 000</td>
<td>215 000</td>
<td>75 000</td>
<td>29 000</td>
</tr>
<tr>
<td>Rainfall (mm per year)</td>
<td>150</td>
<td>200-350 in the North</td>
<td>600-800 (5 month rainy season)</td>
<td>Average of 1 000</td>
<td>250 in the North, 300 in the South</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>12 (January)</td>
<td>360-600 in the South</td>
<td>26 – 28</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>45 (May - June)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetation</td>
<td>Desert (sand) and artificial classified forests</td>
<td>Savannah and forested steppe dominated by species including <em>Acacia senegalensis</em>, <em>Acacia seyal</em>, and <em>Crénia bicolor.</em></td>
<td>Dominated by forest and forested savannah, and species including <em>Isobernia doka</em>, and <em>Damiella olivier.</em></td>
<td>Hardy herbaceous plants, forested savannah, and forest</td>
<td>Dominated by <em>Acacia sieberiana</em> and <em>Vetiveria nigritania</em> (species are determined by the length of submersion under water during floods). Includes the most important fish and bird populations in the country.</td>
</tr>
<tr>
<td>Soil</td>
<td>Sand dunes very susceptible to wind erosion</td>
<td>Tropical iron rich soils, fertile and moderately vulnerable to erosion.</td>
<td>Many diverse soil types, including rocky soils and tropical iron-aluminum plinthite (hard pan)</td>
<td>Tropical red soils with slight iron content, which are relatively fertile. Also transitional hydromorphic soils (gray soils) which are appropriate for rice culture and vegetable gardening.</td>
<td>Hydromorphic alluvial soils</td>
</tr>
<tr>
<td>Agricultural Production Systems</td>
<td>Agro-pastoral (animal husbandry, gardening, rainy season culture)</td>
<td>Animal husbandry, agriculture, harvesting natural forest products</td>
<td>Rainy season cereal production, cotton production, beginning to develop agro-pastoral production around urban zones</td>
<td>Agro-pastoral production. Crops include vegetable gardening, tobacco, maize and sorghum.</td>
<td>Rice, sugar cane, vegetable production in the delta, and agro-pastoral production in the floodplains.</td>
</tr>
</tbody>
</table>
Table 2 (continued). Agroecological zones in Mali (source: SPFS, 1999).

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>ZONE I: Saharan Zone</th>
<th>Zone II: Sahelian Zone</th>
<th>Zone III: Sudanian Zone</th>
<th>Zone IV: Sudano-Guinean Zone</th>
<th>Zone V: Central Niger River Delta</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main crops</td>
<td>Vegetables, forage, animal products</td>
<td>Animal products</td>
<td>Sorghum, maize, cotton, animal husbandry</td>
<td>Sorghum, maize, tobacco, rice, trees</td>
<td>Rice (predominant crop), sorghum, maize</td>
</tr>
<tr>
<td>Water resources</td>
<td>No surface water</td>
<td>Lakes situated near the Niger river, permanent and temporary ponds (mares); significant underground water resources</td>
<td>Rivers, streams and seasonal ponds provide year-round surface water</td>
<td>Abundant surface water</td>
<td>Dams at the Office du Niger and Selingué; Niger river; significant underground water resources; high water flow July–September in Segou, October–December in Mopti, and December–February in Gao</td>
</tr>
<tr>
<td>Opportunities for IIA development</td>
<td>Available support services</td>
<td>Market availability</td>
<td>Important surface water resources</td>
<td>Important land</td>
<td>High irrigation potential</td>
</tr>
<tr>
<td></td>
<td>Existence of farmers’ organizations</td>
<td>Existence of farmers’ organizations</td>
<td>Important and diversified animal husbandry resources</td>
<td>Important surface water resources</td>
<td>Important flood zone</td>
</tr>
<tr>
<td></td>
<td>Available land and pasture resources</td>
<td>Available land and pasture resources</td>
<td>Presence of markets and processing plants</td>
<td>Important and diversified animal husbandry resources</td>
<td>Available forage and pasture resources (Echinochilon stagnina)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Existence of farmers’ organizations</td>
<td>Market availability</td>
<td>Significant biological diversity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Important socio-economic infrastructure</td>
<td>High density of available support services</td>
<td>High population density</td>
</tr>
<tr>
<td>Constraints to IIA development</td>
<td>Low population density</td>
<td>Decreasing water availability</td>
<td>High land use pressures</td>
<td>Low access</td>
<td>Soil degradation</td>
</tr>
<tr>
<td></td>
<td>Very limited water resources</td>
<td>Desertification of natural resources and environment</td>
<td>Decreasing soil fertility</td>
<td>Parasitic diseases (Sleeping sickness)</td>
<td>Conflicts between agriculturalists and herdsm</td>
</tr>
<tr>
<td></td>
<td>Arid climate, violent winds</td>
<td>Lack of socio-economic infrastructure</td>
<td>Soil acidification</td>
<td>Insufficient socio-economic infrastructure</td>
<td>Decreasing biodiversity</td>
</tr>
<tr>
<td></td>
<td>Poverty of the population</td>
<td></td>
<td>Lack of pasture resources</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lack of socio-economic infrastructure</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 3. Irrigation systems, agroecological zones in which they are found, their potential for integration with aquaculture, and constraints to integration.

<table>
<thead>
<tr>
<th>Site or agroecological zone</th>
<th>System</th>
<th>Potential IIA system</th>
<th>Advantages</th>
<th>Problems to resolve</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site No 1: Sudano-Guinean and Guinean Agro-ecological zone (Selingué/Sikasso and Manatali/Kayes)</td>
<td>Large irrigated perimeters Office du développement rural de Selingué, and Projet de développement de l'agriculture dans la vallée du fleuve Sénégal (Selingué and Manatali dams)</td>
<td>Fish ponds built along irrigation canals Stocking irrigation canals Stocking borrow pits Improvement of traditional rice-fish culture</td>
<td>Permanent water availability Gravity water systems Presence of an administrative structure responsible for water resource management and extension Good rice paddy construction Availability of fingerlings in canals</td>
<td>Lack of available land/sites Lack of resources to exploit the land available Lack of economic benefits of integrated production products Dependence on organizations responsible for water management; resistance to integration with aquaculture Inappropriate topographic configuration Cost of leasing and rents Short rice cycles Lack of technical knowledge</td>
</tr>
<tr>
<td>Site No 2: Sudano-Guinean zone and a part of the Niger River Delta Office du Niger/Ségou and Office du développement Baguimenda (Koulikoro)</td>
<td>Large hydro-agricultural irrigated perimeters (Office du Niger and Office de développement rural Baguiménda/Koulikoro)</td>
<td>Fish ponds built along irrigation canals Improvement of traditional rice – fish culture Stocking of irrigation and drainage canals</td>
<td>Permanent water availability by gravity Fingerlings available in irrigation canals Good rice paddy construction Producer organizations</td>
<td>Payment of leases and land rental Lack of available land Dependence on organization responsible for management of the perimeter Short rice production cycles Lack of technical knowledge Need to alter paddy construction to accommodate fish culture</td>
</tr>
<tr>
<td>Site No. 3: Interior Niger River Delta (Mopti, Dagawomina) and parts of the Sudano-Guinean zone in Sikasso and Kayes</td>
<td>Seasonal ponds (mares) and small dams and borrow pits (used for brick making)</td>
<td>Improved stocking, feeding and management practices in traditional rice-fish-garden-animal production systems</td>
<td>Free water (no cash costs involved) Land available (numerous sites) Presence of fish</td>
<td>Siltation of some sites Community management and potential for conflict (competition between fishermen, herders, farmers and gardeners) Variable volume and duration of water Difficult access to some sites Costs associated with construction to improve sites are high in some cases (economics) Lack of technical knowledge</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Month</th>
<th>Hydrology</th>
<th>Fish activity</th>
<th>Fishing activity</th>
<th>Tools used¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>July–August</td>
<td>Flooding</td>
<td>Lateral migration, reproduction</td>
<td>Not very active</td>
<td>Cast Nets, drag nets, dams (nasses, palangres?)</td>
</tr>
<tr>
<td>September–</td>
<td>Maximum water</td>
<td>Migration into floodplains, fish</td>
<td>Not very active</td>
<td>Harpoons, drag nets, cast nets (palangres, nasses)</td>
</tr>
<tr>
<td>October–November</td>
<td>level</td>
<td>growth (maximum food)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>November–February</td>
<td>Recessional flood</td>
<td>Migration, return to river</td>
<td>Beginning of fishing activities</td>
<td>Dams, cast nets, seine nets</td>
</tr>
<tr>
<td></td>
<td>zones</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>March–June</td>
<td>Low water levels</td>
<td>Fish stuck in river beds</td>
<td>Intensive fishing activities, collective fishing</td>
<td>Seine nets, cast nets, drag nets, nasses, palangres, collective fishing</td>
</tr>
</tbody>
</table>

¹Most of the nets used in Mali are imported from Korea, Japan and India, through the port of Lomé. Some of these nets are also exported from Mali to neighboring countries.

Aquaculture inputs

Agricultural by-products are widely available in Mali. Fish stations use combinations of rice bran (70%), cotton waste (25%), and fish meal (5%) as feed materials. Some of the constraints identified by farmers associated with the SPFS include insufficient availability of fertilizer and other inputs in local markets, lack of credit to purchase the necessary means of production, and the high costs of agricultural inputs (SPFS, 2000).

Fingerlings

All of the fingerlings currently stocked in the aquaculture stations came from natural water bodies. However, Miller (2000) reported that the Molodo National Aquaculture Training Center produced up to 100 000 *O. niloticus* and *Clarias gariepinus* fingerlings per year. Because wild fingerlings are widely available in the country, Miller recommended to orient training efforts towards fish identification and sorting techniques for restocking ponds with fingerlings produced in the wild.

Public sector aquaculture services

The DNAER is staffed by a Chef de Section, two trained technicians and one forestry engineer. All staff are located in the field, one in Sélingué and two in Niono. Obviously, there is not enough DNAER staff to manage applied research or extension activities. A national development plan for aquaculture and fisheries was created in 1997, but has not yet been transformed into concrete strategies and development activities.

Apparently fisheries activities used to be managed by the Direction national des eaux et forêts (DNFF), as in Senegal. However, the main role of DNFF agents was to enforce national fisheries and forestry management policies. In 1992, government reformulated fisheries legislation and decentralized the management of natural resources, empowering local communities. It is not clear if these policy changes have resulted in benefits for local farmers.

The mission visited two aquaculture stations: Molondo/Niono in the region of Sikasso; and the fish station in Sélingué. The station in Molondo includes 12 ponds covering approximately 4 800 m², although only two ponds have been partially renovated for production. None of the ponds can be completely drained without pumping water. The purpose of the station is to provide fingerlings and to train farmers and extension technicians. Due to lack of funds, the station is in a state of disrepair. In the past, the station manager experimented with rice-fish culture, but
experienced problems with theft, predation and adapting the technology to the field.

The station in Sélingué includes 13 ponds covering 0.4 ha. The principal objectives of the station are to produce fingerlings and marketable fish. Although the station receives some funding from the Office de Développement Rural de Sélingué, activities have been reduced and the station operates at approximately one quarter of its production potential.

Extension activities in Mali are managed by the Direction d'Appui au Monde Rural in the Ministry of Rural Development. Unlike in Senegal, aquaculture activities and agricultural extension activities are housed within the same ministry. In addition, a number of government agencies and projects support extension activities in irrigation schemes. The Institut d’Economie Rurale (IER) is responsible for aquaculture research, and occasionally intervenes in extension activities as well. In addition, the Institute for Training and Applied Research (IFRA) located near Koulikoro has also been involved in aquaculture research, and is one of the oldest agricultural training centers in Africa.

In reality, the aquaculture training center in Molondo is responsible for most of the aquaculture extension that occurs in the country. They have organized many training sessions, both for farmers and technicians. However, most of these training sessions have dealt with fisheries techniques and technologies not always suited to Malian conditions.

Mali has also developed Chambers of Agriculture (CAM), which represent various producer groups including those involved in agriculture, animal husbandry, forestry and fisheries. They are represented from the village level to the national level in the Permanent Assembly of the Chambers of Agriculture of Mali (APCAM). In addition, each large-scale irrigated perimeter has extension staff (Coulibaly, pers. comm.).

In addition to government ministries, each commune in the country has an action plan and a community development plan, and a budget. Mayors and their advisors are responsible for the implementation of these plans, and government appointed staff (sous prefets and prefets) are only responsible for checking the legality of planned activities. Many of these communes have already identified seasonal ponds (mares) and lowland areas (bas fonds) for improvement (Coulibaly, pers. comm.).

### IIA systems in Mali

The IIA systems currently found in Mali (and their geographic locations) include:

1. **Rice-fish-gardening in large irrigated perimeters** (Niono/Office du Niger, Sélingué/Office de développement rural de Sélingué, Baguiménda/Office de développement de Baguiménda, Mopti/Office du riz de Mopti)

2. **Extensive aquaculture in seasonal ponds and lowlands, associated with gardening and/or animal husbandry** (Kayes, Sikasso, Dagawomina, Gnimitoongo and Koubi/Mopti)

3. **Extensive aquaculture and animal fodder production in seasonal ponds and borrow pits** (Mopti, Niono, Sélingué)

4. **Semi-intensive aquaculture with vegetable, fruit tree and rice production by private farmers** (Baguiménda/Koulikoro)

Table 5 summarizes the general availability of resources required for IIA activities in Mali. The IIA systems with the most potential for successful development include:

1. **Intensive rice-fish culture in large irrigated perimeters.** Rice-fish farming has considerable potential in Mali. However, this mission also noted that farmers were hesitant to practice integrated rice-fish culture. Members of the Fish Farmers’ Association of the Office du Niger stated that they are not interested in pursuing intensive rice-fish culture because of limited access to irrigated land suitable for rice production, the type of irrigation engineering used to create their rice paddies (which may not be conducive to fish production), and fear of losing the fertility of their rice paddies. Water availability, the short production cycle of rice, and the market requirements for large fish were also mentioned as constraints to rice-fish integration.

Rice is the principal source of income for many farmers, even before onions. However, farmers already capture wild fish in their rice paddies and in seasonal flood plains (approximately 25 kg/ha). FAO staff in the country were skeptical of the economic viability of rice-fish culture, and the staff of the Office du Niger do not encourage the integration of aquaculture with rice in their irrigation schemes. However, given the large area in which irrigated rice culture is practiced and the fact that capture of fish in rice fields is a
traditional practice (albeit on a limited scale), this system could have a lot of potential if constraints are addressed.

2. **Traditional aquaculture in seasonal ponds, associated with gardening and animal husbandry.** Miller (2000) suggested that the demonstration of artisanal marsh aquaculture should be promoted with improved stocking techniques, specifically in Dagawomina and Gnimitongo. The IIA team supports this recommendation, with the additional potential to develop and improve water storage and management in seasonal ponds and borrow pits. According to reports from the SPFS, fish culture activities in Mopti are centered on improvements to seasonal ponds (*mares*) and borrow pits. More than 10 villages in Mopti are involved in improvements to dikes in seasonal ponds. The benefits of these seasonal ponds include not only water storage and fish, but also the production of forage grasses (*Echinochloa stagnina*) and vegetables. These villages have organized co-management committees, as well as women's gardening and fish marketing groups (Bamba and Kienta, 2000).

3. **Aquaculture in recessional flood plains (closing off water evacuation routes and trapping fish and water).** Although the team did not visit systems where recessional flood plains were being exploited, the use of recessional flood plains for fish, vegetable and cereal production as well as animal husbandry production is a common farming system practiced in Mali, especially in the Niger River Delta. If low cost techniques could be developed to improve these traditional systems, both the degree of integration and the benefits of production could be increased.

**IIA opportunities**

There are quite a number of successful but unpublicized aquaculture activities that have been launched in the country which should be publicized widely. Aquaculture in irrigation systems could become an important component in the second phase of the SPFS. Sanni and Juanich (2001) also reported several opportunities for the development of IIA activities, including:

- Potentially important unexploited land and water resources and the high demand for irrigation schemes which remains unsatisfied due to their high costs;
- High priority given by governments to food security issues;
- Current policies for transferring management responsibilities of irrigation schemes to beneficiaries along with the adoption of participatory and gender-sensitive approaches to development by support services;
- Policies for diversification being undertaken by governments which are better adapted to the new economical environment and which offer more possibilities for small-scale farmers to choose enterprises for optimal development of the irrigation sites;
- Existing traditions of practicing irrigation (farmers having necessary technical skills for producing irrigated crops such as rice and vegetables) combined with the high motivation of producers (rural communities and private entrepreneurial sector) and an interest on the part of donors in the development of the irrigation sector;
- Awareness of government officials of the decline of fish production;
- Good local markets for rice and fish as well as good prospects for creating regional markets.

The current team identified the following additional opportunities and factors which favor the development of IIA activities:

1. **Interest**
   People in Mali eat a lot of fish, natural fish production has decreased and is erratic, and important numbers of professional fishermen exist. The diversification of agricultural and economic production and increased irrigation capacity is a priority both for the government and the local population.

2. **Water**
   The Niger and Senegal Rivers and floodplains, the Sankanri, and the dams at Manantali and Selingué provide significant water resources and immense irrigation potential. Moreover, unlike Senegal, most of these water resources can be exploited using gravity-flow irrigation systems. Water is a priority for the government, and the government has attached particular importance to the irrigated perimeters created by parastatals.

3. **Economics**
   Fish, cotton and onions are important exports in Mali. Cotton and onion production require
Table 5. Availability of essential resources required for IIA activities.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Resources and inputs required</th>
<th>Availability</th>
<th>Source</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aquaculture</td>
<td>Water</td>
<td>√</td>
<td>Mares, borrow pits, irrigated perimeters</td>
<td>Variable</td>
</tr>
<tr>
<td></td>
<td>Labor</td>
<td>√</td>
<td>Men, women, fishermen</td>
<td>CFAF1000/day</td>
</tr>
<tr>
<td></td>
<td>Land</td>
<td>√</td>
<td>Rural Development Agencies</td>
<td>CFAF60 000/ha/year</td>
</tr>
<tr>
<td></td>
<td>Fingerlings</td>
<td>√</td>
<td>Wild in natural waters</td>
<td>CFAF20 ea</td>
</tr>
<tr>
<td></td>
<td>Tools</td>
<td>√</td>
<td>Local markets, imports</td>
<td>Variable</td>
</tr>
<tr>
<td></td>
<td>Feed</td>
<td>√</td>
<td>Rice and cotton processing</td>
<td>CFAF300 – 5 000/kg</td>
</tr>
<tr>
<td></td>
<td>Information</td>
<td>limited</td>
<td>Molodo Fish Station</td>
<td>Transport</td>
</tr>
</tbody>
</table>

| Irrigation      | Water                         | √            | Rivers, seasonal ponds, borrow pits, irrigated perimeters, groundwater sources | CFAF60 000 per ha per year (average) |
| Land improvement|                               | √            | Consultants, DNAER, Irrigated perimeters | Variable¹                |
| Pumps           |                               | √            | Private sector, NGOs, imports               | Variable                 |
| Spare parts     |                               | √            | Private sector                              | Variable                 |
| Fuel            |                               | √            | Private sector                              | CFAF350/liter            |
| Information     |                               | √            | Irrigation schemes; government              | Free                     |

¹SPFS documents indicated costs up to CFAF4 000 000 to improve seasonal pond irrigation systems in Mopti (SPFS, 2000).

Irrigation and/or water management, and aquaculture could be integrated into their production systems. The devaluation of the CFA Franc, and the importance of regional fish markets make the products of IIA activities particularly attractive in Mali.

4. Knowledge
All irrigated perimeters have staff responsible for extension. Moreover, irrigation practices and perimeters have been around for some time, and there is a critical mass of irrigation knowledge and expertise in the country. In addition, Malians are some of the most successful fishermen in the region, and have significant capture fisheries knowledge, which could be exploited and transformed for aquaculture systems.

5. Institutional opportunities
Mali is a member of numerous organizations which promote the management of aquatic and other natural resources, which indicates an interest on the part of government in improved natural resource management. The recent reorganization of fisheries activities from the DNFF to the DNAER, which is housed in the same ministry as agricultural extension staff, could also facilitate the development and implementation of IIA activities. Decentralization of the management of development activities to the local level also facilitates IIA evolution. In addition, numerous village management committees exist for the management of seasonal ponds and dams (e.g. in Sikasso, Kadiolo, Mopti), which are essential for IIA development.

6. Availability of inputs
Agricultural by-products including rice bran and cotton meal, and numerous fish species and wild fingerlings in natural water bodies are available.

**IIA constraints**

The constraints to IIA development can be grouped into technical, environmental, institutional and socio-economic.

Technical constraints include the challenge to develop low-cost technologies or make more profitable use of existing systems without increasing associated costs. The potential need to modify large-scale irrigation schemes to allow for mixed rice-fish culture is a significant constraint. In the past, sandy soils and high
infiltration rates limited aquaculture development in some areas, but technicians have found that these problems are alleviated over time, and infiltration is currently only a problem in new or recently rehabilitated sites. Feed costs and the costs of intensifying production are also a challenge for poor farmers. Technologies should be developed which allow farmers to use feed and fertilization materials which are produced on-farm, or in the community.

Environmental constraints include sandy and rocky soils, insufficient rainfall in large parts of the country coupled with high evaporation rates as well as topographical limitations at many sites. Water supplies are unreliable in seasonal ponds particularly during drought years.

Socio-economic constraints include the large number of competing income generating activities available to farmers in irrigated perimeters, which could limit the time and interest farmers have in aquaculture. The size of the parcels given to families in large irrigated perimeters may be insufficient for combined production. In addition, difficulties inherent in working with migratory fishermen, and land tenure and access issues between fishermen and farmers, and between resources used by members of multiple communities could also pose problems. Theft by professional fishermen using nets at night was also mentioned as a constraint to the development of IIA activities. In some irrigated perimeters such as Bangunimenda, family fish ponds have been completely abandoned due to theft.

On the institutional side, Mali is one of the few countries with no national fisheries programme or department. The Section d’Aménagement et Gestion des Ressources Halieutiques is only a section of the DNAER, housed within the Ministry of Rural Development. They are located outside the realm of most decision-making bodies, and have no one directly representing their interests to the authorities. Moreover, all fisheries infrastructures has been transferred to local communities with the implementation of decentralization policies. In addition, aquaculture knowledge, research and extension have been limited in Mali. The current lapse of funding for SPFS activities in Mali, and the existing lack of collaboration and coordination between SPFS and DNAER activities further constrain IIA development. Finally, some of the large irrigated perimeters do not permit the integration of aquaculture with rice culture in drainage canals due to fears that such systems could lead to blocked canals, or create drainage difficulties during harvest periods. Additional institutional issues include:

- Past project approaches in which beneficiaries did not participate in decision making processes;
- Lack of public awareness of fish farming as an income generating activity;
- Lack of information and data from successful fish farming operations;
- Lack of funding for the Department of Fisheries and fish farming, and lack of staff trained in aquaculture;
- Too much emphasis on unnecessary infrastructure development such as fingerling production centers;
- Lack of regular, dependable aquaculture extension activities;
- Lack of statistics on fisheries and aquaculture;
- Lack of involvement of universities and research institutions in the organization of aquaculture studies and data collection;
- Highly technical, costly approaches used by past projects, which did not take into consideration the local context;
- Lack of qualified staff with a good knowledge of aquaculture and IIA;
- Lack of participatory approaches used in previous development projects;
- Lack of coordination between projects and actors in the field of irrigation and aquaculture;
- Insufficient organization of extension activities;
- Lack of a package of IIA technologies adapted to local circumstances and needs.

Recommendations for the development of IIA in Mali

IIA development in Mali should be seen in the context of the Africa Regional Aquaculture Review (FAO, 2000) which concluded to establish national development policies and an Aquaculture Development Plan in consultation with stakeholders, to reduce expensive and unsustainable aquaculture infrastructure, to promote and facilitate private sector production of seed and feed, to encourage credit for medium and large scale producers, to revise aquaculture extension (establishing a flexible and efficient structure to meet producers’ needs), to advocate farmer-friendly existing technologies that use readily available culture
species and local materials, and to facilitate the formation of farmers’ associations.

Specifically for Mali, and based on additional information from Miller as well as Sanni and Juanich mission reports, there are opportunities for the integration of aquaculture particularly in marsh environments and in rice fields. Artisanal marsh aquaculture may be promoted in Dagawomina and Gnimitongo, while IIA in rice-fish systems has potential in Mopti, Koulikoro, and Kayes areas. The rice-fish integration can be done in an intensive way in irrigated rice areas under complete water control, whereas floods have to be managed in lowlands before promoting more intensive forms of integration there. Improved extensive rice-fish farming options exist particularly along waterways and in mangrove areas (provided that environmental considerations in these fragile cosystems are met). Development must be based on improved local knowledge and increased local capacity, and integrated pest management in rice needs to be advocated.

To achieve a wide adoption rate, participatory approaches should be used, and collaboration enhanced between NGOs, other donor funded initiatives, volunteer associations, community based organizations, women’s groups and research organizations involved in IIA activities. Subsidies should be avoided.

Further areas that deserve attention include the reduction of post harvest losses, especially in Mopti and Niono, the promotion of rural savings and credit options, the establishment of communications programmes with aquaculture success stories, and the provision of logistical support for aquaculture extension activities.

The Direction Nationale d’Aménagement et Equipement Rural (DNAER) of the Ministère du Développement Rural should focus on:

1. Identification and training of DNAER staff in aquaculture and IIA, and increasing staff levels;
2. Evaluation and follow-up of SPF S IIA activities, and feasibility studies to define priority IIA zones and sites;
3. Development of a package of IIA technologies adapted to priority sites and systems (applied research);
4. Harmonization of interventions between different development partners and actors; and increased collaboration between irrigation and aquaculture specialists and practitioners;
5. Identification and training of public and private sector partners (farmers’ organizations, extension staff, NGOS);
6. Training of producers.

Support should be provided by external organizations such as FAO to reinforce the capacity of the DNAER to manage IIA activities in terms of administration, training, and extension/communication. A revitalized and reinforced SPF Programme should also focus on IIA activities.

**Conclusions**

Mali has all of the essential resources necessary to produce large quantities of fish. Land, water, labor, fingerlings, inputs and indigenous knowledge of inland capture fisheries are available. However, there are opportunity costs associated with using each of these resources, and in many cases alternate uses of these inputs are more profitable than their use for aquaculture production. For example, land with year-round access to water and irrigated land can be used to produce cash crops such as vegetables, or subsistence crops like rice. Cash crops may generate several times more income per cubic meter of water than fish culture.

In areas which do not require water pumping, aquaculture may be more profitable, but water is not always available year round in those sites (generally seasonal ponds, borrow pits, recessional flood plains and lakes). Moreover, these sites do not always offer the potential for complete drainage of fishponds. There are also competing uses for water in these sites, including gardening and animal husbandry. These competing and generally more profitable uses of land and water require the development of innovative aquaculture systems which are not geared to the principal production of fish, but rather incidental or secondary fish production. The development of fish production in short cycle systems, using locally available, low cost techniques, which allows for the production of fish with minimal competition with other, more profitable exploitations is required.

More research needs to be done on the profitable production of local fish species, and on extensive aquaculture production systems and IIA systems in seasonal ponds and lakes. Competing uses of limited resources – especially water – needs to be taken into consideration. Aquaculture should be integrated into local farming systems, as well as irrigation systems.
References/Further reading


1 A modified version of this report is included in this volume (see Chapter 5).
THE POTENTIAL FOR INTEGRATED IRRIGATION-AQUACULTURE (IIA) IN SENEGAL

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Abstract
The paper provides an analysis of the potential for integrated irrigation aquaculture in Senegal. It is based on general information available from workshops and meetings facilitated by FAO in 1999 and 2000 as well as a field report from a mission to Senegal by experts in agronomy, aquaculture, and socio-economics in December 2001. It is concluded that Senegal has all of the essential resources necessary to produce large quantities of fish. However, there are opportunity costs associated with using each of these resources. Competing and generally more profitable uses of land and water require the development of innovative aquaculture systems which are not geared principally to the production of fish, but rather to incidental or secondary fish production. The development of fish production in short cycle systems, using locally available, low-cost techniques, which allows for the production of fish with minimal competition with other, more profitable exploitations is required. Integrating low-cost, extensive aquaculture systems into existing irrigation and production systems is a potential solution to the situation. More research needs to be done on the profitable production of local fish species, and on extensive aquaculture production systems. Competing uses of limited resources – especially water – needs to be taken into consideration, and aquaculture should be integrated into local farming systems rather than into irrigation systems, per se.

Introduction
Located on the western edge of the Sahel, Senegal has the highest per capita consumption of fish in Africa (37 kg/person/year). Unfortunately, inland fisheries production has been decreasing steadily. Despite an extensive water network that includes the Senegal, Gambia and Casamance rivers, as well as over 500 km of Atlantic Ocean coastline, Senegal suffers from severe water constraints. Some areas of the country receive less than 300 mm of water per year, and rainfall has decreased an average of 10 to 20 mm per year since the 1980s (CILSS, 1995).

Because of the importance of national and regional water resources in the country and the decreasing availability of fish, the government of Senegal submitted a request to the Food and Agriculture Organization of the United Nations (FAO) to participate in a planned regional Integrated Irrigation and Aquaculture (IIA) programme. A mission was sent to Senegal in November 2001 to explore opportunities for the development of IIA activities in the country. This report presents the findings of the mission. The findings of previous FAO missions to Senegal to explore aquaculture resources (December 2000; Miller, 2000) and to examine the possibility of integrating aquaculture into rice production systems (March 2001; Sanni and Juanch, 2001) were taken into consideration during the elaboration of this report.

The mission
Three technical specialists participated in the IIA exploratory mission in Senegal – a socio-economist and team leader, an irrigation specialist and an aquaculture specialist. They were joined in Senegal by an aquaculture specialist from the Department of Inland Fisheries and Aquaculture, who participated in all field exercises and in the analysis of results.
evaluating potential opportunities for and constraints to the development of IIA activities in the country. This was done on the basis of (i) review of available documents; (ii) meetings with the FAO Programme Officer, the FAO Special Programme for Food Security (SPFS) Coordinator, staff of the Department of Inland Fisheries and Aquaculture, representatives of donor organizations, national and international non-governmental organizations and government organizations including the Center for Environmental Monitoring, the Service of Hydrology, the Center of Assistance, Experimentation and Extension for Artisanal Fisheries (CAEP); and (iii) field visits to three regions of the country including Saint Louis and the Senegal River Valley (Richard Toll, Matam, and Bakel), Tambakunda (Mbouléme and Kédougou), and Kolda (Anambé).

The main findings include a list of past, current and future IIA activities, an evaluation of the potential for IIA development and integration into local farming systems, a list of opportunities, and a list of constraints to the development of IIA activities. In general, the main changes in the IIA situation since previous visits include the creation of a separate Ministry of Fisheries in Senegal, and the start-up of aquaculture projects funded by Taiwan Province of China and the Belgian government.

Past, present and planned IIA activities

Government activities

Although the government has not promoted integrated irrigation and aquaculture systems per se, it has actively supported the development of irrigation infrastructure. Moreover, it has collaborated with donor-funded aquaculture initiatives implemented by NGOs. Currently, the government has three programmes promoting aquaculture. Although these programmes do not specifically target the integration of irrigation and aquaculture, all the areas targeted by these programmes require irrigation to support aquaculture and therefore a certain amount of integration is implied.

The current programmes include the development of aquaculture research and extension activities in Richard Toll supported by Taiwan Province of China, research into the potential for developing aquatic biological control techniques to control weeds in irrigation canals funded by the Cooperation Belge, and activities promoting the creation of an aquaculture network for youth funded by the Ministère d’Emploi. None of these programmes promote water re-use or integration specifically. Each programme is described in more detail in Table 1.

Special Programme for Food Security (SPFS)

During the mission 200 specialists from Viet Nam in Senegal were implementing the SPFS in the field. Activities include the promotion of market gardening, agricultural and aquaculture processing, rice culture, agroforestry, aviculture, apiculture, and aquaculture. Vietnamese technicians working with local community members have improved seasonal ponds and developed integrated aquaculture and irrigation systems in Kédougou, Velingara and Fatik. They have also developed traditional fish ponds integrated into gardening irrigation systems in Matam. In most cases, Vietnamese technicians provided technical advice as well as feed and fertilization inputs for project communities.

Donor and non-governmental organization (NGO) activities

USAID/Peace Corps

From 1981 to 1986, the United States Agency for International Development (USAID) in association with the US Peace Corps funded the development of aquaculture in the Senegal River valley (Richard Toll, Dagana, Podor, Matam and Bakel). The objectives were to demonstrate the feasibility of fish culture in the Senegal River valley and to produce marketable fish. Problems included technical mistakes, the use of imported rather than local fish, lack of trained technicians and fishermen, and a lack of clear definition of responsibilities between SAED, DNFF and Peace Corps. Farmers in Bakel also mentioned water infiltration, land tenure issues and predators as constraints. The lack of efficacy and unreliability of pumps for the provision of water in the fish ponds was a serious technical constraint.

L’Agence française des volontaires pour le progrès (AFVP)

French volunteers posted in Matam experimented with cage culture in the Senegal River and pond aquaculture. Although the mission did not discover records of activities
or accomplishments, discussions with farmers who previously worked with AFVP revealed that the cost of creating the cages was a significant constraint to implementation and adoption. The technical viability of the endeavour in the area remains unproven.

Miller (2000) mentioned several other projects supported by the Canadian, Vietnamese and Chinese governments in Ziguinchor (Casamance region). The mission did not receive any information about those programmes.

Current projects

There are several irrigation projects currently funded by local and international NGOs and international donors in Senegal. Africare, Aquadev, CRS, LWR, Oxfam, GADEC, Terre Nouvelle (a Belgian NGO), the Belgian government (Coopération belge) and USAID are just a few of the NGOs and donors who implement irrigation programmes in the field. Cooperation Belge is funding a 2.5 billion CFAF project in collaboration with four local and four international NGOs called PESA, Programme de l’eau pour la sécurité alimentaire – the Water Programme for Food Security. Despite the potential for integration of irrigation with aquaculture if appropriate integration systems are developed, little integration is planned. No aquaculture programmes are currently promoted by NGOs or donors, apart from those being implemented in collaboration with the Senegalese government.

Planned projects

The mission is not aware of any IIA projects that are currently planned. A more detailed description of past, present and future IIA programmes is included in Table 1.

IIA potential and fit into local farming systems

Farming systems

The agroecological zones of Senegal are described in Table 2. Most land is used for crops: groundnuts, cotton and rice are major crops, followed by tomatoes, onions (repeatedly mentioned as the most profitable crop), cassava and sweet potatoes. Maize, cowpeas, okra, hibiscus, watermelon, fonio (Digitaria exilis) and bananas are produced on a minor scale. Green beans and melons are becoming increasingly important cash crops.

Animal husbandry is an important source of income, and women practice sheep and goat fattening as an income generating activity around holidays and celebrations. Most households own at least a few chickens, sheep and goats. Donkeys and horses are important sources of labour and income. In some areas, conflicts arise between owners of migrating animal herds (generally cattle) and local farmers. In the southern forest region, charcoal production is a major income generating activity and competes with other (less destructive) land use management practices.

Many of the farmers visited produce rice in the rainy season (July–October), vegetables or maize and sorghum in recessional flood plains during the cold season (November–February), and have alternative income-generating activities during the March–June hot season (charcoal production, cloth dyeing, small-scale commerce). In some areas farmers supplement rice production during the rainy season with other cash crops such as okra and hot peppers. Both men and women participate in agricultural activities, including land preparation, planting, weeding and harvesting.

Land use and tenure

All land in Senegal is technically owned and managed by the state. Along rivers and the ocean, land is publicly owned. Customary land use rights are slowly giving way to private ownership in many areas, and land is currently being purchased from the Ministry of Finance for 99-year leaseholds. Land purchasing has become highly politicized in urban areas and in resort locations, and this concern is partly behind the political problems in the Casamance region.

Although access to land is not generally restricted, access to irrigated land can be difficult to obtain. In one area around Richard Toll, farmers said that where they used to cultivate one hectare of land, now they only cultivate 0.3 to 0.65 hectare per person. It costs about 600 000 CFAF/ha to rent irrigated land to grow tomatoes, and 300 000 CFAF/ha to grow rice (SAED, Bakel)

1 CFAF740 = US$1 (November/December 2001)
Table 1. Past, current and planned IIA activities in Senegal. Information on constraints and lessons learned was gleaned during interviews with Abdoulaye Diop, CAED; Aboubacar Ndiaye, SAED/Bakel; Deme Diallo, Ministère d’emploi, Richard Toll; Samba Ka in Bakel.

<table>
<thead>
<tr>
<th>Donor</th>
<th>Years</th>
<th>Target zone</th>
<th>Type of IIA system</th>
<th>Objectives</th>
<th>Constraints/lessons learned</th>
</tr>
</thead>
</table>
| USAID/Peace Corps              | 1981 – 1986      | Richard Toll, Nianga, Matam, Bakel | Derivation ponds pumping water from the Senegal River into irrigated perimeters | Demonstrate feasibility of fish culture in the Senegal River valley                                   | • Lack of training, lack of technical knowledge of farmers and extension agents  
• Lack of appropriation by the population/ lack participatory approach  
• Targeted traditional fishermen but land belonged to cultivators  
• Technical problems and mistakes (poor fish growth - 80 g; feed transported from Richard Toll; ponds leaked; imported fish vs. local species; poor site selection; inappropriate and poorly adapted technologies)  
• Lack of effective coordination between SAED, DNFF and Peace Corps |
| AFVP                           | 1987 - 1990      | Matam       | Cage culture in the Senegal River                                                | Develop fish culture in cages and ponds                                                               | • Materials to create cages were expensive making the technology as promoted unsustainable (superficial feasibility studies)                                                                                                     |
| FAO/ SPFS                      | 1995 - ongoing   | Matam, Kédougou Velingara, Podor, Fatick  | Integration of fish culture with gardening, animal husbandry, rice in private irrigated perimeters, seasonal ponds and borrow pits | Improve water management, intensify crop production, diversify crop, analyze constraints             | • Fish culture has potential for development in seasonal ponds and borrow/ gravel pits  
• Prices of commercially available feed and fertilizer too high for most farmers  
• Community management and conflict resolution techniques for shared resources need to be developed or better understood |
| Taiwan Province of China       | 2001 – 2003 (first phase) | Dagana/ Richard Toll | Integrated rice-fish culture with derivation ponds using pumped water from the Senegal River and Lac de Guiers | Develop fish culture in rural ponds; restock natural water bodies; extension in 10 villages per year | The project supports the distribution of inputs at reduced or subsidized prices, free distribution of tools and fingerlings to farmers and builds lab for sexing and artificial reproduction. This approach does not promote sustainable development. Research into production of sexed fish and development of lab may not be sustained by the government  
The techniques being developed are very high tech, and will be of use mainly to resource endowed companies like CSS, or for large scale dam projects (OMVS/OMVN) |
| Belgian Government, Univ. de Liège, CSS (sugar company), Min. of Finance | 2001 – 2003 (pilot phase) | Richard Toll | Integration of ponds with sugar cane in canals, with pumped water from Senegal River and Lac de Guiers and triploid carp to avoid biological contamination | Test biological control methods of invasive weeds in irrigation canals and dams (Projet d’aquaculture et lutte biologique) | The techniques being developed are very high tech, and will be of use mainly to resource endowed companies like CSS, or for large scale dam projects (OMVS/OMVN) |
| Ministère d’emploi             | 2001- ?          | Richard Toll/ Dagana, Matam, Podor | Derivation fish ponds using pumped water from the Senegal River and Lac de Guiers | Create network of fish farmers in the Senegal River valley                                             | Project is being supported with technical assistance and support based in Dakar. As a result, implementation has been slow                                                                                                                      |
Table 2A. Agroecological zones of Senegal. Zones I-III (Source: Programme spécial de sécurité alimentaire 1999).

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>ZONE I: Senegal River Valley</th>
<th>Zone II: Niayes and the coastal region</th>
<th>Zone III: Groundnut production zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>From Bakel to the beginning of the Senegal River; includes department of Bakel, region of Tambacounda and Saint-Louis</td>
<td>South of Saint Louis to island of Cap Vert, band from 5 to 50 km wide and 180 km long</td>
<td>Old region of Sine Saloum (Kaolack-Fatick) to Diour Bel, Thies (outside of the Niayes), Louga Ndamdé, Darou, Nousti, Sagalatta, Koki, Mbédenne, Salkal and Tambacounda</td>
</tr>
<tr>
<td>Size (km$^2$)</td>
<td>9,658 (600 km long and 15 km wide)</td>
<td>2,754</td>
<td>46,387</td>
</tr>
<tr>
<td>Population (1988)</td>
<td>600,000</td>
<td>1,700,000</td>
<td>3,200,000</td>
</tr>
<tr>
<td>Population density (no./km$^2$)</td>
<td>57</td>
<td>600 with an extreme of 3,400</td>
<td>68 min: 5 – 10 people/km max: 150-160 people/km Thies</td>
</tr>
<tr>
<td>Average rainfall (mm)</td>
<td>200 - 500 (500 in Bakel, 360 in Matam and 200 in Podor)</td>
<td>200 - 500 mm</td>
<td>200-500 (north) 500-800 (south)</td>
</tr>
<tr>
<td>Average temperature (°C)</td>
<td>20 - 40 with extremes of 12 (Nov-Feb) and 45 (May-June)</td>
<td>24-25</td>
<td>35; min: 15-18; max: 40-45 (May-June)</td>
</tr>
<tr>
<td>Vegetation</td>
<td>Badly degraded and composed of Acacia nilotica, Acacia senegal, Zizyphus mauritiana and combretum</td>
<td>Shrubby savannah with Acacia spp. Vegetation is progressively deteriorating due to drought and the extension of gardening practices.</td>
<td>Natural forest vegetation is seriously degraded. Forest islands remain around Thies</td>
</tr>
<tr>
<td>Soil quality</td>
<td>3 principal soil types: (1) Walo soils (alluvial soils in the delta and the lower valley); (2) Diédiogol soils (alluvial soils in the transition zone, sands and clay-sands); (3) Dier soils (very sandy soils in Matam and Bakel)</td>
<td>Mineral soils; hydromorphic soils; poorly developed soils (sandy); halomorphic soils (impossible to cultivate)</td>
<td>Iron soils (acidic, low pH); brown hydromorphic soils; laterite soils; holomorphic soils (saline and high in sulphuric acid (Fatick and Kaolack)</td>
</tr>
</tbody>
</table>
Table 2A (continued). Agroecological zones of Senegal. Zones I-III (Source: Programme spécial de sécurité alimentaire 1999).

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>ZONE I: Senegal River Valley</th>
<th>Zone II: Niayes and the coastal region</th>
<th>Zone III: Groundnut production zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production system</td>
<td>Rainfed crops, irrigated crops, recessional crop production, pastoral and agro-pastoral production, horticultural production (fruit, vegetables, green beans), large animal husbandry, chicken raising, milk production</td>
<td>Family gardening (0.2–0.5 ha); private and large scale irrigation systems (20–300+ ha); horticulture</td>
<td>Subsistence agriculture, groundnut - millet rotations, agroforestry (saw mills)</td>
</tr>
<tr>
<td>Principal crops</td>
<td>Rice; millet; maize; sorghum</td>
<td>Gardening; horticulture; animal husbandry (cattle, sheep, goats, rabbit); agriculture</td>
<td>Groundnuts; millet; animal husbandry; sorghum; maize; gumbo and vegetables</td>
</tr>
<tr>
<td>Water resources</td>
<td>The Senegal river (and the dams at Manantali and Diamant which regulate water level and salinity), Lac de Guiers and the Taowey river</td>
<td>No surface water except ocean inlets and old inlets which have become saline lakes.</td>
<td>Surface water is more rare and temporary in nature. Seasonal tributaries of the Gambia River flow during the rainy season. Streams below the bas-Bolong have become salty due to droughts and soil type</td>
</tr>
<tr>
<td>IIA opportunities</td>
<td>• Emergence of a private entrepreneurial sector  • Available labor  • Public services available  • Irrigation potential/ important water resources</td>
<td>• Market proximity (Dakar, Thies and Saint-Louis)  • Important horticulture potential  • Dynamic economy  • Active farmers associations and horticultural producer groups</td>
<td>• Market proximity (Dakar, Thies and Saint-Louis)  • Main roads (Dakar/ Thies/ Louga/ Saint-Louis and Dakar/ Fatick/ Kaolack/ Tambokounda)  • Tradition of groundnut and subsistence culture</td>
</tr>
<tr>
<td>IIA constraints</td>
<td>• Arid climate and strong wind erosion  • Soil degradation and natural resource degradation  • Insecure land tenure  • Inappropriate production techniques</td>
<td>• Decrease in rainfall and underground water resources  • Fragile ecosystem  • Salinification of underground water resources (fertilizers and pesticides)  • High population density and land use pressure  • Land speculation</td>
<td>• Decreased rainfall  • Degradation of natural resources and vegetative cover  • High population density and land use pressure  • Salinification of some water resources</td>
</tr>
</tbody>
</table>
Table 2B. Agroecological zones of Senegal. Zones IV-VI (Source: Programme spécial de sécurité alimentaire 1999).

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Zone IV: Sylvo–pastoral zone (Ferlo)</th>
<th>Zone V: Casamance</th>
<th>Zone VI: Center and South-East</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Most of the region of Louga and a small part of the Senegal River region</td>
<td>Southern Sénégal, Casamance and upper Casamance, (regions of Kolda and Zuiganchor)</td>
<td>Includes region of Tambacounda, except département of Bakel and parts which are included in the groundnut basin</td>
</tr>
<tr>
<td>Size (km(^2))</td>
<td>57 651</td>
<td>28 324</td>
<td>51 918</td>
</tr>
<tr>
<td>Population (1988)</td>
<td>325 000</td>
<td>700 000</td>
<td>300 000</td>
</tr>
<tr>
<td>Population Density (average number of people per Km(^2))</td>
<td>6</td>
<td>46</td>
<td>6</td>
</tr>
<tr>
<td>Average rainfall (mm)</td>
<td>200-500</td>
<td>900-1 400</td>
<td>700-1 300</td>
</tr>
<tr>
<td></td>
<td>(400-500 in the South)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average temperature (°C)</td>
<td>Max. 40 (May-June)</td>
<td>26-31</td>
<td>26-31; max: 45</td>
</tr>
<tr>
<td>Vegetation</td>
<td>Sahelian vegetation – shrubby steppe and forested savannah</td>
<td>Forests cover 1,400,000 ha and are the most important forests remaining in the country. Soudano-guinean vegetation, and 100,000 ha of mangroves composed of Avicenia nitida and Rhizophora</td>
<td>North – south passage composed of shrubby steppe and forested savannah, as well as Soudano-guinean forest and vegetation</td>
</tr>
<tr>
<td>Soil quality</td>
<td>Sandy to sandy-clay soils in the west, and dark gravel isohumic/ hydromorphic soils</td>
<td>Wide range of soil types from iron soils (red and beige), hydromorphic soils (often saline), transitional hydromorphic soils (gray), good for rice culture and gardening</td>
<td>Tropical iron rich soils, hydromorphic and halimorphic soils in alluvial areas, brown mineral soils subject to erosion and poorly developed lithosols</td>
</tr>
</tbody>
</table>
Table 2B (continued). Agroecological zones of Senegal. Zones IV-VI (Source: Programme spécial de sécurité alimentaire 1999).

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Zone IV: Sylvo–pastoral zone (Ferlo)</th>
<th>Zone V: Casamance</th>
<th>Zone VI: Center and South-East</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production system</td>
<td>Sylvo-pastoral and agro-pastoral production systems Rainfed agriculture and animal husbandry</td>
<td>Rainfed agriculture on slopes; rice culture in low lands (bas-fonds) Small irrigated perimeters used for gardening and horticulture</td>
<td>Exterior fields, low lands (bas-fonds), Irrigated perimeter (Sénégal Oriental), animal husbandry</td>
</tr>
<tr>
<td>Principal crops</td>
<td>Rice; cotton; fonio; maize; manioc/cassava</td>
<td>Maize; millet; sorghum; rice; groundnuts; manioc/cassava; cowpeas</td>
<td>Maize; millet; sorghum</td>
</tr>
<tr>
<td>Water resources</td>
<td>There are few sources of surface water except seasonal ponds (mares).</td>
<td>The Casamance and the Kayanga rivers, plus numerous temporary streams and tributaries.</td>
<td>Significant water potential composed mainly of temporary ponds (mares) and portions of the Senegal, Gambia and Falemé rivers, as well as numerous streams</td>
</tr>
<tr>
<td>IIA opportunities</td>
<td>• Development of a milk network</td>
<td>• Dense water network</td>
<td>• Good rainfall</td>
</tr>
<tr>
<td></td>
<td>• Presence of NGOs</td>
<td>• Favorable rainfall</td>
<td>• Important agro-sylvo-pastoral production potential</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Available labor</td>
<td>• Important water resources</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Soil amenable to diverse agricultural production needs and potentials</td>
<td>• Aquaculture potential</td>
</tr>
<tr>
<td>IIA constraints</td>
<td>• Drought</td>
<td>• Political insecurity and conflict</td>
<td>• Distance from main markets; access</td>
</tr>
<tr>
<td></td>
<td>• Degradation of vegetative cover</td>
<td>• Poorly adapted and managed infrastructure</td>
<td>• Low population density</td>
</tr>
<tr>
<td></td>
<td>• Mobile population</td>
<td>• Inaccessible to the rest of the country</td>
<td>• Exploited forest resources Limited access to public services</td>
</tr>
<tr>
<td></td>
<td>• Limited services available</td>
<td>• Degradation of forest resources</td>
<td>• High organic matter content of soil</td>
</tr>
</tbody>
</table>
**Labour**

Farmers said they are busiest from July to October (during the rainy season), less busy from October to March (generally gardening season), and have low labour demands from April to June (because it is hot outside, they don't have access to water and food supplies run low). Remittances from family members living abroad are important income sources during the "hungry" season (July to October). People with access to water fish from November to June, and most seasonal ponds are harvested from March to June. Animal herders are busy from July to February, moving their herds away from crop land.

There is some paid labor available in the areas visited during the mission. Farmers in Falde mentioned that they try to do most of their gardening activities themselves, but occasionally they pay for extra labor. However, given the high degree of seasonal migration in the country, labor shortages could pose a problem in some areas.

**People**

There is a traditional caste of fishermen and women (Toucouleur) who are generally considered lower caste than other community members. They were traditionally slaves, and speak a type of Peuhlar. There are also traditional fishing families who come to Senegal from Mali and create mobile fishing communities where they harvest and process fish, which they later transport for sale. In the Velingara area these Malian families have intermarried with local community members and teach local farmers how to smoke and process fish.

**Knowledge**

Although there is a lot of capture fisheries knowledge among certain Senegalese farmers, their knowledge of aquaculture and raising fish is quite limited. Similarly, most technicians were trained in either marine fisheries or forestry. The few technicians trained in aquaculture were trained in Bouaké, Cote d'Ivoire where aquaculture systems are quite different. Irrigation knowledge on the part of both farmers and technicians in the country is quite advanced.

**Water**

- Water costs CFAF45 000 to 60 000 per ha per season (Aboubacar Ndiaye, SAED, Bakel).
- Pumps cost approximately CFAF3 000 000 to 4 000 000 for a 2 HP motor, and CFAF8 000 000 for a 3 HP motor (Aboubacar Ndiaye, SAED, Bakel).
- It costs roughly CFAF3 000 000 per ha to create an irrigated perimeter (construct canals, leveling, etc.). If the labor is done locally, it costs approximately CFAF600 000 per ha (Aboubacar Ndiaye, SAED, Bakel).
- In Richard Toll, water temperatures vary from 19°C in the cold season to 31°C in the hot season (Belgian CSS project data). The average water temperature is roughly 28°C (Chinese technical advisors, Richard Toll).

**Feeds and fertilizers**

Several different kinds of agricultural input stores with gardening seeds, improved varieties of rice, fertilizers and pesticides are scattered throughout the country. They were noticed in all regional capitals and markets. However, most of these inputs are expensive for small scale farmers, and are used for cash crops (vegetables) rather than subsistence production. Most of the gardeners we met were using some fertilizer, pesticides and manure for vegetable production. Although agricultural by-products are widely available (including rice bran, groundnut leaves and even fishmeal) they are often used for animal husbandry production.

Many of the aquaculture projects visited were purchasing formulated feed from Dakar (either already pelleted or purchasing the main ingredients from Dakar and pelleting them locally). They were feeding their fish rations with up to 30% crude protein (CP) made of groundnut meal, wheat bran, rice bran and molasses. Chinese technical advisors in Richard Toll estimated the prices of locally pelleted and composed feed at 100 CFAF/kg, including transport costs, and it takes them about 2 kg of food to produce 1 kg of fish using local rations. If they purchase prefabricated food in Dakar, it costs 180 CFAF/kg. If fish are fed rice bran only, they grow to approximately 150 grams in 6 to 8 months; with pelleted feed, they grow to 200 to 250 grams. Some input prices are listed in Table 3.
Table 3. Some prices of inputs for IIA.

<table>
<thead>
<tr>
<th>Product</th>
<th>Cost in CFAF (quantity)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice bran</td>
<td>30 (1 kg)</td>
<td>Pont Gendarme</td>
</tr>
<tr>
<td></td>
<td>70 (1 kg)</td>
<td>SAED</td>
</tr>
<tr>
<td>Rice straw</td>
<td>500 (1 bale)</td>
<td>Pont Gendarme</td>
</tr>
<tr>
<td>Rice seed</td>
<td>1 150 (5 kg)</td>
<td>Pont Gendarme</td>
</tr>
<tr>
<td>Rice</td>
<td>8 250 (50 kg) local rice</td>
<td>SAED</td>
</tr>
<tr>
<td></td>
<td>11 750 (50 kg) TCS 10</td>
<td>Pont Gendarme</td>
</tr>
<tr>
<td></td>
<td>11 250 (50 kg) imported</td>
<td>Pont Gendarme</td>
</tr>
<tr>
<td>Fish bran</td>
<td>130 (1 kg)</td>
<td>Dakar</td>
</tr>
<tr>
<td>Groundnut waste</td>
<td>150 (1 kg)</td>
<td>Dakar</td>
</tr>
<tr>
<td>Molasses</td>
<td>6 000 (20 Litres)</td>
<td>Richard Toll</td>
</tr>
<tr>
<td>Fertilizer (18-40-6)</td>
<td>9 000 –10 000 (50 kg)</td>
<td>Richard Toll</td>
</tr>
<tr>
<td>Manure</td>
<td>50 (1 wheelbarrow)</td>
<td>Matam</td>
</tr>
</tbody>
</table>

**Fingerlings**

Fingerlings are currently procured from the Richard Toll fingerling station for most projects. However, wild fingerlings are also harvested from irrigation canals, rivers and Lac de Guiers, especially during the cold season. With support from Chinese technicians, the station currently produces 50 000 fingerlings per year, and should produce up to 600 000 fingerlings per year in the future. It will be possible to harvest 30 000 fingerlings every two months from six ponds. Plans are to keep 200 000 fingerlings per year to stock village ponds, and use the rest to restock Lac de Guiers.

The Belgian technical advisor reported that *Tilapia zillii* are found in local waters, but he believes that although *T. rendalli* were introduced they are no longer found. The Belgian project has been importing sterile Chinese carp from Belgium for stocking purposes. They also harvested 240 gram *T. zillii* from Lac de Guiers, and stocked fingerlings produced on site.

**Marketing and economics**

Credit was previously available to farmers in Senegal through the Caisse National de Crédit Agricole (CNCA). On several occasions, the government has written off debts to national credit institutions during elections and people know they will not have to pay them. As a result, default rates have been very high. Currently, most banks give credit to economic interest groups (GIE) rather than to individuals. This practice, in turn, encourages people to form groups in order to get access to credit.

Several farmers mentioned that low prices for imported rice made local rice production unaffordable, and several farmers mentioned buying imported rice, sugar and salt from Mauritania even though all those products are also produced in Senegal. They believe that differential import taxes in the two countries account for the differences in price.

In one area 20 km east of Saint Louis, women were selling four large fresh Tilapias and one catfish for 3 000 CFAF. In most regional capitals, fresh fish sells for about 350 to 500 CFAF/kg. In Dakar the price is up to 700 CFAF/kg. Around Podor, we saw four 300 to 400 gram fresh local tilapia selling for 1 000 CFAF, compared to two freshwater fish (mullets) from Saint Louis selling for 150 CFAF. Four 200 gram dried tilapias sold for 500 CFAF. Women in the market said that capitain sells best, followed by tilapia. *Labeo* spp. and catfish are also sold in local markets, but women said *Labeo* have too many bones. Meat was selling for 1 300 CFAF/kg. Although meat and vegetables

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² Mr N’Gom told us he captured 4 000 fingerlings in an irrigation canal at Richard Toll in one day during the cold season.
are sold by the kg, fish are almost always sold by the piece, or in piles.3

Public sector services

Extension

In the 1970s and 1980s, the government developed agricultural companies in each region of the country. The purpose of these companies was to help Senegal diversify agricultural production from groundnuts to other cash crops such as rice and sugar cane. In 1992, Senegal embraced decentralization, and agricultural companies and producer associations took over the role of extension and technical advisors in the field. Ministry of Agriculture staff members were responsible only for collecting and reporting agricultural production figures, and their numbers were reduced accordingly.

Currently, most farmers receive little or no technical advice on production. However, most of them are quite competent in the agricultural systems they manage and the irrigation systems they use. In Bakel and Anambé, SAED and SODAGRI continue to play major extension roles, although producers' organizations are starting to organize extension support on their own. The Centre Horticole de Camberene also provides technical training for both technicians and farmers, and several local and international NGOs provide assistance in terms of organization, funding and advice. Agricultural companies continue to be responsible for the maintenance and upkeep of the irrigation infrastructure developed for local users.

Aquaculture extension was traditionally supported by the Direction National des Eau et Forets, which at one time had 300 field agents. Currently the reorganized Direction of Aquaculture and Inland Fisheries (DPCA) has less than 10 field agents, which makes it quite impossible for them to participate in extension activities.

Research

Senegal has not produced much aquaculture research. Most of the past research efforts have focused on marine fisheries production and the production of high value exotic crops such as oysters and shrimp. In the past, CAEP was predominantly concerned with artisanal fisheries and the production of fisheries equipment. Currently their priorities are capacity building and the role of women in fisheries production. There is no aquaculture research facility at the University of Dakar, but there is some support for aquaculture research through the biology department.

Role of women in IIA

Traditionally, women are actively involved in both gardening and fisheries activities in Senegal. In one area along the Senegal River about 20 km from Saint Louis (near the Diama dam), women who were selling fish said that in their area, women dry and sell fish and make sails for local boats. Men make nets and repair motors. In most of the markets we visited, women were responsible for selling both fish and vegetables.

In the Tambacunda area, women used to make earthen dikes and small depressions in recessional flood plains, so that when the water receded they could harvest captured fish. During the rainy season, people in these areas used small nets to harvest fish. In the cold season, they used gill nets. In the hot season, they used baskets to remove the remaining water and harvest fish.

Women have a problem getting access to good land, especially irrigated or fertile land. Low literacy rates hamper women's efforts to work together and form clubs. In one of the first ever aquaculture programmes implemented in Mauritania funded by UNICEF, only one of 153 women cooperative members knew how to read and write (Sarr, 1999). In discussions with a women's group outside of Matam, women said their main priority is hunger, and the second is a better future for their children.

Irrigation systems

In general, seven types of irrigation systems found in Senegal:

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3 In comparison, an adult goat costs CFAF12 000-25 000, a sheep CFAF20 000-40 000 (all depending on season), a horse CFAF100 000, a cow CFAF100 000–250 000, and a horse cart around CFAF50 000. With intensive techniques, a farmer can harvest 55 sacks of rice from a 50×30 m rice paddy (interview with SPFS farmers in Matam, and information from Mr N’Gom, DPCA). Average cereal production in SAED irrigated perimeters in Bakel in 2000 was: rice 5.1 tonnes/ha, sorghum 3.4 tonnes/ha, maize 2.4 tonnes/ha (Aboubacar Ndiaye, SAED, Bakel).
SPFS Case Study: Babacar Sarr's integrated fish pond and gardens in Matam, Senegal

Mr Sarr works with Vietnamese Technicians associated with the Special Programme for Food Security. He has one 225 m² pond, and recently harvested 120 kgs from his pond after one year. In Matam, one kg of fresh fish sells for CFAF1 000. After 10 months, the fish averaged 150 grams. The pond was stocked with 1 250 O. niloticus (15 g each) and 50 Clarias fingerlings. He fed the fish rice bran mixed with millet bran. He fertilized the pond 1–2 times per month with manure and/or fertilizer. He had some problems with white mold on his fish, but treated the pond with neem leaves. He noticed 2–3 reproductions of tilapia fingerlings, but the catfish ate some of them. To completely drain the pond, he has to pump water out. He tried to cement the pond to reduce infiltration. He adds water to his fish ponds every 3–4 days for 2 hours.

He has a pump which brings water from the Senegal River to a holding tank, where it is stored for use in his gardens and fish ponds. He grows 30 ares of eggplant, fruit trees, hot peppers and okra for sale locally. He makes CFAF1.5 million/season in his garden, with most of his money coming from the sale of hot peppers. One hundred hot pepper plants bring in CFAF300 000. Hot peppers sell locally for CFAF1 750/kg. He staggered his vegetable planting from October to July. He uses some fertilizer on his vegetables, but mostly manure. He is testing out an intercropping system for hot peppers under banana trees from May to July, when it is usually too hot to produce vegetables. He waters his vegetables every other day. His pump requires 0.5 liters of fuel per hour. In his household, he and his brothers plant and water vegetables, but his wife harvests and sells them. Mr Sarr has been trained by SAED, AFVP, UNICEF and Caritas. Mr Sarr has also worked with cage culture, and provided technical assistance to women’s groups in Mauritania. He is involved with several different credit schemes. He plans to build a second pond, and go into fingerling production. His only constraint so far has been lack of land to expand production. However, he has failed in his activities in the past when he tried to do things on a very big scale.

1. Government managed agricultural irrigation schemes (AHA) with elaborate pumping stations and large areas of irrigated land (over 10 000 ha in some schemes);
2. Village irrigation schemes (PIV) with pumping stations or small pumps on hand-leveled irrigated land (averaging 10–40 ha, but ranging up to 150 ha);
3. Private irrigation schemes (PIP) with small pumps and small (generally less than 20 ha) irrigated parcels;
4. Small-scale micro-dams;
5. Marshes, seasonal ponds and borrow pits (areas where dirt has been removed for road building, dam building and other construction projects);
6. Recessional floodplains (areas along the Senegal River banks which temporarily flood each year; these areas have decreased since dams were built regulating water flow from Mali, and their size changes each year, depending on rainfall);
7. Wells (sometimes with small electric pumps or treadle pumps).

Irrigation is a true government priority in Senegal. In the 1960s and 1970s, the government created infrastructure to irrigate over 145 400 ha of land to increase the production of cash crops (mostly rice, sugar cane and cotton). Water for irrigated land costs approximately CFAF35 000–60 000/ha/season (roughly equivalent to US$50–85), and large irrigated perimeters are found in almost every region of the country. Recently, the Ministry of Hydrology has actively supported the development of community level micro-dams and the improvement of traditional ponds and mares. In the past year, over 1 000 local ponds were improved using small amounts of government funds and local labour. There are over 3 000 natural ponds in Senegal, and 1 000 pumps on Lac de Guiers alone.

In addition to government activities GADEC, a local NGO in Tambacunda, has been working with Action Micro-Barrage (AMB), a NGO from Burkina Faso, to develop and promote submersible earthen dams, approximately 1.5 m tall. AMB developed a technology for 100% earthen dams, which originally took 3–4 years to build using local labour. Working with local communities, GADEC modified the technology using additional cement, less earth and local labour, to build dams in 2.5–3 months. These dams have proven to be more solid and require less maintenance than earlier models, and the construction timing fits better into the local seasonal calendar. The dams cost about 8 million CFAF to build. GADEC has also developed dams to be used in recessional flood plains, with submersible wells and dams. They have a team of trained technicians and villagers who promote the technology.
**Aquaculture systems**

In October 2000, the Government of Senegal established the Ministry of Fisheries, separating fisheries programmes and activities from the Water and Forest Management Ministry (Eaux et Forêts). In February 2001, the government nominated a minister to this newly created ministry, and the Department of Inland Fisheries and Aquaculture (the DPCA, which is a department within the Ministry of Fisheries) currently has 6–7 agents in the field, some of whom are former Eaux et Forêts staff. The priorities of the new ministry are to review and ratify a plan of action for fisheries, establish an office, create and pass a revised national fisheries management code, and integrate activities more closely with existing large scale irrigation systems.

Government fish stations are currently being privatized. The Richard Toll fingerling production station was sold to SECA International, and it is expected that the rest of the national fish stations will also be sold. However, the DPCA would like to create three regional training centers, one at Richard Toll and two others in different regions.

Very little aquaculture research has been done in Senegal. There are few qualified fisheries technicians, and all research data has been adapted from Bouaké, Cote d’Ivoire. All technical bulletins and technologies are also from either Bouaké or Niger. CAEP has two agents who have been trained by the government of Taiwan Province of China to identify opportunities and develop technologies for high value marine species for export. They are still in the early stages of evaluating the feasibility of such endeavors.

Government currently has a very limited extension capacity. Most extension duties are decentralized to rural communes, which organize Economic Interest Groups and Farmers Associations who are charged with accessing the technical competencies they need. However, some of the large irrigation schemes (SAED, SODAGRI) have extension staff.

As a result of all these factors (lack of research, lack of extension, recent reorganization), aquaculture has been effectively abandoned in Senegal. Despite projects and efforts funded by AFVP and USAID, extension agents were neither able nor motivated to continue aquaculture extension activities. Eaux et Forêts officers were more concerned with planting trees and enforcing national forest and water regulations and policies than with aquaculture extension. However, police functions (functions relating to the enforcement of national rules, regulations and policies) have been removed from the duties of field staff.

With the exception of the Casamance region, aquaculture is in an early stage of development in Senegal. In the past, high river production made raising fish in ponds less of a necessity. With the decrease in natural production, aquaculture has become increasingly important to the country, both for domestic consumption and as an important export commodity.

Many traditional fishing villages exist all along the Senegal/Mauritania border. However, natural fish production has declined, at least partly due to the installation of two large dams on the Senegal river and the regulation of seasonal flooding which previously nourished traditional fisheries resources.

In the Casamance region, farmers produce upland rice in the rainy season. Because the water is salty, they build fish ponds above their rice paddies to purify the water. Palm tree trunks serve as inlet pipes, and fish are trapped in the pond (no stocking occurs). Fish species include *Tilapia guineensis*, *Sarotherodon* spp., shrimp, mullet and crabs. Over the past three years, government research teams have tried to improve the system by stocking the ponds with 60–80 cm fish captured in the river and by improving pond construction techniques. Their goal is to increase production in these systems from 350 to 1 000 kg/ha/year. Fish are harvested using baskets and consumed locally. There are approximately 800 traditional fish ponds in 66 villages in the area, covering 800 ha (V. Ndiaye, Centre de recherche océano-graphique, personal communication).

Most existing fish ponds in Senegal require either pumping water in for stocking, or pumping water out for drainage. The cost of pumped water is a serious constraint to aquacultural development in the country, especially given the current price of fresh fish. However, if pumping costs can be shared among several crops (e.g., pumping for both rice and fish, or into fish ponds used as storage facilities for gardens) the activity could become more economically viable.

We visited a few fish farmers during our trip. The first farmers we visited used to work with Peace Corps volunteers in the early 1980s, and now work with Chinese Technical
Case Study: Subalo Women’s Group (Matam)

Aishata Sarr is the president of a group of women who cultivate a 0.25 ha plot in an irrigated perimeter in Jemel. Ms Sarr formed the group in 1987. Each month, group members pay CFAF100/person (they originally paid CFAF500/person but decided to decrease dues). This money is used to rent land and purchase inputs. There were originally 33 members in the group – now there are 130 members.

They originally received 12 ha of land from the government in Matam, in an old classified forest. However, they are not able to cultivate all of that land. SAED provided technical assistance for the irrigation scheme, and they dug the canals themselves. SAED also gave them a used pump, but it breaks down a lot. Last year it cost CFAF500 000 to repair it. The pump mechanic is the son of the group president, so he does not get paid for his work. However, he is given a parcel of land to cultivate, and free water. Some parcels are managed as a group, but members also have individual parcels they cultivate on their own.

The first year the group produced rice. They invested CFAF40 000 and earned CFAF100 000 (gross). In the cold season they produced onions and made another CFAF200 000. They put all their earnings in the bank, and continued to pay their monthly membership fees. They tried to buy and sell fish from Richard Toll, but they lost money and ended up owing the bank CFAF2 300 000, which they repaid through membership dues and their savings. They also dye cloth and buy and resell items to make money.

Problems they have encountered include lack of experience, and a truck driver who cheated them out of CFAF250 000 during the fish transport scheme. They also have problems with the quality of their irrigation canals. It takes 4 hours for water to reach some areas, and they have to fix their canals a lot. They often use all their savings to repair the pump. Currently, they are only able to cultivate for two seasons, but they would like to be able to use their plot all year. They tried to plant a living fence, but all the trees died due to lack of water. They are working with UNICEF to get fencing materials.

Before the construction of the Manantali dam, these women fished. They are from a fishing caste. They prefer capițain (Nile perch), then tilapias (#2) and catfish (#3). They know how to dry and process fish, and extract fish oil. They used to get 4–5 canoes filled with fish from nets. Entire communities used to come to this area to fish and work during the off-season; now they go elsewhere.

advisors from Richard Toll. They practiced pure aquaculture in a specially prepared pond, irrigated with pumped water from the Senegal River. The water is managed as part of a large-scale irrigation scheme planted with rice or tomatoes (see case study below).

The second site we visited was an area which had been renovated by the sugar company (CSS) in exchange for village land. Most of the land was planted with rice. A group of farmers working with Chinese technical advisors from Richard Toll had started renovating the site one month earlier. The advisors gave the group equipment to renovate the pond. The fish found by farmers in their rice fields are too small to eat, so they are thrown back into the river or given to children. People in this area do not like to eat small fish. Although they have never practiced aquaculture before and have only fished a few times in their lives, they expect to harvest 50 wheelbarrows of 400 g fish from their pond!

In Bakel we visited a series of classic fish ponds which had been developed with Peace Corps Volunteers as part of a USAID funded project. All of these ponds were empty, and are no longer used. Farmers mentioned problems with water pumps, predation and land tenure as the main reasons for abandoning the ponds. They also lacked technical assistance to continue the projects after Peace Corps Volunteers left the area.

One of the more interesting integrated aquaculture systems we saw were borrow pits in the Velingara/Anambé area. These ponds were formed when earth was removed to construct two large dams in the area, and the holes filled with rain water. These ponds hold water all year, and with Vietnamese technical assistance provided through the SPF they have been stocked with catfish and tilapia. The ponds are integrated with animal husbandry and gardening and provide drinking water for animals during the dry season. There are approximately 50 of these pits in the area. In one pond advisors reported harvesting 2 tonnes of fish, several times per year.

Cage culture had been attempted by AFVP in Matam but was not successful. Food (66%) and infrastructure costs (US$5 558) were high. The technology promoted was complex, involving the use of metal cages, thermometers, regular growth monitoring, sexing of fish, cement, and purchased feed (rice bran and groundnut meal) (Babacar Sarr, Matam; personal communication).
Farmers in the Tambacunda area mentioned that before, their river (a tributary of the Gambia River) did not dry up and they used to eat fish all the time. Nowadays there are no more fish in their area, and they have to follow the stream 15 km up to the confluence with the Gambia River to find fish. These farmers are very interested in developing aquaculture and integrating fishponds with their gardening irrigation system. They have a small micro-barrage and a pump irrigation system, and receive technical support from a local NGO (GADEC). They said they would be happy to get even small fish and would consume most of them locally. Although they used to dry fish, they don’t do this anymore because fish is in short supply. They were able to list about 13 different kinds of fish they used to find in the river.

**IIA systems**

**Existing IIA systems in Senegal**

1. Aquaculture in irrigation canals of large irrigated perimeters (Richard Toll/CSS);
2. Rice culture, aquaculture and gardening relay systems in large irrigated perimeters (Ndiareme/Dagana and Anambé/Velingara);
3. Traditional (unmanaged, unplanned) rice-fish culture in large irrigated perimeters;
4. Gardening, fruit tree production and aquaculture in fish ponds in private irrigation systems (Babacar Sarr/Matam); marshes/seasonal ponds (Moudéri/Bakel), micro-dams (Mboulémou/Tamba); and borrow pits (Anambé/Velingara);
5. Rice culture, aquaculture, gardening and animal husbandry in marshes/seasonal ponds (Kédougou/Marsh of Fadinga and Samakuta);
6. Aquaculture and animal husbandry in marshes/seasonal ponds (4 marshes in Richard Toll/Niari, Kounkan/Bakel);
7. Rice-fish culture in mangroves in Casamance (not visited).

**Potential IIA systems**

The easiest systems in which to integrate aquaculture are those where water is free. Seasonal ponds (*mares*), dams (*bac de stockage*) and rice paddies (where the water is paid for by the rice component) are some of the cheaper options for practicing and promoting aquaculture. Cage culture in rivers is another alternative which makes use of free water but would not promote the integration of aquaculture into existing irrigation systems. Aquaculture could also be practiced in water storage basins in large irrigated perimeters, but only if the water management schemes used by rice and vegetable growers allowed sufficient water to keep fish ponds productive. Fish culture cannot be promoted in the canals of these systems, since most of them dry out at various times throughout the season (with the exception of sugar cane systems).

**Semi-intensive rice-fish systems (large irrigation systems)**

Fish are already harvested in rice paddies in Senegal. However, they are harvested after only three months of growth and are not stocked in a regular manner. One possibility for improving traditional integration techniques would be to stock fish which could get to a marketable size in three months (i.e. 3–4 month old tilapia), or to harvest the fish with the rice and hold them in a holding tank or alternative pond until they reach marketable size. Farmers seemed generally less interested in modifying rice paddy construction to accommodate additional fish production. This could be due to costs associated with renovation, or land tenure issues in irrigated perimeters. However, farmers are willing to feed fish locally available, low-cost products and are interested in growing fish in their rice paddies if appropriate techniques are developed.

It should be noted that most rice in Senegal is direct seeded; few farmers transplant rice from nurseries. Water levels would not be adequate for fish production until several weeks after the ponds are planted with rice. Most paddies are planted in July and harvested in October. Although many people have tried rice-fish culture or had heard of it, noone was actively practicing it and many seemed skeptical about the potential for semi-intensive rice–fish production. However, rice-fish relay cropping was considered a potential alternative. Part of the problem may be the rice irrigation management system, in which fields are irrigated for a week only once (during the cold season) or twice (during the hot season), to a depth of less than 15 cm. Integration of aquaculture with vegetable production may be easier as vegetables often require more frequent watering. There seems to be a lot of
Aquaculture Case Study: Abdoulaye Djaie, Gaya

Mr Djaie started growing rice on a large irrigated perimeter in 1975. From 1979 to 1980, he and a group of three other men worked with Peace Corps volunteers and learned how to produce rice and fish. With the assistance of the Peace Corps volunteer, they modified their rice fields and from 1984 to 1989, they practiced rice-fish culture. They did not have any problems with the system, but after the Peace Corps Volunteer left, they did not receive any additional technical assistance, and in 1989 they ceased production because the irrigated perimeter was remodeled. After the fields were renewed in 1990, they did not practice fish culture until now. This year, the Chinese working at Richard Toll gave them fish to stock their pond, and rice bran and dried fish meal from Dakar. They manage the pond together. They think they stocked 5000 fish in their pond, which has a surface area of about 500 m². Their pond is about 1.5 m deep. They are the only people producing fish in their area. They stocked their ponds in August, and plan to harvest them in May.

Mr Djaie also produces rice (4 months) and tomatoes (4 months). He plants tomatoes in October, and harvests from March to May. He plants rice in November, and harvests in July and August. His daughters help him harvest the rice, but the fish is not much work, so he does that work alone. However, after the Chinese advisors measure his yield, his wife will sell his fish for him – he cannot write. He usually has 10–16 sacks of rice left after he repays his loans for his field. After expenses associated with traditional and religious holidays, there is not much left. He earns CFAF200 000–300 000 per season from tomatoes. Women plant potatoes, tomatoes, and onions in his area. The hungry season is June–October. May–July is a slow season for his family.

Mr Djaie doesn’t think he can rotate his rice fields with tomatoes because of weeds. However, he does think he may be able to rotate his rice fields with fish. He thinks his biggest problem will be food for the fish – he needs someone to teach him alternatives to rice bran and flour. He thinks there will be no problem selling the fish. It would cost CFAF40 000/hour to rent a tractor to redo the rice paddies to make them more amenable to fish production.

Concern about pesticide contamination in rice-fish ponds, but people are already eating fish which are grown in rice paddies.

Semi-intensive gardening-fish systems in private irrigation schemes

Private farmers are already paying for pumps to bring water several hundred meters from rivers to their private irrigation schemes. Some farmers believed it was possible to build fish ponds near the source of their irrigation water to hold water to irrigate their gardens. Pump maintenance would be the major problem, but pumping costs could be shared among multiple gardening activities, and most vegetable crops require frequent watering. Pond fertilization might also be a problem since the pond would essentially be a flow-through system. On the other hand, fertilized water would improve crop growth and less fertilizer might be required overall in the system. Soil characteristics, infiltration and drainage would need to be considered as well. The benefits of this system are that fish is produced at no extra production costs (except fish feed, which could be provided from garden waste), and water is individually rather than communally managed.

Extensive production systems around marshes/seasonal ponds, flood plains (rice, fish, animal husbandry and gardening)

Farmers already plant gardens around seasonal ponds (mares) or in recessional flood plains. These production systems could be improved with simple, low cost stocking techniques using locally available fish, and low cost management systems using resources available in the community. Some simple construction techniques could also help to improve water holding capacity, and overall productivity. The main drawbacks to this system are that seasonal ponds and floodplains are communally managed, and water is difficult to control. However, the system has been promoted by Vietnamese technicians associated with the SPFS, and appears to be working in some areas.

IIA opportunities

There are a number of reasons why IIA has considerable potential for development in Senegal.

Farmer interest

There is a lot of interest in fish in general and aquaculture in particular in Senegal. People eat a lot of fish, river production has
Irrigation Case Study: Samba Diene Diop, Dagana (PIP)

Samba owns 15 acres, which he purchased in 1994 from villagers where he lives. The land cost CFAF1 725 000. He owns a pump, which requires approximately 150–200 liters of fuel/ha/season (about 6 months) to operate. The pump cost CFAF2 900 000. His brother in Mauritania loaned him the money to buy the land and the pump. It cost CFAF30 000/hour to rent a machine to prepare irrigation parcels, so he prepared his land by hand. He plants eggplant, sweet potatoes, carrots, groundnuts, cabbage, sweet potatoes, onions and hot peppers in his field, and he cultivates all year long.

His gardens are located 1 km from the stream where he pumps water. He has some parcels of land closer to the stream which he believes would be better for fish production, and the water could be stocked there for use in gardens downstream.

Although he always has water in his canals, he does not have any overflow from the gardens which he could use to produce fish, because most of the water evaporates or seeps into the soil. He has found wild fish in his canals before, but they die because he only irrigates his gardens once per week or after 10 days (in the cold season).

He worked with a Japanese rice culture project, so he feels he has all the technical advice he needs for gardening. His main problems are lack of money for fertilizer, which costs CFAF9 800 per sack, whereas his eggplants sell for CFAF4 000 per sack. He is learning how to make compost and use organic fertilizers, but feels they take too long.

decreased, and the demand for fish for export has increased with concerns over mad cow disease and international health. All the farmers we met said they were willing to try aquaculture.

Government interest

There is also an interest on the part of the Senegalese government, which has just created a Ministry of Fisheries and a Department of Inland Fisheries and Aquaculture specifically to address diminished natural production and the need to diversify production and increase exports. The government also has given high priority to food security issues, and increasing irrigation capacity and integrating aquaculture into irrigation systems is one way to improve local food security.

Local knowledge

People have been fishing in Senegal as long as there have been people in Senegal. Although they are not aquaculturists by nature, certain ethnic groups in the country are fish masters and have great traditional knowledge about fish species, habits, reproduction, and processing techniques. However, they have never raised fish.

Availability of numerous indigenous fish species in the flood plains of the Senegal, Gambia, Casamance, Falemé and Anambé rivers

Farmers in Tambacunda were able to name 13 species of fish found in local streams. Although the team did not see any inventory data of Senegalese fish species, technicians and research staff felt there was a significant untapped potential to develop local fish species for aquaculture production.

Water resources and irrigation

Although water is a scarce resource in the Sahel and rainfall is erratic, there are significant water resources available in the country. There are huge rivers, important lakes and 3 000 seasonal ponds. The main problem is accessing and controlling it.

There are large irrigated perimeters in almost every region of the country, and there are over 200 000 ha of irrigated land. These perimeters have been in existence for over 20 years, and both technicians and farmers have been trained in their construction, management and use. Although farmers didn’t always practice the “best” irrigation techniques, they felt comfortable with their knowledge and their capacity to get additional technical assistance if required (generally from SAED or another agricultural company).
The devaluation of the CFA, and market opportunities

The devaluation of the CFA could make fish exported from the region more competitive and allow Senegal to break into European export markets currently dominated by Asia. There are already good local and regional markets for fish.

Special Programme for Food Security (SPFS), and the importance of crop diversification

Another opportunity is the existence of the SPFS team, supported by FAO and the Ministry of Agriculture. The Vietnamese technicians currently in the field are already promoting IIA, and have many of the technical competencies and experience necessary to develop, test and disseminate new IIA technologies. In addition, the traditional importance accorded by the Government of Senegal to crop diversification and its inclusion as a special objective of the SPFS further support the development of the aquaculture sector.

Decentralization

Current policies allowing the transfer of irrigation management responsibilities to beneficiaries, along with the adoption of participatory and gender-sensitive approaches to development should help foster a sense of responsibility in local communities, and ensure greater participation in development activities.

IIA constraints

The mission identified several constraints that may limit the development of IIA in Senegal many of which are also hindering general aquaculture development in the Sahel (see Miller, Chapter 5, this volume).

On the technical side, fingerling supplies are an issue since currently there are no improved fingerlings available, and transporting fingerlings from Richard Toll would be costly. However, fingerlings of local species can be caught in natural water bodies. Expenses also for other inputs including for improving land and costs associated with building and maintaining irrigation systems as well as for water access and use can be significant. Limited availability and competing uses make feeds costly. Potential negative effects of pesticides used to produce rice and vegetables on fish and animals in integrated systems have to be considered as well as predation, especially by snakes, cormorants, and king fishers. Marketability of small fish has to be considered in some areas. In general (with the exception of more isolated locations such as Bakel, Tambacunda, and Kédougou) the economic costs and benefits, the impact of remittances, and competition with more profitable enterprises have to be taken into account.

Institutionally, the capacity of staff to deal with aquaculture and IIA research and development, both in terms of numbers and knowledge, at the newly created Ministry of Fisheries is quite limited. There is also a lack of developed extension mechanisms (especially aquaculture and IIA extension). Importantly, there is a lack of coordination of aquaculture and irrigation research, training, technology development and extension as these are handled in different ministries.

On the environmental side high evaporation and soil infiltration rates were cited, which in combination with low rainfalls may lead to water shortages. This in turn may aggravate competition for water and trigger conflicts between agriculturalists and pastoralists. Other social and cultural constraints include land tenure, especially tenure in irrigated systems, access of women to irrigated land, and possibly the low level of literacy.

The general lack of participatory development approaches coupled with failures of previously introduced technologies is a serious constraint. After talking with many different farmers, the IIA team concluded that there are many examples of unsustainable approaches taken by past projects. Japanese technical advisors gave a women’s group a refrigerator to start buying and selling fish, but they had no previous experience with the activity and the costs of operating and using the refrigerator were more than the costs of using locally available ice. Chinese technicians are giving farmers tools and inputs in exchange for building fish ponds. The US Embassy built wells for farmers in exchange for planting trees. Vietnamese technicians offered credit for labor, feed and fertilizer for fish ponds. Even farmers working with the SPFS were given large quantities of fertilizer to grow improved rice. It is almost as if projects are paying people to do what they want them to do, rather than supporting farmers in what they are already doing.
Recommendations for the development of IIA in Senegal

IIA development in the Sahel should be seen in the context of the Africa Regional Aquaculture Review (FAO, 2000). Specifically for Senegal, and based on additional information from Miller (2000) as well as Sanni and Juanich (2001), there are significant opportunities for the integration of aquaculture and irrigation. The team recommends eight priority areas to the Department of Inland Fisheries and Aquaculture (DPCA) in Senegal emphasizing applied research and technology development, training, and information sharing:

1. Identification and training of DPCA personnel in aquaculture and integrated irrigation and aquaculture technologies (specifically low-cost, extensive systems);
2. Identification and inventory of potential sites for aquaculture and IIA development, and review of past lessons learned;
3. Feasibility studies of priority IIA sites and systems, and applied research involving national and international research institutions, private enterprise, farmers, NGOs and multiple government agencies;
4. Development of IIA extension packets for sites and systems identified and studied;
5. Harmonization and coordination of IIA interventions among national and local partners;
6. Identification and training of potential IIA partners, private enterprises, extension agents, farmer organizations and NGO staff;
7. Identification, demonstration and training of farmers’ organizations;
8. Association and collaboration with national, regional and international IIA organizations, institutions and partners.

Support should be provided by external organizations such as FAO to strengthen the capacity of the DPCA by supporting training activities for technical staff and research specialists, facilitating the exchange of information and applied research results between regional IIA programmes, and supporting opportunities for the exchange of information between research and farmers. In addition, IIA activities should be programmatically and systematically included in activities funded through the SPFS, and new partnerships should be formed between SPFS staff and local research organizations, the Ministry of Fisheries, and the many NGOs currently working on irrigation systems.

Proposed target zones and population

Senegal River Valley (rice-fish in large irrigated perimeters). In the Senegal River Valley, rice farmers should be targeted for the development of rice-fish systems. Specifically, farmers in Mbundum (around Dagana), Guédé and Nianga (around Podor) were recommended for rice-fish integration. Of all the districts along the Senegal River valley, Dagana has the most developed extension structures and large irrigation schemes. The population is very organized and agro-industrial companies are present to facilitate access to agricultural wastes and by-products. It is also an accessible region where it is easy to obtain land.

Failures of past projects, cost of pumping water from the river, and competition with other economic activities for inputs are some of the constraints to IIA development in the valley. However, inputs are available, large-scale irrigation systems and pumps are already installed, and extension agents and technical irrigation expertise are available. Traditional fishing communities and fishing casts should be targeted to develop fish processing and marketing.

Casamance (rice-fish in gravity fed systems). Farmers in the Casamance region are more familiar with aquaculture techniques than any other group in the country. They have already integrated aquaculture with rice production, and their traditional knowledge should be explored, documented and shared with other farmers. Additional benefits of IIA development in this region are that farmers do not have to pay for water (it is not pumped) and people eat fish of any size. However, the area has been plagued by political unrest for a number of years and transport to the region is considered dangerous. Most of the NGOs currently active in the area work through local intermediaries.

Another problem in the area is the high salt content of the water.

Kolda/Anamabe (integration of gardening with animal husbandry and fish in borrow pits and

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4 DPCA staff should obtain and summarize research results from past projects, including the USAID project which operated in Nianga/Podor.
above dams). This area has over 50 borrow pits created during construction of the Anambé dam, and the two huge lakes formed when the dams were created. These borrow pits and the areas above the dams should be targeted for low cost, extensive IIA activities, such as improved stocking and simple management techniques. Construction and engineering improvements should be avoided, and pumps should not be promoted.

Tambacunda/Kédougou (gardening-animal husbandry-rice-fish in seasonal ponds). Tambacunda and Kédougou are isolated areas. As a result, farmers have fewer income generating opportunities, and a lot of interest in aquaculture or any new production system. They have fewer developed irrigation systems, but more rain (up to 900 mm), and opportunities exist for IIA development in seasonal ponds and valleys. The area has a lower population density (6–7 inhabitants per km\(^2\)) and more natural resources than any other region of the country. Despite this potential, farmers in the region are also among the poorest in the country, and in greatest need of new technologies which could increase agricultural production and improve food security.

**Conclusions**

Senegal has all of the essential resources necessary to produce large quantities of fish. Land, water, labor, fingerlings, inputs and indigenous knowledge of inland and capture fisheries are available. However, there are opportunity costs associated with using each of these resources, and in many cases alternate uses of these inputs are more profitable than their use for aquaculture production alone. For example, land with year-round access to water and irrigated land can be used to produce cash crops such as vegetables, or subsistence crops like rice. Cash crops may generate several times more income per cubic meter of water than fish culture. The cost of pumping water for fish culture alone is not profitable, with the possible exception of high value aquaculture crops like oysters and shrimp. The price of fish in local markets is extraordinarily low, and the cost of imported feeds is extraordinarily high, which contributes to the lack of profitability of semi-intensive aquaculture systems in the country.

In areas which do not require water pumping, aquaculture may be more profitable, but water is not often available year-round in those sites (generally seasonal ponds and lakes). Moreover, these sites do not always allow complete drainage of ponds and often there are competing uses of water, including gardening and animal husbandry. These competing and generally more profitable uses of land and water require the development of innovative aquaculture systems which are not geared to the principal production of fish, but rather to incidental or secondary fish production. The development of fish production in short cycle systems, using locally available, low-cost techniques, which allows for the production of fish with minimal competition with other, more profitable exploitations is required. Integrating low-cost, extensive aquaculture into existing irrigation and production systems is an option.

Labor could be a constraint in areas with high emigration (in some villages in Senegal almost every household has a member living abroad sending remittances). Human capacity could also be a constraint in areas with extraordinarily low literacy and numeracy rates, and in populations with no experience in raising fish.

Finally, potential aquaculture inputs – rice bran, millet bran, peanut cake, fish meal – are currently used for animal husbandry activities, including sheep and goat fattening, horse and donkey rearing (the primary source of transport in many rural and semi-urban areas), and milk production. People in Senegal are primarily either fishermen (generally considered a low caste occupation) or practice animal husbandry as their principal occupation (if not their principal source of income, which is often remittances). These priorities and preoccupations of farmers need to be taken into consideration when identifying and developing aquaculture production systems and IIA technologies.

More research needs to be done on the profitable production of local fish species and on extensive aquaculture production systems. Competing uses of limited resources – especially water – needs to be taken into consideration, and aquaculture should be integrated into both local farming systems and irrigation systems. Intensive and semi-intensive aquaculture production systems which focus on the production of fish alone are not likely to succeed in Senegal. Applied research and training should be major priorities.

The development of integrated aquaculture systems in Senegal is not only possible but probable, given the consumption
of fish in the country, and the decrease in capture fisheries production. However, these systems will not follow traditional intensive aquaculture models, and will require significant ingenuity and innovation on the part of both farmers and technicians before aquaculture will evolve into a productive and profitable activity.

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INTEGRATED IRRIGATION-AQUACULTURE OPPORTUNITIES IN NIGERIA: THE SPECIAL PROGRAMME FOR FOOD SECURITY AND RICE-FISH FARMING IN NIGERIA

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Abstract

Fish farming started in Nigeria more than forty years ago, but aquaculture has never contributed substantially to domestic fish production. Poor agricultural extension services have neglected to point out the benefits to local farmers. The Nigerian government invested in more than 50 fish farms, including a few with feed mills, but most of those lie abandoned today. Nigeria now seeks import substitution with increased domestic production through aquaculture and agriculture-based fisheries. The Nigerian Special Programme for Food Security is launching 80 small (2.5 ha) irrigation schemes, which are to include integrated irrigation-aquaculture (IIA) demonstrations. Benefits of IIA include increased efficiency in water use and added value to agricultural by-products. An example, rice-fish trials in Niger State used a local swamp/lowland rice variety (FARO15) integrated with Nile tilapia (Oreochromis niloticus) over a four-month production period. The results indicate significant advantages in rice-fish farming, such as a ten percent increase in rice yield and more than 50 percent increase in revenue due to income from rice and fish. There are many small dysfunctional irrigation schemes from past projects scattered around the country. Communities in these areas desire to use these schemes, but the Government owns the land. Local farmers hesitate to invest in rehabilitation as they fear the Government may repossess the land. Clearly, development of the commercial aquaculture industry and inland fisheries remain the best solutions for increasing domestic fish production and meeting the large demand for fish.

Introduction

Integrated irrigation-aquaculture (IIA) is only beginning in Nigeria. With poor agricultural extension services in the country, there has been little effort at increasing public awareness for viable integration of agricultural activities, even though the benefits to rural farmers have been well documented during the past twenty years. Benefits of IIA include increased yield, improved water management with multiple-use of water, heightened synergies, increased revenues and poverty reduction. However, this situation is changing with the paradigm shift towards a private sector-driven economy. Projects are now in place to encourage integrated agriculture enterprises, offering hope for development of a more dynamic agriculture in Nigeria.

The Nigerian Special Programme for Food Security (NSPFS)

The four-year Aquaculture and Inland Fisheries Project (AIFP) has a budget of US$6.9 million, and is a component (called Annex II) of the NSPFS (US$45 million). The NSPFS is entirely funded by the Nigerian Government and has five annexes as follows:

- Annex I: Food Security: US$32 500 000 (includes sub-project 5);
- Annex II: Aquaculture and Inland Fisheries: US$6 900 000;
- Annex III: Animal Disease and Transboundary Pest Control: US$4 400 000;
- Annex IV: Marketing of Agricultural Commodities and Food Stock Management: US$1 200 000;
Annex I is the pivotal Food Security Project and includes smallholder irrigation, production and marketing of field crops and horticulture, livestock production, breeding and nutrition, aquaculture, farm mechanization and agro-processing. Integrated aquaculture is included as a diversification strategy to assist rural farmers to increase income and improve household food security.

Annex I was launched in 109 sites in all 36 States and the Federal Capital Territory (FCT) in January 2002, but Annex II was only launched in July 2003, corresponding with the release of funding. The NSPFS programme is also strengthened with assistance to be provided by a total of 524 Chinese technicians (including 70 in aquaculture) in the framework of the South-South Cooperation Programme ($US22 million). At the time of preparation of this paper (2003) twenty-nine Chinese are already in the country assisting farmers in rural areas and several are already working with private fish farmers. The remaining Chinese will arrive towards the end of the year.

More than 70 percent of Nigerians live in rural areas and over 65 percent of the labour force is occupied in the agricultural sector. Thus the programme's focus on expanding farm activities through integrated activities and increasing on-farm revenues can diversify livelihoods and improve rural economies in areas where poverty is heavily concentrated. The NSPFS Programme empowers communities and farmers through its "bottom-up" approach. Farmers benefit from "packages" of their own choosing and all activities are implemented on a cost recovery basis, with farmers repaying the cost of their package to the programme. The long-term perspective of this programme is to eliminate rural poverty.

Thus, the Government has marshalled significant efforts and financial support towards improving agricultural production through the NSPFS, with FAO designated to manage these efforts. As regards the AIFP, it is noteworthy that the Government has focused its efforts on private sector aquaculture development (see Appendix 1). Towards this end, the AIFP has been designated as the most appropriate vehicle for providing assistance to private fish farmers for increasing domestic fish production and creating a sustainable aquaculture industry. Aquaculture development is expected to take a similar path as that taken by the poultry industry, which today is completely privatised and successful in Nigeria.

Nigeria is also a participant signatory to the FAO 1999 African Aquaculture Review (FAO, 1999; see Appendix 2), which proposed a five-year framework for regional aquaculture development with targets including divestment of Government fish farms, most of which have been abandoned.

AIFP objectives and target group

Because the AIFP is to provide technical backstopping to Annex I in aquaculture, in effect, there are two target groups of fish farmers. While the target group for Annex I is the smallholder farmer practicing integrated agriculture, the Annex II target group are 50 private fish farmers whose principal agricultural enterprise is aquaculture. The AIFP seeks to address the complete value chain in aquaculture including inputs (fish seed and feed), support for farmer-driven professional groups, financing and marketing. Annex II also targets members of inland fishing communities to empower them in co-management of 43 small water bodies.

Need for increased domestic fish production

Fish farming was first started in Nigeria over forty years ago and yet aquaculture has never substantially contributed to the domestic fish production. Government at all levels (federal, state and some local Governments) invested in more than 50 fish farms, including a few with feed mills, but most lie abandoned today, never having contributed to solving the constraints facing the private fish farmers: fish seed and fish feeds. Nigerians are large fish consumers with a total consumption estimated at more than 1.3 million tonnes. National fish production is stagnating at some 450 000 tonnes, due to years of over-fishing and lack of management. Nigeria is one of the largest fish importers with some 800 000 tonnes annually contributing to a loss of jobs to overseas fishermen and a negative impact on the balance in trade. Nigeria now seeks import substitution with increased domestic production through aquaculture and culture-based fisheries-development, which can increase rural employment, improve food security and reduce rural poverty. This calls for a great increase in production of fish seed and aquaculture feeds in the country.

Present fish production from aquaculture is estimated at 25 000 tonnes, while fish production from largely unmanaged inland waters amounts to 150 000 tonnes. The
Table 1. Estimates of smallholder farmers cultivated area (000 ha) for rice farming in Nigeria, 2000 (PCU, 2001).

<table>
<thead>
<tr>
<th>State</th>
<th>Season dry (000 ha)</th>
<th>Season wet (000 ha)</th>
<th>Total (000 ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kaduna</td>
<td>230.00</td>
<td>230.00</td>
<td>230.00</td>
</tr>
<tr>
<td>Niger</td>
<td>205.42</td>
<td>200.00</td>
<td>205.42</td>
</tr>
<tr>
<td>Taraba</td>
<td>200.00</td>
<td>200.00</td>
<td>200.00</td>
</tr>
<tr>
<td>Benue</td>
<td>138.24</td>
<td>142.36</td>
<td>280.60</td>
</tr>
<tr>
<td>Borno</td>
<td>92.00</td>
<td>92.73</td>
<td>184.73</td>
</tr>
<tr>
<td>Kano</td>
<td>81.60</td>
<td>81.60</td>
<td>163.20</td>
</tr>
<tr>
<td>Adamawa</td>
<td>65.00</td>
<td>65.16</td>
<td>130.16</td>
</tr>
<tr>
<td>Ebonyi</td>
<td>45.46</td>
<td>46.16</td>
<td>91.62</td>
</tr>
<tr>
<td>Kogi</td>
<td>45.00</td>
<td>45.00</td>
<td>90.00</td>
</tr>
<tr>
<td>Nassarawa</td>
<td>45.00</td>
<td>45.00</td>
<td>90.00</td>
</tr>
<tr>
<td>Bayelsa</td>
<td>40.20</td>
<td>40.20</td>
<td>80.40</td>
</tr>
<tr>
<td>Ekiti</td>
<td>37.40</td>
<td>38.11</td>
<td>75.51</td>
</tr>
<tr>
<td>Gombe</td>
<td>38.00</td>
<td>38.00</td>
<td>76.00</td>
</tr>
<tr>
<td>Kebbi</td>
<td>32.20</td>
<td>32.39</td>
<td>64.59</td>
</tr>
<tr>
<td>Katsina</td>
<td>30.00</td>
<td>30.00</td>
<td>60.00</td>
</tr>
<tr>
<td>Yobe</td>
<td>30.00</td>
<td>30.00</td>
<td>60.00</td>
</tr>
<tr>
<td>Plateau</td>
<td>29.60</td>
<td>29.60</td>
<td>59.20</td>
</tr>
<tr>
<td>Kwara</td>
<td>29.00</td>
<td>29.00</td>
<td>58.00</td>
</tr>
<tr>
<td>Bauchi</td>
<td>22.43</td>
<td>22.43</td>
<td>44.86</td>
</tr>
<tr>
<td>Zamfara</td>
<td>22.10</td>
<td>22.10</td>
<td>44.20</td>
</tr>
<tr>
<td>Ondo</td>
<td>21.58</td>
<td>21.63</td>
<td>43.21</td>
</tr>
<tr>
<td>Jigawa</td>
<td>21.00</td>
<td>21.00</td>
<td>42.00</td>
</tr>
<tr>
<td>Sokoto</td>
<td>20.00</td>
<td>20.00</td>
<td>40.00</td>
</tr>
<tr>
<td>Anambra</td>
<td>12.48</td>
<td>12.48</td>
<td>24.96</td>
</tr>
<tr>
<td>Ogun</td>
<td>10.28</td>
<td>10.28</td>
<td>20.56</td>
</tr>
<tr>
<td>Enugu</td>
<td>10.00</td>
<td>10.00</td>
<td>20.00</td>
</tr>
<tr>
<td>Osun</td>
<td>9.00</td>
<td>9.00</td>
<td>18.00</td>
</tr>
<tr>
<td>Abia</td>
<td>8.42</td>
<td>8.42</td>
<td>16.84</td>
</tr>
<tr>
<td>Fct</td>
<td>6.42</td>
<td>6.42</td>
<td>12.84</td>
</tr>
<tr>
<td>Edo</td>
<td>5.00</td>
<td>5.14</td>
<td>10.14</td>
</tr>
<tr>
<td>Lagos</td>
<td>1.60</td>
<td>2.20</td>
<td>3.80</td>
</tr>
<tr>
<td>Delta</td>
<td>1.50</td>
<td>1.50</td>
<td>3.00</td>
</tr>
<tr>
<td>Oyo</td>
<td>0.70</td>
<td>0.70</td>
<td>1.40</td>
</tr>
<tr>
<td>Imo</td>
<td>0.06</td>
<td>0.35</td>
<td>0.41</td>
</tr>
<tr>
<td>Akwa Ibom</td>
<td>0.12</td>
<td>0.12</td>
<td>0.24</td>
</tr>
<tr>
<td>Cross River</td>
<td>0.10</td>
<td>0.10</td>
<td>0.20</td>
</tr>
<tr>
<td>Total</td>
<td>7.94</td>
<td>1586.90</td>
<td>1594.84</td>
</tr>
</tbody>
</table>

Potential for increased production in both areas is great as Nigeria is blessed with more than 12 million ha of inland waters and suitable soils for aquaculture development. In recent years, more investors have been entering catfish farming. There exists a large unmet demand for catfish and market prices are more than double those of other species. Additionally, a number of highly intensive recirculating, closed aquaculture systems have been developed in the country with European technical assistance. Currently these catfish farms and other large catfish farmers are importing some 40,000 tonnes of high quality fish feed from Europe. In a recent study, the World Bank’s International Finance Corporation (IFC) predicted catfish production to increase by 40,000 tonnes over the next four years (Irene Arias, personal communication, 2003). Other indicators support this appraisal as two feed companies are launching fish feed production facilities.

Integrated aquaculture in Nigeria

The National Institute for Freshwater Fisheries Research conducted a National Aquaculture Diagnostic Survey and noted that 48 percent of all the fish farms evaluated practiced integrated agriculture (Ayeni, 1995). Fishponds are integrated with poultry, pigs, rabbits, sheep, goats, and cattle as well as with rice, plantains and bananas, fruit trees, vegetable crops, etc. Poultry was the most popular integration as 50 percent of the fishponds were associated with chicken farming. This was followed by sheep/goats/cattle at 38 percent, while pigs were integrated with 14 percent of the ponds surveyed. Rice farming was observed to be the least integrated with fish farming at only 1.6 percent.

Since 1995, integration of fishponds with poultry, pigs and livestock has become more popular and this includes many of the 1,940 fish farms in the country (AIFP, 2003). Although clear information is not available, rice-fish farming is also on the increase. In fact the Government is excited about using IIA to extend rice-fish farming throughout the country to increase both rice and fish production. Other benefits of IIA include increased efficiency of water use and added value to agricultural by-products used as nutrient inputs. This translates into reduced pressure on natural resources and the environment. Clearly, development of the commercial aquaculture industry and inland fisheries remain the best solutions for increasing domestic fish production and meeting the large demand for fish.

IIA can be developed through use of the numerous irrigation schemes in the country. Nigeria has 99 irrigation schemes located in 26 States with a total area of 47,000 ha. Opportunities could arise for IIA to be included in these schemes. The estimated potential for
irrigated lands in Nigeria is up to 868,000 ha, offering much potential for private investors in agriculture.

Currently, the NSPFS Programme is launching 80 small (2.5 ha) irrigation schemes which are to include IIA demonstrations. At those sites having suitable clay soils, fishponds will be built within the irrigation system to demonstrate multiple water use and synergies encouraging increased production. This is a significant commitment on the part of NSPFS, which can greatly encourage aquaculture development in Nigeria. Ezenwa (1991) identified over 1.5 million ha of swamp areas in the Niger Delta, and many more hectares of large areas for rice farming in Anambra, Imo, Benue, Plateau, Niger and Cross River States. He predicts bright prospects for rice-fish farming.

**Rice farming in Nigeria**

Rice is a major staple and the most popular cereal crop consumed in Nigeria with a demand estimated at 5 million tonnes. Domestic production is placed at only 3.2 million tonnes, resulting in a 1.8 million tonnes deficit, which is met by imports. In spite of various policies put in place – including the goal of self-sufficiency in rice production by 2005 – domestic production has not increased significantly to meet the ever-increasing demand. Nevertheless, of all the crops in Nigeria, rice is the most commercialized.

The potential land area that could be put under rice production is estimated at about 4–6 million hectares, but out of this only some 2 million ha (40 percent) are currently cultivated. This includes some 250,000 ha of irrigated rice and about 1,600,000 ha of lowland rice grown in swampy areas that periodically flood. The seven states of Kaduna, Taraba, Niger, Benue, Borno, Kano and Adamawa make up half the area in rice cultivation in the country. Thirteen other states with large areas of rice cultivation include Kogi, Nassarawa, Bayelsa, Ekiti, Gombe, Yobe, Katsina, Kebbi, Kwara, Ondo, Bauchi, Zamfara, and Sokoto. Rice production in all states is presented in Table 1.

Rice is one of the few crops grown nationwide including all agro-ecological zones from the Sahel to the coastal swamps. The major rice production systems in Nigeria include rainfed upland rice (30%), rainfed lowland rice (47%) and irrigated lowland rice (16%). Less common is the deepwater rice production which amounts to some five percent of the total.

The majority of rice producers are small-scale farmers who grow different varieties on less than 0.5 ha of land, and produce less than a tonne of paddy in any given season. Still, average rice production is estimated at 2.1 tonnes/ha/year. Traditional farming methods fraught with drudgery due to lack of mechanization are used, making Nigerian rice production more costly on a per hectare basis in comparison with neighbouring countries due to lack of best management practices. In lowland areas, farmers depend on annual flooding that is virtually impossible to control and does not allow for efficient use of fertilizer application.

**Rice-fish farming in Nigeria**

At present, rice-fish farming is primarily “captural” in practice whereby wild fish that enter the flooded rice fields from irrigation canals and streams are trapped in the fields, and allowed to grow along with the rice. When the rice is harvested, fish are captured for consumption or sales. Visits with rice farmers in Adim, in Cross River State, revealed up to 92 kg of fish were harvested per ha of rice under such conditions (NSPFS, 2003). Most fish harvested in such conditions are catfish (Clarias or Heterobranchus species), which are much sought after by consumers who pay 300 Naira or more per kilogram (1.00 US$ = 126 Naira; 1993 official exchange rate). Tilapia and other species sell for only one third to one half this amount. It is obvious that the sale of fish caught in rice paddies contributes significantly to farmer’s incomes as 92 kg of mostly catfish could have a market value of 25,000 Naira (US$190) or more. In considering an average rice production of 2.1 tonnes per ha with a value of US$777 (US$370 per tonne), income from wild fish adds more than 20 percent to the value of the rice to the farmer’s revenues.

On-farm adaptive research trials (OFAR) in rice-fish farming have been undertaken with favourable results in Lagos, Niger and Imo States as well as in the Federal Capital Territory (FCT) near Abuja through the Agricultural Development Programme (ADP) extension staff. Rice-fish trials in Niger State used a local swamp/lowland rice variety (FARO15) integrated with the tilapia Oreochromis niloticus over a four-month production period. Results were compared with a non-integrated rice field of the same area as the integrated field. The results indicate significant advantage in rice-
Table 2. Comparison of rice farming with rice-fish farming in Niger State (Yaro, 2001).

<table>
<thead>
<tr>
<th>Comparison Parameter</th>
<th>Rice</th>
<th>Rice-fish</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice production (kg/ha/yr)</td>
<td>3 051</td>
<td>3 357</td>
</tr>
<tr>
<td>Fish production (kg/ha/yr)</td>
<td>0</td>
<td>690</td>
</tr>
<tr>
<td>Gross revenues (Naira/ha)</td>
<td>45 200</td>
<td>59 955</td>
</tr>
<tr>
<td>Net revenues (Naira)</td>
<td>14 874</td>
<td>22 962</td>
</tr>
<tr>
<td>Benefits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Increased rice yield (%)</td>
<td></td>
<td>+10</td>
</tr>
<tr>
<td>- Increased revenues due to fish (%)</td>
<td></td>
<td>+54</td>
</tr>
</tbody>
</table>

fish farming (Table 2). Results could actually be more interesting if catfish were included as they sell for a higher price.

This technology was extended to twenty rice farmers in Lagos State using the Small Plot Adoption Technique (SPAT). Results from these trials showed an average of 18.7 percent increase in rice yield in the rice-fish plots over the sole rice plots (Kogbe et al., 2000). Other encouraging findings were obtained in rice-fish trials in Niger State, Abuja FCT, Borno State and Gombe State. These were conducted in 18 experimental plots at the National Cereals Research Institute (NCRI) Rice Experimental Farm, Badeggi (Niger State), at Iddo and Gwagalada Farms of Abuja ADP in the FCT and at the Dadin-Kowa (Gombe State) outstation of NIFGR. These experiments evaluated sole tilapia (O. niloticus), sole catfish (C. gariepinus), sole common carp (Cyprinus carpio) and mixed tilapia and Clarias systems using improved FAR08, 15 and 37 rice varieties. The growth performance of the fish species and rice yields were considered to be encouraging.

The NSPFPS is making efforts to sensitize and create awareness of the rice-fish culture technology through farmer participatory demonstrations. These are directed to convince farmers of the technical and economic viability of rice-fish farming in lowland/swampy areas, fadamas (floodplains) and irrigation schemes. So far, on-going demonstration plots have been established in Ondo State at Ogbese with two 0.5 ha and four 0.25 ha plots in each location. In Abia State four other plots have been installed at Okafia, Amiyi, Umuobasi-ukwu and Ogbono-Ozuitem.

A past World Bank assisted project supported rice-fish trials under the National Agricultural Research Project (NARP) for rice-fish research by the School of Agriculture, Federal University of Technology in Minna, Niger State (Gomna et al., 2000; Yaro and Lamai, 2000).

Looking to the future

Development of rice-fish farming in Nigeria can be greatly facilitated through use of the irrigation schemes in the country. Several large schemes are operating in the North and fish farming could be integrated within these large farms. Additionally, there are many dysfunctional small irrigation schemes, originally set up by World Bank and other development projects, scattered around the country. Communities in these areas desire to use these schemes but hesitate to invest in their rehabilitation because they fear repossession of the Government-owned land. Thus ownership is a problem which can best be solved by a clear transfer of such lands to the communities through a privatization plan. Until this occurs, these largely abandoned Government irrigation schemes will remain unproductive.

A big boost to IIA regional development could occur with a framework for “on-farm adaptive research” across the region. Protocols for this need to be established and agreed among participating countries, supported by sharing of information through an online IIA network. Neither rice farming nor fish farming are traditional practices in Nigeria and water management in general is often inadequate. Much needs to be learned from others regarding successful approaches and opportunities developed elsewhere.

In Nigeria we are excited about the many challenges and opportunities that lie ahead for IIA to create rural employment and increase on farm production and revenues.
References


Appendix 1

Introduction
The project is designed to increase the output of the country’s inland freshwater resources. It will provide technical assistance to fish farmers and farmers living around the country’s reservoirs and dams to provide them with technologies for increasing fish production, leading to improved food security. The project will start by quantifying and qualifying the country’s surface water resources while initiating an immediate programme of stocking under-utilised reservoirs and training neighbouring communities in improved management techniques. The project will also establish a favourable environment for the development of fisheries support services (i.e., seed and feed suppliers) as well as facilitate credit for project beneficiaries. At the end of the project, a sample of 43 dams and reservoirs will be under improved management resulting in at least a 50 percent increase in output. There will also be a core of 50 small-medium scale commercial fish farms producing ten times more than the current national average aquacultural production. The project will also assist with capacity building for the Federal Department of Fisheries and its sister institutions, providing formal and on-the-job training.

Benefits
1. Increased job opportunities in rural areas
2. Food security and poverty alleviation
3. Reduction in rural-urban drift
4. Better use of Nigeria’s water and other natural resources
5. Popularisation of aquaculture and culture-based fisheries as vehicles for improved domestic fish production
6. Increased availability of fish, especially in those areas not having ready access to current supplies
7. Capacity building at the Federal, State and local levels

Development Objective
Improved freshwater fish production and food security through increased aquacultural output including greater harvests from fish farms and culture-based fisheries.

Immediate Objectives
1. To quantify and evaluate the country’s fish farms, hatcheries and other aquatic resources with fish production potential and develop a monitoring system
2. To optimise the output from the country’s dams, reservoirs and lakes through the adoption of improved culture-based fishery techniques
3. To establish a core of small-/medium-scale commercial fish farms complete with necessary private sector support services including hatcheries and feed mills

Outputs
1. Comprehensive inventory of the country’s aquatic resources indicating high priority areas for development
2. Information compiled for inventory available in an interactive database
3. Six pilot dams stocked and communities trained in post-stocking management
4. Detailed description of the country’s dams, reservoirs and lakes including present situation and potential
5. Methodologies for enhanced management of, and production from, these resources
6. Thirty-seven dams or reservoirs having improved harvests through adoption of recommended management methodologies
7. Methodologies for economically viable small-/medium-scale commercial fish farming
8. Functioning private sector support services including hatcheries and feed mills
9. Credit available for small-/medium-scale fish farmers and support services
10. A self-sufficient core of 50 small-/medium-scale commercial fish farms actively supporting NAFFA, FISON and similar producer support groups

Direct Beneficiaries: 93 sites and 1 350 families
Indirect beneficiaries: 1 770 communities and 53 100 families
Staff time: 73 person years
Project period: 4.25 years
Project budget: US$6,989,615
Appendix 2

<table>
<thead>
<tr>
<th>Immediately</th>
<th>Within 1 Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Initiate reduction of number of government stations</td>
<td>- Evaluate national training needs and capacity at all levels</td>
</tr>
<tr>
<td>- Focus effort on selected areas</td>
<td>- Incorporate social, cultural and economic aspects into research agendas</td>
</tr>
<tr>
<td>- Promote Farmers’ Associations</td>
<td>- Establish national information network</td>
</tr>
<tr>
<td>- Promote farmer-to-farmer communication</td>
<td>- Initiate national research programme on brood stock management</td>
</tr>
<tr>
<td>- Focus on limited number of culture organisms</td>
<td>- Establish national research programme on brood stock management</td>
</tr>
<tr>
<td>- Focus on locally available inputs and existing technology</td>
<td>- Establish national information network</td>
</tr>
<tr>
<td>- Improve national coordination</td>
<td>- Organize a regional feasibility study on credit for large-scale enterprises</td>
</tr>
<tr>
<td>- Develop demand-driven research agendas through improved linkages with development</td>
<td>- Organize annual meeting of African Aquaculture Group together with FAO</td>
</tr>
<tr>
<td>- Increase involvement of universities</td>
<td></td>
</tr>
<tr>
<td>- Establish informal exchanges</td>
<td></td>
</tr>
<tr>
<td>- Increase use of Farmers’ Associations for collecting statistics</td>
<td></td>
</tr>
</tbody>
</table>

| Within 2 Years                                                                 |
|----------------------------------------------------------------------------|--------------------------------------------------------------------------------|
| - Establish aquaculture development policy including privatisation of fingerling | - Establish aquaculture development policy including privatisation of fingerling |
| - Production, focused extension and participatory approach                 | - Establish aquaculture development policy including privatisation of fingerling |
| - Create national Aquaculture Advisory Committee                           | - Establish national Aquaculture Advisory Committee                           |
| - Select and retain stations for research and training (government funding) | - Select and retain stations for research and training (government funding)   |
| - Establish national brood stock management programme                      | - Establish national brood stock management programme                          |
| - Initiate regional research programme on brood stock management           | - Initiate regional research programme on brood stock management              |
| - Develop socio-economic indicators of impact                              | - Develop socio-economic indicators of impact                                |
| - Promote private sector involvement and better management through long-term lease. | - Promote private sector involvement and better management through long-term lease. |
| - Organize regional specialized training courses for commercial entrepreneurs | - Organize regional specialized training courses for commercial entrepreneurs |
| - Privatise seed supply for medium-to large-scale enterprises              | - Privatise seed supply for medium-to large-scale enterprises                |
| - Initiate national and regional research programmes on formulated feed quality, involving government and private sector | - Initiate national and regional research programmes on formulated feed quality, involving government and private sector |

| Within 3 Years                                                                 |
|----------------------------------------------------------------------------|--------------------------------------------------------------------------------|
| - Evaluate training regional needs and capacities (centres of excellence)  | - Evaluate training regional needs and capacities (centres of excellence)      |
| - Establish regional information network                                     | - Establish regional information network                                       |
| - Revise and improve statistics collection                                   | - Revise and improve statistics collection                                    |

| Within 5 Years                                                                 |
|----------------------------------------------------------------------------|--------------------------------------------------------------------------------|
| - Elaborate national Aquaculture Development Plan                           | - Elaborate national Aquaculture Development Plan                           |
| - Reduce by at least 50 percent the actual number of government stations    | - Revise extension structure                                                 |
| - Improve understanding/knowledge of traditional systems and their potential for enhancement | - Improve understanding/knowledge of traditional systems and their potential for enhancement |
| - Develop national or intra-regional practical training for farmers, extensionists, administrators and decision-makers | - Develop national or intra-regional practical training for farmers, extensionists, administrators and decision-makers |
| - Establish regional specialized research network (centres of excellence)   | - Establish regional specialized research network (centres of excellence)     |
| - Establish national database                                               | - Establish national database                                                |
Abstract

The Central Western Fish Culture Project (Projet piscicole Centre Ouest, or PPCO, in French) was developed between 1992 and 1995, and implemented in 20 villages in Côte d’Ivoire in 1996. In 2001, a network of more than 420 fish farmers produced 170 tonnes of fish per year, from 160 ha of water. The project was assisted by two NGOs, APDRA-CI and APDRA-F (Association pisciculture et développement rural en Afrique tropicale humide–Côte d’Ivoire and France). The project was based on an extensive technology with fish yields between 0.5 and 2 tonnes/ha/yr, combined with extension and training through farmer field schools and participatory research and monitoring. The PPCO was extended to other parts of Côte d’Ivoire and other aquaculture projects were initiated in the forest region of Guinea and in Cameroon. The aquaculture development approach provides opportunities for integration with agricultural activities and produces synergies in terms of water and labour utilization.

Introduction: brief history of the creation of APDRA

In sub-Saharan Africa in the early 1990s, daily household consumption of animal protein continued to decrease, and was primarily composed of marine fish which was expensive and overexploited. Faced with such a situation, farmers appeared very motivated by aquaculture programmes which allowed them to decrease one of their principal food costs and to diversify their activities. In Côte d’Ivoire, as in numerous other countries, aquaculture development among farmers in rural areas was constrained by poorly performing technical models. In 1992, the Central Western Fish Farming Project (in French Projet piscicole Centre Ouest or PPCO) was launched (with funding from the French Cooperation and CCFD, Catholic Committee against Hunger and for Development, or Comité Catholique contre la Faim et pour le Développement, a French NGO), with the following objectives:

- The development of peri-urban fish farming;
- The development of an appropriate fish farming model for rural areas.

The latter was developed between 1992 and 1995, and implemented in twenty or so Ivorian villages from 1996. In 2001, a network of more than 420 fish farmers produced 170 tonnes of fish per year from 160 ha of ponds. During the implementation of PPCO, two non-governmental organizations (NGOs) were created to assist rural fish farming development, including:

- APDRA-CI (Association Pisciculture - Rural Development in Tropical Humid Africa – Côte d’Ivoire, or in French Association pisciculture - développement rural en Afrique tropicale humide – Côte d’Ivoire), an Ivorian NGO composed of fish farmers and created in 1994 to extend and adapt the results of PPCO to the entire country;
- APDRA-F (Association Pisciculture - Rural Development in Tropical Humid Africa – France, or in French Association pisciculture - développement rural en Afrique tropicale humide – France), an international association created in 1996 to develop and extend the experiences of PPCO throughout tropical humid Africa. APDRA-F is composed of technically qualified fish culture experts, agronomists, and agricultural development specialists and works in partnership with the French Association of Volunteers of Progress (Association française des volontaires du progrès; AFVP).
The “rural development fish-farming model”

Technical model

To address input and supply problems (lack of fingerlings, fish feed, etc.) which often limit intensive fish farming, APDRA based their programme on farms located in valley bottoms or low-lying areas (bas-fonds) which are seasonally flooded. They developed an extensive, profitable model, where fish production satisfied consumer needs. They promoted completely drainable barrage ponds that were supported by service ponds. With an average surface area of 0.3 ha, these barrage ponds permitted harvests ranging from 0.5 to more than 2 tonnes/ha/yr, depending on water management and fertilization.

The culture system was based on the polyculture of tilapia (*Oreochromis niloticus*) and *Heterotis niloticus*. In addition, many wild catfish existed in many bas-fonds, mostly *Clarias anguillaris* and *Heterobranchus isopterus*. In Côte d’Ivoire, Chinese carp (*Ctenopharyngodon idella*) was sometimes also cultured. Population densities were adjusted depending on the fertility of the area, and a carnivorous fish (generally *Hemichromis fasciatus*) was added to regulate tilapia populations which are quite prolific.

Social dimensions of the programme

All of the fish farmers benefited from extension, training and site-specific advice. Neither investment nor production costs were subsidized. However, farmers were given the opportunity to be trained in fish farming. Such approach ensured the sustainability of production by creating an environment conducive to exchanges of fish, by facilitating access to specialty services, etc. Within a range of 1–2 kilometers, fish farmers had to commit themselves and to succeed to develop a sustainable professional local environment that permitted them to practice economically viable fish farming and to overcome its main constraints.

Monitoring and orientation of actions

Evaluation

Farmers were given choices in the selection of production techniques and inputs. Evaluation was therefore based on a farming systems approach (an assessment of agricultural dynamics and a socio-economic comparison of production units), and on innovative anthropology tools (taking into consideration the interests of stakeholders in the intervention, the networks in which fish farmers operate, and the processes of transmission-adaptation of knowledge). Evaluation was also based on the historical reactions of fish farmers vis-a-vis the actions proposed.

Development research

Whenever a new constraint was identified, all scientific means available to the operator or to his or her partners were a priori useful to develop solutions. The selection of identified practices to mitigate constraints was left to the fish farmers: they participated in dimensioning the experiments and in the full-scale tests, before choosing the techniques that were to be adopted by the operators.

Main activities for the rural development of fish farming

The reference point for activities in tropical humid Africa remains the development dynamic initiated in the central western region of Côte d’Ivoire, which is still monitored by APDRA-CI and supported by APDRA-F, despite the end of the main sources of financing (suspension of the PPCO follow-up as a result of the political troubles in Côte d’Ivoire). A new 3-year agreement for support to the organization and professional training is being developed with CCFD and MAE (Ministry of Foreign Affairs, or Ministère des Affaires Etrangères).

Other interventions in Côte d’Ivoire

- Expansion of PPCO to the South West of Côte d’Ivoire, implemented by APDRA-CI from 1996 to 2000, essentially with funds from the Region Centre (France), negotiated by APDRA-F;
- Pilot project in the Central East region, financed by the forest exploitation company IMPROBOIS from 1999 to 2002. The Central East region presents more difficult conditions (a longer dry season and soil less favorable for the construction of fish ponds), which have required an adaptation of the management techniques and culture systems.
Fish farming project in the forest region of Guinea

APDRA-F, in partnership with AFVP, has implemented the Fish Farming Project in the Forest Region of Guinea (*le Projet piscicole de Guinée Forestière;* PPGF). Since 1999, in a region that has had practically no fish farming interventions, PPGF has been able to show that the establishment of rural fish farming using the proposed model was possible and sustainable. The dynamics of the programme are still new, but their importance indicates a great potential for their development and a great innovation capacity of the farmers for such a complex activity.

**Increasing target zones and coverage**

- Cameroon: contacts made with different partners, and agreements obtained to begin working on the reproduction of common carp (*Cyprinus carpio*);
- Madagascar: brainstorming in process to support increased professionalism, the transfer of knowledge, and innovation processes;
- Negotiations underway in Ghana, Burundi, Benin and Angola.

**IIA initiated in the APDRA network**

Unlike other models, the type of fish farming proposed by APDRA-F constitutes an important reorientation of the production system, and sets in motion a process of innovation which involves substantive modifications to production systems. *Barrage* ponds facilitate increased water management, which permits farmers to transform their current production systems in valley bottoms and to develop, through integration with the production of fish, other activities such as rice culture, gardening or animal husbandry.

Thus, in Côte d’Ivoire, the fact that numerous valley bottoms normally dry up during half of the year transforms barrage ponds into water storage devices, which makes them a capital resource for agricultural activities. The recent availability of this new production factor allows the development, throughout the year, of diversified activities which were unimaginable without them.

In the Forest Region of Guinea, the cultural calendar in valley bottoms is not changed and remains dependent upon the rainy season. On the other hand, the practice of irrigated rice culture in the *barrage* ponds frees up a considerable amount of time for the fish farmer (no clearing, no deep ploughing, no weeding) which can be reinvested in other activities. Such activities thus benefit from water availability, from spatial

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**Table: Actual Operations**

<table>
<thead>
<tr>
<th>Country</th>
<th>HQ APDRA-F</th>
<th>HQ APDRA-CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>France</td>
<td>- 1 director</td>
<td>- 1 coordinator</td>
</tr>
<tr>
<td></td>
<td>- 1 secretary</td>
<td>- 1 trainer</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- 1 technician</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- 1 extension agent</td>
</tr>
<tr>
<td>République de Guinée</td>
<td><strong>PPGF</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 coordinator</td>
<td></td>
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<tr>
<td></td>
<td>1 technician</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 extension agent</td>
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<tr>
<td>Other Countries</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Côte d’Ivoire</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 1. Structure and mode of operation of APDRA.**
complementarity and from the geographic proximity of the various types of production. While developed voluntarily by fish farmers, without incentives from operators, these types of IIA are the object of close monitoring (yield and output studies, technical studies, research for new varieties adapted to IIA conditions, etc.) designed to support fish farmers in their progress.

**APDRA-F: Institutional description**

APDRA-F is an association of international solidarity which intervenes at the following levels:

- The definition of sectoral policies: diagrams and organizational charts, feasibility studies, and the identification and design of projects;
- The implementation and monitoring of operations: coordination of projects, assistance and advice to operators and implementers, support to professional organizations;
- Training and information: high-level staff training sessions, training of managers of professional organizations and students, organization of round tables, workshops, and support for specialized networks;
- Development research: on-farm and on-station trials, development of research protocols, management of the interface between researchers and producers, cross-sectional studies.

Partnership agreements exist with AFVP, CCFD and other French or European organizations (Water Agency, MAE, FLAC de Lorraine, schools, etc.). The principal financial partners are AFD, CCFD, MAE, the Water Agency (Agence de l’Eau), Regions of France (Île de France, Lorraine, Région Centre), some private companies, etc. The budget in 2003 was approximately 350,000 euros.
INTEGRATED POND AQUACULTURE IN LAKE VICTORIA WETLANDS

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Department of Environmental Resources
UNESCO-IHE Institute for Water Education
Delft, The Netherlands


Abstract

Wetlands are important for the livelihoods of millions of people. They provide food and income, support biodiversity and form a hydrological and ecological buffer between upland areas and water bodies. Population growth and the associated environmental degradation exert increasing pressure on wetlands. An example is the Lake Victoria region in East Africa, where human population growth, introduction of exotic fish species, overfishing and eutrophication have led to a deterioration of the wetland resources. For the riparian communities, this means a threat to their livelihoods as they depend on the wetland for food and income from fishing, seasonal agriculture and harvesting of wetland products. There is a need for integrated food production and waste processing technologies that enable communities to secure their livelihood without endangering the integrity of the natural resources. One such technology is integrated wetland pond aquaculture, or "fingerponds". Ponds are dug from the landward edge of wetlands and extend like fingers into the swamp (hence the term "fingerponds"). Soil from the ponds is heaped between the ponds to form raised beds for crop cultivation. The ponds are stocked with fish through natural flooding in the rainy season. As the waters recede, the trapped fish are cultured using manure, crop and household wastes to fertilize the ponds and feed the fish. UNESCO-IHE and partners in Tanzania, Uganda, Kenya, Czech Republic and UK are currently involved in an EU-funded project to investigate the feasibility of this technology. Research focuses on the technical aspects, and on the socio-economic and environmental impacts of this technology. Also, options for integrating fingerponds with other wetland technology, such as the use of natural or constructed wetlands for wastewater treatment, need to be evaluated. Initial results of the research from Kenya and Uganda show that flooding can yield enough fish for stocking the ponds and that manuring of the ponds can increase their productivity.

Introduction

Wetlands are important for the livelihoods of millions of people. They provide food and income, support biodiversity and form a hydrological and ecological buffer between upland areas and water bodies. A definition given by the Ramsar Convention states that wetlands are "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres". In addition, wetlands "may incorporate riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than six metres at low tide lying within the wetlands". This includes habitat types like rivers and lakes, coastal lagoons, mangroves, peatlands, and coral reefs, and also human-made wetlands such as fish and shrimp ponds, farm ponds, irrigated agricultural land (including ricefields), salt pans, reservoirs, gravel pits, sewage farms, and canals (Ramsar Info Pack, http://www.ramsar.org/index_about_ramsar.htm).

Population growth and the associated environmental degradation exert increasing pressure on wetlands. An example is the Lake Victoria basin in East Africa with approximately 30 million people, where human population growth, introduction of exotic fish species, overfishing and increasing waste discharges (leading to eutrophication) have led to a deterioration of the wetland resources. For the riparian communities, this means a threat to their livelihoods as they depend on the wetland for food and income from fishing, seasonal agriculture and harvesting of wetland products. There is a need for integrated food production
and waste processing technologies that enable communities to secure their livelihoods without endangering the integrity of the natural resources (Salafsky and Wollenberg, 2000).

In this paper, one technology which may contribute to sustainable wetland management is highlighted. This technology is integrated wetland pond aquaculture, or "fingerponds". We explain the concept of fingerponds, and describe the current research efforts of UNESCO-IHE and its partners, together with some preliminary results from the first year of research (mainly 2002). The potential for further development and priority research issues are also discussed.

Fingerpond concept

Fingerponds are ponds dug from the landward edge of wetlands that extend like fingers into the swamp (hence the term "fingerponds") (see Figure 1). Soil from the ponds can be heaped between the ponds to form raised beds for crop cultivation. The ponds are stocked with fish through natural flooding in the rainy season. As the waters recede, the trapped fish are cultured using manure, crop wastes and household wastes to fertilize the ponds and feed the fish. The water level in the ponds is maintained into the dry season by seepage from the adjacent wetland. The idea of fingerponds in the Lake Victoria region was described by Denny (1989; 1991) and Bugenyi (1991). It has developed from flood retreat farming and flood-based fishing practices found in many seasonally-flooded areas as the Sudd and Lake Chad. It is also similar to the many other seasonal aquaculture systems in other parts of the world, e.g. traditional coastal aquaculture systems like the tambak systems for milkfish production in Indonesia or the dambo ponds in southern Malawi.

The main features of fingerponds are: (1) water supply by natural flooding; (2) self-stockling through fish coming in with the flood water; (3) polyculture; (4) integration with crop production on the beds and with wastes and/or manures from household and livestock. Natural water supply and natural fish stocking in combination with waste inputs mean that the operating costs of these systems are kept low. The downside of this is that control over the operation is limited. Sites may remain flooded longer than expected, may flood unexpectedly during the culture season or may dry up sooner than expected, thus reducing the length of the culture period. The management of such systems and their economics are as yet unknown, hence the research project reported in this paper.

Collaborative research and training in wetland aquaculture

In 2001, a research project entitled "The dynamics and evaluation of fingerponds in East African freshwater wetlands" and funded by the European Union INCO-DEV program (the program that promotes scientific cooperation between EU member and developing countries) was started. In the project, three partners from Africa (Uganda, Kenya and Tanzania) and three from Europe (UK, Czech Republic, Netherlands) collaborate (see Table 1 for details of the partners). The objectives of the project are: (1) to establish criteria for optimal fish yields; (2) to assess the socio-economic benefits and evaluate trade-offs between fingerponds and other activities; (3) to develop practical fish production guidelines.
Table 1. Partners and work packages in the EU-INCO-DEV Fingerponds project ("The dynamics and evaluation of fingerponds in East African freshwater wetlands").

<table>
<thead>
<tr>
<th>Partner</th>
<th>Name of work package</th>
<th>Chief scientist/ contact person</th>
</tr>
</thead>
<tbody>
<tr>
<td>UNESCO-IHE Institute for Water Education, Department of Environmental Resources, Delft, The Netherlands</td>
<td>Wetland dynamics and ecological modelling</td>
<td>Dr. Anne van Dam, Prof. Patrick Denny</td>
</tr>
<tr>
<td>King's College, Division of Life Sciences, London, UK</td>
<td>Fish biology, secondary production and foodwebs</td>
<td>Dr. Roland Bailey</td>
</tr>
<tr>
<td>ENKI o.p.s., Trebon, Czech Republic</td>
<td>Fish pond management</td>
<td>Dr. Jan Pokorny</td>
</tr>
<tr>
<td>Makerere University, Institute of Environment and Natural Resources, Kampala, Uganda</td>
<td>Nutrient dynamics and phytoplankton production</td>
<td>Dr. Frank Kansiime</td>
</tr>
<tr>
<td>University of Dar Es Salaam, Department of Zoology and Marine Biology, Dar Es Salaam, Tanzania</td>
<td>Aquaculture technology</td>
<td>Prof. Yunus Mgaya</td>
</tr>
<tr>
<td>Egerton University, Department of Zoology, Njoro, Kenya</td>
<td>Socio-economics and co-management</td>
<td>Prof. Jude Mathooko</td>
</tr>
</tbody>
</table>

The research is carried out in six field locations, two in each of the African partner countries, where the local community participates in the project. During the first year of the project, four ponds measuring 8 X 24 meter and with a depth of 2 m on the landward side and about 1 m towards the lake were constructed at each site. The local communities were involved in the choice of the sites and the construction of the ponds. For all sites, standardized protocols for ecological and hydrological monitoring and data collection were agreed and equipment (e.g., piezometers, evaporation pans) was installed. Here, we report some preliminary results from the sites in Kenya and Uganda (see Figure 2).

In Kenya, the study sites are located in Kusa (Nyanza province, Nyando district) at the mouth of the Nyando river and in Nyangera (Nyanza province, Bondo district) in the delta of the Yala river, both on the shores of Lake Victoria. A survey was carried out among the local community in both sites to document the use of the wetlands and their importance in the livelihoods of the communities. Papyrus harvesting, cattle grazing and seasonal agriculture were the main activities. Fish is an important part of people's diets and fishing is an important part-time activity. Papyrus (Cyperus papyrus) and Phragmites mauritianus Kunth. are important macrophytes: they are used for mats, in house construction, and as a fuel. Grasses and sedges (notably Digitaria scalarum; Cyperus involucratus) are also harvested from the wetlands. Seasonal agricultural crops are sugar cane, coco yam, arrow roots, bananas, rice and vegetables (spinach, kale, tomatoes, onions).

There are usually two flooding periods in this area, a major flood that occurred in May 2002 (Kusa) and from May-July 2002 (Nyangera), and a minor flood at the end of the year. These floods brought the water needed to fill the ponds and the fish needed for stocking. After the flood receded, a census of the fish population was done by pulling seine net through the ponds three times. In Kusa, about 800 fish per pond were caught in three of the ponds, and 56 fish in the fourth pond, or on average about 3 individuals per m² (Kipkemboi, 2003). After the census, the fish were re-distributed to achieve a uniform stocking density per pond. Species encountered were Oreochromis niloticus, O. variabilis, O. leucostictus, Clarias gariepinus, Aplocheilichthys sp., Ctenopoma murei, and Proopterus aethiopicus. The majority of the fish (85-90%) were Oreochromis juveniles (< 5 cm). Further research at the Kenyan sites concentrates on the management of the ponds (nutrient enrichment using cattle manure), the economics of fingerponds and their role in the livelihoods system of the local communities, and the environmental impact of the ponds on the wetland ecosystem.

In Uganda, the study sites are located in Gaba wetland, 13 km south east of Kampala in the Inner Murchison Bay, and in Walukuba wetland in Jinja, near the Napolean gulf of Lake Victoria. The natural vegetation of these
People in the communities have expressed their doubts about the size of the fish in the ponds. They seem to expect big fish, like the ones they see landed for the export market from Lake Victoria. When they learn that it is unlikely that such big fish will ever be produced in fingerponds, they express disappointment. On the other hand, many people must be used to eating smaller fish from occasional fishing in the wetlands. To produce meaningful fish harvests in these ponds, technical research is necessary to improve the management of the ponds, especially nutrient enrichment using chicken manure and the use of local plant materials (papyrus, Phragmites, bamboo and raffia) as substrates for periphyton.
should concentrate on two main topics: (1) pond fertilization strategies using locally available resources to increase pond productivity; and (2) fish harvesting strategies that optimize fish density and fish growth. With regard to the latter point, initial results from natural stocking show that differences in fish abundance after flood recession between neighbouring ponds can be substantial. Redistribution of fish is then necessary. Also, initial densities can be quite high. Excess fish may have to be removed from the ponds. It is not clear whether there may be a market for these (generally small) fish, or whether implementation of fingerponds on a larger scale might constitute a threat to fish recruitment in the lake.

**Options for further development and research needs**

At this point, it is too early to draw firm conclusions about the technical and economic feasibility of fingerponds1. Initial results show that it is possible to flood ponds naturally and achieve self-stocking with fish. Baseline fish yields based on natural stocking of the ponds without additional inputs will be established, and there seem to be no major soil or water quality constraints to culturing fish. A wide range of organic materials for fertilizing ponds are available, ranging from different types of manure to wetland grasses and crop wastes. Technically, extensive to semi-intensive pond management will be possible. There is a demand for fish among the local population, since most fish from the Lake Victoria capture fisheries is going to export markets or to the fishmeal industry (Okeyo-Owuor, 1999).

One point that needs more research is the context for development of aquaculture in the Lake Victoria basin. Apart from fishing, communities in this area are involved mainly in harvesting and processing of natural products from the wetlands like papyrus. Agriculture is practiced seasonally by clearing part of the wetland and growing the crops on the residual moisture without much fertilization. In Kusa, clearing of the land is done communally, but subsequent management of the plots is done individually (J. Kipkemboi, personal communication, 2003). It is not clear how fishponds fit into this system, e.g. in terms of ownership. The initial investment for pond construction is considerable, and it is not clear yet how much maintenance is needed for ponds after a year of flooding and drying up. Adoption of this system will probably depend to a large extent on the trade-off between the benefits of fingerponds and other wetland or off-farm activities. This issue will be addressed in our research by bio-economic modelling of the wetland agro-ecosystem.

The partners in the Fingerpond project are considering a continued collaboration in this area after the current project ends in 2005. There are ideas about integrating several wetland wise-use technologies, implementing participatory field trials with communities in the Lake Victoria basin and doing research on the links between technology development, adoption and policy and decision-making for wetland management. Examples of these other technologies are constructed and natural wetlands for wastewater treatment (Kansiime and Nalubega, 1999; Okurut, 2000) and dry sanitation techniques.

**Acknowledgements**

The Fingerponds project described here is funded by the EU INCO-DEV program, contract no. ICA4-CT-2001-10037. The PhD-research projects of Julius Kipkemboi and Rose Kaggwa are partially supported by grants from the Netherlands Fellowship Program. We thank Patrick Denny for his comments and suggestions. The Fingerponds project collaborates with several other projects, organizations and institutions in the Lake Victoria region. Here, we would like to mention the support of the National Water and Sewerage Corporation, Uganda and the RELMA-SIDA project, Kenya.

**References**


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1 Between the presentation of this paper and its publication in this volume, additional reports about the Fingerponds project have been published (e.g., Bailey et al., 2005; Kaggwa et al., 2005; Pokorny et al., 2005).


ECONOMICS OF INTEGRATED IRRIGATION-AQUACULTURE

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FAO, Rome, Italy


Abstract

The paper highlights the importance of economic analysis in technological development. Principles and methods of “first-aid economics” are presented to allow non-economists to monitor economic performance of integrated irrigation and aquaculture systems. Emphasis is placed on the distinction between farmer’s and economist’s perspectives, with the relevance and calculation of economic indicators explained. Methods of data collection and analysis are also presented and a case study of rice-fish farming which provides an illustrative example of applied economic assessment is presented in an appendix.

Introduction

Economic analysis is an important part of farm activities. It allows farm managers to evaluate the performance of the farm and project managers to assess impacts of development programmes or interventions on food production, household food security and the economy. With few exceptions, past experiences of aquaculture development in Africa, including integrated irrigation-aquaculture (IIA), have not reached their full potential. While reasons for failure may be complex and attributed to a combination of factors, giving full consideration to the assessment of economic performance of aquaculture with the joint participation of both farmers and project managers can ensure the long-term adoption of the activity. As aquaculture is the activity to integrate in existing systems, measuring its economic performance can assist in answering questions related to its chances to be economically viable and attractive as a livelihood strategy. The paper should be viewed as a “first-aid economics” guide aiming to present an overview of simple approaches that can be used by non-economists to address these questions. Readers are encouraged to consult the literature references for more in-depth information and illustrative examples of methods presented. The first section describes the main tools and indicators used in economic analysis. A second section specifies methods of data collection and analysis, making reference to the example of rice-fish culture in Madagascar (detailed in Appendix 1). In a third section the conclusions are summarized.

Types of economic analysis and performance indicators

While the term “economic” is commonly used, financial and economic analyses need to be differentiated. Financial analysis addresses the profitability of an activity, based on its technical characteristics, costs and returns. This type of analysis is of direct concern to the farmer. On the other hand, an economic analysis deals with flows of real resources and assesses the viability and impact of a programme on the local economy or the wider society. It is more precise and of direct concern to project managers and economists. Both rely on financial data, collection of which is the subject of a later section.
Table 1. Economic indicators of farm performance, from a farmer’s and an economist’s perspective.

<table>
<thead>
<tr>
<th>Item</th>
<th>Definition and interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Basic economics</strong></td>
<td></td>
</tr>
<tr>
<td>I. Gross revenue (GR)</td>
<td>= Quantity harvested × price received (market price).</td>
</tr>
</tbody>
</table>
| II. Variable costs (VC), also called operating costs | = Sum of costs of all inputs necessary to production. E.g.:  
- fingerlings / seeds  
- fish feed, crop fertilizers etc.  
- paid labour¹  
- (opportunity cost of variable costs)² |
| III. Gross margin (GM), also called income above variable costs or operating profit. | = Gross revenue net of variable costs  
= GR – VC |
| IV. Fixed costs (FC) | = Sum of expenses incurred regardless of output levels. E.g.:  
- Depreciation of equipment and infrastructures (pond, cages etc.)  
- Interest on borrowed capital (opportunity cost of capital)  
- etc. |
| VI. Net returns to land, labour and management (NRLLM) | = Returns net of fixed and variable costs:  
GR – (FC + VC) |
| Additional data required: |  
- opportunity cost of land = X₁  
- opportunity cost of unpaid labour = X₂  
- opportunity cost of unpaid management = X₃  
- interest rates  
- opportunity costs of variable costs² (if not already included in variable costs). |
| VII. Total costs | = Sum of all costs and opportunity costs  
= FC + VC + X₁ + X₂ + X₃ |
| VIIi1. Net returns to land and management (NRLM) | = NRLM – X₂ |
| VIIi2. Net returns to management (NRM) | = NRLM – X₁ |
| VIIi3. Net returns (NR) | = NRLM – X₁ OR = NRLM – (X₁ + X₂ + X₃) |
| VI. Ordinary Benefit/Cost ratio (B/C)³ | Ratio giving the relative proportion of benefits in relation to costs.  
= NR/(VC+FC) [with imputed opportunity costs] or  
= NRLM/(VC+FC) [without imputed opportunity costs]  
The greater the ratio, the greater the profitability. |
| VII. Pay-back period⁴ | The time (in years or production cycles) it takes for an activity or project to recover its initial cost, calculated as the ratio of initial investment cost to annual cash flows, before depreciation. It is equal to:  
\[\frac{\sum_{i=0}^{N} \frac{A_i}{(1+r)^i}}{FC}\]  
\(N\) being the number of periods (or years) |
| **Advanced economics** | |
| VIII. Net present value (NPV) | Reflects the fact that an investment has a higher value in the present than in the future because of risk and uncertainty regarding future earnings.  
Its formula is:  
\[V_0 - \frac{V_N}{(1+r)^N}\]  
with \(V_0\) = present value, \(V_N\) = future value, \(r\) = interest rate (discount rate), \(N\) = number of periods, or years of operation.  
If \(V_0 > 0\), the investment will be profitable.  
If \(V_0 < 0\), the investment will not be profitable.  
If \(V_0 = 0\), the investment will not bring any returns (break-even situation). |
| IX. Internal rate of return (IRR) | The interest rate (or discount rate), \(r\), at which NPV equals zero. It represents the average earning power of the money used in a project over its whole life. It is obtained by solving the equation, on a trial-and-error basis:  
\[\sum_{i=0}^{N} \frac{A_i}{(1+r)^i} = 0\]  
where \(A_i\) = net benefits over individual period \(N\) (difference between total benefit or revenue and total costs), \(r\) = interest rate (discount rate).  
If IRR is greater than the appropriate opportunity cost of capital, the investment is feasible and worthwhile. |
| X. Discounted Benefit / Cost ratio = Discounted NR / (FC + discounted VC). | Opportunity costs of land, labour and capital are imputed. |

¹Marketing time, if appropriate, should be included. ²This inclusion of this type of cost in variable costs may not be amongst farmers’ concerns. It is important however from an economist’s perspective and should be included in further analysis. ³This indicator is of relevance to commercial-scale operations but is of little use in the context of small-scale, subsistence-based operations. ⁴As a dimensionless ratio, C/B can be calculated too [(VC+FC)/NR]. In this case, the smaller the ratio, the greater the profitability.
Table 2: Essential data collection for basis assessment of performance of an IIA system.

**COSTS**

<table>
<thead>
<tr>
<th>Fixed costs</th>
<th>Variable costs (linked to quantities used)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pond excavation</td>
<td>Stocking of fish seed/fingerlings</td>
</tr>
<tr>
<td>Cage construction</td>
<td>Feed</td>
</tr>
<tr>
<td>Rice field design to accommodate fish production</td>
<td>Fertilizers</td>
</tr>
<tr>
<td>Irrigation charges (if fixed regardless of quantity of water used)</td>
<td>Harvest</td>
</tr>
<tr>
<td>Labour costs</td>
<td>Paid labour (production and post-harvest)</td>
</tr>
<tr>
<td></td>
<td>Unpaid household labour(^1)</td>
</tr>
</tbody>
</table>

**INCOME**

<table>
<thead>
<tr>
<th>Margins</th>
<th>Production quantities (sold and home consumed)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Farm-gate or market price of commodity sold</td>
</tr>
</tbody>
</table>

\(^1\)Paid and unpaid labour (expressed in person-day or hour per day) should be quantified separately. For the latter, the role of women and children in daily management activities should be included.

**Types of economic analysis**

Defining the time scale as well as the scale of operation (subsistence–extensive, small-scale commercial–semi-intensive, commercial or industrial–intensive), is of prime importance to deciding which type of analysis to carry out. Micro-economic approaches to farm management are of higher relevance to IIA development, in particular at subsistence and small-scale commercial levels.

Denomination and definition of approaches and methods can sometimes overlap and vary from one source to the other. To overcome possible confusion, it may be easier to consider the problem of farm economics from two perspectives: the farmer’s and economist’s (or project manager’s).

From the farmer’s perspective, farm management based on the keeping of farm budgets allows him/her to analyze inputs and outputs from farm operations. It excludes variables such as labour costs and opportunity costs of resources and tends to underestimate the importance of amortisation.

From an economist’s perspective, farm management can be broadened to include production economics (economics of transformation of resources, their allocation and productivity at the farm level) and household economics (impact of farm activities on household economies). Other approaches with a wider scope are macro-economics, which deals with flows of resources at regional, national or global levels; and environmental economics, which looks at the valuation of impacts created by an activity on the environment and on the communities who depend on it. Cost-Benefit Analysis (CBA) is a method used to operationalize these two approaches. To accurately reflect reality, such analyses include information related to the opportunity costs of resources (labour, land, capital etc.), and take into account market distortions.

The following section provides details on the calculation of indicators used to measure the economic efficiency of farms, both from the farmer’s and the economist’s points of view. Indicators are presented as they would be in the context of a ‘real-life’ analysis.

**Indicators and ratios**

For the evaluation of the performance of IIA activities on a pilot scale, a farm management approach may be initially sufficient to assess the immediate profitability of the enterprise. However, to forecast the long-term viability of the operation additional indicators, based on a number of assumptions, are necessary. Table 1 describes the information needed for the calculation of relevant indicators and ratios used in economic analysis, and their interpretation. It also illustrates the progress from farm management to more complex economic analysis.

The calculation of the net present value (NPV) is necessary to compare costs and
Table 3: Example of economic prices and corresponding financial prices, assuming market efficiency, in the case of aquaculture.

<table>
<thead>
<tr>
<th>Economic prices</th>
<th>Financial prices (used as proxies)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of labour (valuation of household labour)</td>
<td>→ Marginal value product of agricultural labour</td>
</tr>
<tr>
<td>Cost of land</td>
<td>→ Market price of land</td>
</tr>
<tr>
<td>Cost of machinery</td>
<td>→ Market price of hiring a machine</td>
</tr>
<tr>
<td>Cost of construction materials</td>
<td>→ Market price of these materials</td>
</tr>
<tr>
<td>Cost of seed-fry-fingerlings</td>
<td>→ Market price of seed-fry-fingerlings</td>
</tr>
<tr>
<td>Cost of feed and fertilizer (pond)</td>
<td>→ Market price in the next best alternative use (feed for cattle or poultry, fertilizer for crops etc.)</td>
</tr>
<tr>
<td>Cost of fish at harvest</td>
<td>→ Market price of fish</td>
</tr>
<tr>
<td>Opportunity cost of unpaid labour</td>
<td>→ Government minimum wage or reservation wage or estimated value of labour paid in kind¹</td>
</tr>
<tr>
<td>Opportunity cost of capital</td>
<td>→ Basic interest rate on savings (paid by banks)</td>
</tr>
<tr>
<td>Opportunity cost of land</td>
<td>→ Net return (per unit of land) from the next alternative use of land</td>
</tr>
</tbody>
</table>

¹Reservation wage refers to wages that are below minimum government wages. Labour paid in kind can be valued at market price of the output kept.

revenues while correcting for the time that elapses between the date of initial investments and the date of first revenues. It involves a process called discounting. Discounted values (or present values) are obtained by dividing the future estimated revenues in year \(N\) by \((1+r)^N\), which is the interest that would be generated over period \(N\) (\(r\) is the interest or discount rate).

Using discounting over ordinary methods limits inflating revenues and future costs and allows for better comparison of various projects or scenarios envisaged over different time spans (Hishamunda and Manning, 2002).

### Data collection and analysis

#### Data requirements

While all the above indicators are important for accurate analysis and monitoring, resources are often limiting and prevent the collection of detailed data.

**Essential (minimum) data** to collect to obtain an overview of the performance of an IIA system is presented in Table 2. **Additional data**: for an economic perspective on farm performance, assumptions are often needed regarding the value of resources that are not directly marketed. Table 3 suggests suitable ‘proxies’, drawn from the market prices of goods and resources in alternative uses. To be valid, they rely on the critical assumption that market prices are efficient (competitive economy).

In addition to the above, information on prevailing interest rates, expected economic life-time, depreciation, as well as salvage values will be valuable in economic viability assessments. Analysis of opportunity costs of resources consumed by aquaculture and trade-offs at the household level requires collection of in-depth information related to household activities, decision-making and resource use. Because data to collect is wide-ranging and context-specific it has not been listed here. Suitable approaches to the collection of such data are suggested in the next section.

**Data collection**

Data collection can be a lengthy process bearing heavy demands on the time of all stakeholders. To avoid wasting resources, it is therefore important to **plan ahead**; to decide what has priority in **data collection** and how the data will be **analysed**; and then **stick with the plan**. Keeping in mind a checklist based on **WHAT, WHERE, WHEN, WHO, and HOW**, questions can help avoid data omissions. Examples are provided in Table 4.
Table 4: Planning data collection – example of a checklist.

<table>
<thead>
<tr>
<th>WHAT</th>
<th>WHERE</th>
<th>WHEN</th>
<th>WHO</th>
<th>HOW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of operation</td>
<td>Demarcation of area of</td>
<td>Time scale of survey:</td>
<td>Groups under</td>
<td>Methods of data collection</td>
</tr>
<tr>
<td>(scale) under</td>
<td>survey</td>
<td>- if over time: frequency and overall</td>
<td>investigation.</td>
<td>(structured questionnaire, participatory</td>
</tr>
<tr>
<td>investigation</td>
<td></td>
<td>length of data collection</td>
<td></td>
<td>appraisal).</td>
</tr>
<tr>
<td>Sample size</td>
<td></td>
<td>- if snap-shot: period of recollection</td>
<td></td>
<td>- Methods of</td>
</tr>
<tr>
<td>(very important –</td>
<td></td>
<td>of data (back in time), period of year</td>
<td></td>
<td>analysis and reporting.</td>
</tr>
<tr>
<td>stratified, random</td>
<td></td>
<td>(can influence results, in particular in</td>
<td></td>
<td></td>
</tr>
<tr>
<td>etc.) and its</td>
<td></td>
<td>areas with strong seasonal variations)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>justification</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>What we need to know</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>/ what we want to</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>know / what needs to</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>be shown</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>What will be done</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>with the collected</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>data (i.e. planning</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>the analysis)</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Structured questionnaires are often used for the collection of economic data as they allow the systematic collection of information and are useful in the case of large samples. However, they have limitations in terms of quality of data obtained from farmers. Preparatory studies, careful preparation and field-testing prior to implementation, and training of enumerators or farmers involved in collection are of prime importance to ensure quality and limit bias. For example, with respect to labour information, it is often easier for respondents to estimate the quantity of labour used if management activities are disaggregated, but only questionnaire pre-testing can reveal such weaknesses in the collection process. On an ad-hoc basis, in-depth semi-structured, face-to-face interviews are then useful for quality checks. In addition, the qualitative information gained from participatory appraisals can be useful in gaining a broad understanding of a situation prior to its quantitative appraisal, as well as provide an insight in intra-household issues, including gender relationships, decisions and responsibilities. This type of information, whilst not substituting quantitative data, can shed valuable light on the results obtained.

Data analysis

No complex software is needed for data analysis: an MS Excel spreadsheet is sufficient and includes pre-programmed ratio calculations.

As underlined above, the inclusion or exclusion of household labour is critical in the interpretation of results. Two analyses are generally carried out in parallel: one excluding household labour from calculations, and one including estimates of non-monetary cost to the pursuit of an activity.

In planning the development of a new activity or estimating its potential, running sensitivity analyses with varying figures (for example interest rates, prices of inputs), can show the thresholds beyond which an activity may not be economically viable. Similarly, a cost structure analysis, whereby each variable cost is estimated as percentage of total variable costs and total costs, can suggest where cost reductions can be made and estimate the impacts of modified resource allocation on other activities.

Case study – Madagascar

For an illustrative case study of the methods of data collection and analysis described above, readers are encouraged to refer to the "comparative economic analysis of rice, fish and rice-fish culture in Madagascar" (Appendix 1). In this study, reference is made to farm management from the farmer's perspective: ratios are presented and their interpretation allows for the determination of comparative advantages and disadvantages of each type of activity.

Conclusion

The paper has highlighted what can be achieved with basic economic analysis applied to aquaculture and IIA activities and has shown that a few strategically chosen indicators can
go a long way in assessing the performance and long-term viability of such operations. At the farmer’s level, simple and regular assessments can allow for difficulties to be spotted early in the development of a new activity, and allow for its redirection or readjustment. An economist’s approach can, in addition, enable to consider the longer-term viability of a project and anticipate its potential for adoption and impacts on poverty alleviation and livelihood diversification. The two perspectives however diverge mainly over their estimation of unpaid household labour: it is rarely accounted for by farmers but should be adequately valued and included in analysis, in addition to all other non-market costs, by economists. Despite the quantitative nature of the data used, remaining sensitive to local knowledge and practices and adopting participatory principles during data collection can assist in collecting quality information and achieving meaningful economic analysis.

Acknowledgements

Dr. Hishamunda’s comments on an early draft are gratefully acknowledged.

References


Further reading

Appendix 1. COMPARATIVE ECONOMIC ANALYSIS OF RICE, FISH AND RICE-FISH CULTURE IN MADAGASCAR

Introduction

With its long coastline of 4,500 km and a continental shelf of 117,000 km², Madagascar has excellent potential for fisheries and aquaculture development. According to the National Statistical Institute, the fisheries sector contributed more than seven percent to the national GDP over the last years. A further increase to nine percent in the next few years is expected. The total population of Madagascar is 16.4 million (2001) and is growing at a rate of three percent annually. Around five percent of the working population depends on income from activities in the fisheries and aquaculture sector (Razafitseheno, 2001). The capture fisheries sub-sector saw a rapid growth in species was reported recently. The total fisheries export earnings were about US$ 101 million in 1999; an increase of 5.5 percent over 1998 (FAO, 2002b).

Although fish and aquatic animal products are a potentially important nutritional source for Malagasy people current consumption figures are low, estimated at 7.6 kg/year in 1999. Consumption of fish and aquatic animal products is expected to increase further as it is considered as healthy food.

Within the fisheries sector, aquaculture is important and developing rapidly in the rural areas of Madagascar. Shrimp aquaculture in particular has shown its economic potential in recent years, attracting many investors. As a result, its production has increased from production from 107,590 tonnes in 1990 to 143,859 tonnes in 2000 (FAO, 2002a), showing an increase of 4 percent from 1999 to 2000. However, the potential for capture fisheries is limited, and a decrease in catches of various species was reported recently. The total fisheries export earnings were about US$ 101 million in 1999; an increase of 5.5 percent over 1998 (FAO, 2002b).

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1 The work on which this comparison of production systems is based was commissioned by the FAO Inland Water Resources and Aquaculture Service to Mr Etienne Randimbiharimanana who collected the farm level data and other relevant information. The comparative economic analysis of the three culture systems and interpretation was performed by Mssrs Van Anrooy and Hishamunda of the FAO Fisheries and Aquaculture Department.
The top carp production of 6,105 tonnes in 1997 was followed by a steep decline the year after. Most recent FAO figures of the year 2000 show a carp aquaculture production of 2,480 tonnes (Figure 1). One of the main reasons for the sharp decline in carp production in 1998 was the tropical cyclone Gretelle which hit the country in 1997 leaving 200 casualties and affecting some 570,000 people. This first cyclone in 40 years destroyed large parts of the cash crops, including aquaculture. Because of the damage to hatcheries, fingerlings were in short supply the following year.

About 71 percent of freshwater aquaculture production in Madagascar comes from rice-fish culture (Remanevy, 1999). The remaining (29 percent) is produced in pond systems. While carp has been the main species used in rice-fish culture, tilapia is also becoming popular. Rice-fish farming in Madagascar is a simple, low-cost and low-technology practice. It was promoted by various nationally and internationally funded projects, like e.g., the FAO/UNDP project MAG/92/004 “Programme de développement de la pêche et de l’aquaculture” and the project “Initiatives Genre et Développement: Le projet rizi-pisciculture (Sud et Nord) a Madagascar” funded by the European Union. However, the economics of rice culture, fish culture and rice-fish culture are not well understood.

**Methodology**

Economic data were collected from ten rice farms, ten fish farms (carp culture) and ten rice-fish farms (tilapia/carp culture) in the Vakinankaratra area in 2001. Data was analysed by using the “Enterprise budget technique”. The average sizes of rice, fish and rice-fish farms were 0.21, 0.09 and 0.45 hectare, respectively. However, due to the small sample size, standard deviations were high: 0.20, 0.15 and 0.60 ha, respectively. Depreciation rates used for the investment costs in ponds and rice-fish fields were based on similar studies from other countries in Sub-Saharan Africa. They were 20 and 10 years for fish ponds and rice-fish field structures, respectively. Most farmers interviewed for the study were among the poorer part of the rural population, as the study aimed to identify the opportunities and constraints of fish culture for the rural poor in Madagascar. Photographs of the three production systems are provided in Appendix 2.

**Results**

Table 1 presents bio-physical data for the three production systems. Although in all systems only one production cycle per year is practiced,
the length of the cycle is diverse and ranges from 144 days for rice to 240 days for fish culture. Lime, organic and in-organic fertilizers are used in all three systems although in different quantities. For instance, fish farmers use more lime in the preparation of their ponds, while rice-fish farmers add more organic fertilizers to their rice-fish fields than farmers in the other two systems. Rice-fish farmers use around 22 percent of the rice seeds that rice farmers use, and around 38 percent of the fingerlings that fish farmers use per hectare. The average weight of the fingerlings stocked in rice-fish culture is higher than in fish-only systems (± 10 g vs 5 g). The quantity of feed used by fish farmers is about double that used by rice-fish farmers. Rice-fish farming appears to be the most labour-intensive. Rice-fish farmers hire relatively more labour. Of the three systems, fish farming has the lowest labour intensity. Yields from the three systems are also very diverse. Rice yields from a rice-fish field are 22 percent higher than yields from an ordinary rice field. This could be an indication that the integration of fish and rice culture has a positive impact on rice yields. The rice-fish system on average utilizes three times more fertilizers per unit of land than the rice system. This is probably another important reason for the higher rice yield from the rice-fish systems in this study.

Economic data and the results of the cost-return analysis are presented in Tables 2 and 3. Total variable costs are lowest for rice culture, which also shows low gross revenues and net returns compared to the other production systems. The total costs associated with rice-fish culture or fish culture are almost similar (around 1 175 US$/year). Net returns from rice-fish culture however are 182 US$/year higher than for fish culture. This means that, although the initial investment needed for the preparation of the rice field for rice-fish culture is higher than for the construction of fish ponds, investment costs are recovered sooner as gross revenues are higher.

The benefit/cost ratio for rice, fish and rice-fish farming was 0.75, 0.34 and 0.51, respectively without imputed costs of land, labour and management. This indicates that increases in costs related to rice-fish culture and fish culture systems do not automatically result in proportionally higher returns.

Break-even points calculated for the yields at current costs and prices are presented in Table 4. Rice farmers should produce at least 2 317 kg of rice/ha/year, fish farmers 516 kg of fish/ha/year and rice-fish farmers 594 kg of fish and 2 766 kg of rice/ha/year to recover their total costs of production.

### Discussion and conclusions

#### Financial returns

Of the three production systems analysed, rice-fish culture offers the highest net returns per hectare per year. Rice farmers interested in fish culture should be advised to start rice-fish culture instead of building ponds for fish culture. The rate of return on investment is

<table>
<thead>
<tr>
<th>Item</th>
<th>Rice (FMG/kg)</th>
<th>Fish (FMG/kg)</th>
<th>Rice-Fish (FMG/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average market price rice</td>
<td>1 360</td>
<td>-</td>
<td>1 245</td>
</tr>
<tr>
<td>Price of rice seeds</td>
<td>1 360</td>
<td>-</td>
<td>1 245</td>
</tr>
<tr>
<td>Average market price fish</td>
<td>-</td>
<td>13 825</td>
<td>11 950</td>
</tr>
<tr>
<td>Price of organic fertilizer</td>
<td>55.30</td>
<td>57.50</td>
<td>86.25</td>
</tr>
<tr>
<td>Price of chemical fertilizer</td>
<td>3 300</td>
<td>3 000</td>
<td>3 225</td>
</tr>
<tr>
<td>Price of lime</td>
<td>2 700</td>
<td>800</td>
<td>750</td>
</tr>
<tr>
<td>Price of fingerlings</td>
<td>-</td>
<td>40 566</td>
<td>18 556.7</td>
</tr>
<tr>
<td>Price of fish feed</td>
<td>-</td>
<td>1 292</td>
<td>825</td>
</tr>
<tr>
<td>Cost of pond construction</td>
<td>-</td>
<td>10 450 000</td>
<td>14 080 000</td>
</tr>
<tr>
<td>Cost of hired labour</td>
<td>970 284</td>
<td>123 913</td>
<td>1 558 719</td>
</tr>
<tr>
<td>Cost of family labour</td>
<td>332 500</td>
<td>168 000</td>
<td>210 000</td>
</tr>
<tr>
<td>Cost of management</td>
<td>50 000</td>
<td>30 000</td>
<td>30 000</td>
</tr>
<tr>
<td>Land tax (FMG/ha/year)</td>
<td>117 453</td>
<td>112 319</td>
<td>64 732</td>
</tr>
</tbody>
</table>
Table 3. Cost and returns analysis (per hectare per year) for rice, fish and rice-fish culture in Madagascar, 2001.

<table>
<thead>
<tr>
<th>Item</th>
<th>Rice a (US$/ha)</th>
<th>Fish a (US$/ha)</th>
<th>Rice-Fish a (US$/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Gross Revenues (GR)</td>
<td>858.63</td>
<td>1565.66</td>
<td>1746.90</td>
</tr>
<tr>
<td>II. Variable Costs (VC)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lime</td>
<td>15.58</td>
<td>104.36</td>
<td>0.67</td>
</tr>
<tr>
<td>Organic fertilizer</td>
<td>54.77</td>
<td>104.19</td>
<td>164.32</td>
</tr>
<tr>
<td>In-organic fertilizer</td>
<td>47.91</td>
<td>5.03</td>
<td>149.58</td>
</tr>
<tr>
<td>Fingerlings</td>
<td>−</td>
<td>415.91</td>
<td>133.33</td>
</tr>
<tr>
<td>Rice seeds</td>
<td>108.04</td>
<td>−</td>
<td>22.11</td>
</tr>
<tr>
<td>Fish feeds</td>
<td>−</td>
<td>275.04</td>
<td>54.77</td>
</tr>
<tr>
<td>Hired labour</td>
<td>162.48</td>
<td>20.77</td>
<td>267.83</td>
</tr>
<tr>
<td>Opportunity cost of capital b</td>
<td>46.65</td>
<td>111.04</td>
<td>95.11</td>
</tr>
<tr>
<td>Total VC</td>
<td>435.43</td>
<td>1036.34</td>
<td>887.72</td>
</tr>
<tr>
<td>III. Gross Margin (GM)</td>
<td>423.20</td>
<td>529.32</td>
<td>859.18</td>
</tr>
<tr>
<td>IV. Fixed Costs (FC)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depreciation</td>
<td>0</td>
<td>87.60</td>
<td>235.85</td>
</tr>
<tr>
<td>Land tax</td>
<td>19.60</td>
<td>18.76</td>
<td>10.72</td>
</tr>
<tr>
<td>Total FC</td>
<td>19.60</td>
<td>106.36</td>
<td>246.57</td>
</tr>
<tr>
<td>Opportunity costs of land</td>
<td>NA</td>
<td>NA a d</td>
<td>NA</td>
</tr>
<tr>
<td>Opportunity cost of unpaid labour</td>
<td>55.70</td>
<td>28.14</td>
<td>35.18</td>
</tr>
<tr>
<td>Opportunity cost of unpaid management c</td>
<td>8.38</td>
<td>5.03</td>
<td>5.03</td>
</tr>
<tr>
<td>TOTAL COSTS</td>
<td>519.10</td>
<td>1175.86</td>
<td>1174.49</td>
</tr>
<tr>
<td>VI. NRLLM</td>
<td>403.60</td>
<td>422.96</td>
<td>612.61</td>
</tr>
<tr>
<td>VII. NLM</td>
<td>347.90</td>
<td>394.82</td>
<td>577.43</td>
</tr>
<tr>
<td>VIII. NRM</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Viv. NRL</td>
<td>339.53</td>
<td>389.80</td>
<td>572.41</td>
</tr>
<tr>
<td>VI. B/C with imputed opportunity costs of land, labour and management</td>
<td>0.89</td>
<td>0.37</td>
<td>0.54</td>
</tr>
<tr>
<td>VI. B/C without imputed opportunity costs of land, labour and management</td>
<td>0.75</td>
<td>0.34</td>
<td>0.51</td>
</tr>
</tbody>
</table>

a Exchange rate: USD 1 = FMG 5970 (Malagasy franc, 2001)
b Calculated on the basis of interest rate on savings = 12 percent.
c Calculated on the basis of manager’s salary per month = FMG 300 000.
d NA = no data available.

Higher for rice farming than for rice-fish farming, indicating that the additional investment cost offers relatively less returns. However, it should be noted that in most cases little opportunity exists for rice farmers to reach a rate of return on investment similar to that obtained from rice-fish culture by increasing investment in rice culture.

Investments in land, capital and labour

Farmers who initiated rice-fish culture are generally the better-off farmers, who have access to more land (0.4 ha vs 0.2 ha for rice farmers). However, the analysis shows that the net returns of the smaller farms (300-400 m² of rice-fish field) is higher per m² than of larger farms. Understocking of fingerlings by the larger farms might be an important reason for the relatively smaller returns. Current problems related to land ownership also negatively affect the investments made by farmers in rice fields and inputs. Much of the land is not privately owned; inheritance processes are complicated and often only oral agreements on land use are made. Short-term thinking and fewer concerns about long-term
Table 4. Break-even analysis for rice, fish and rice-fish farming activities in Madagascar (2001).

<table>
<thead>
<tr>
<th></th>
<th>Rice</th>
<th>Fish</th>
<th>Rice-Fish</th>
</tr>
</thead>
<tbody>
<tr>
<td>Break-even yield (kg/ha/year)</td>
<td>2316.6</td>
<td>516.2</td>
<td>NA</td>
</tr>
<tr>
<td>Break-even price (FMG/kg)</td>
<td>835.9</td>
<td>10 557.5</td>
<td>NA</td>
</tr>
</tbody>
</table>

*NA – calculation not possible with the data available.*

environmental benefits are a consequence of this situation.

Initial capital investment needed to start rice-fish culture activities is relatively high for the poor rice farmers; the investment equals the average net returns of 6 years of rice farming. This may be a high hurdle for entering this activity. As information on credit access, collaterals, interest rates and repayment details was not collected, it is not known which financial opportunities and constraints are connected to obtaining loans for rice-fish culture or fish culture.

Because rice-fish culture needs considerably higher labour inputs than fish pond culture and rice culture, it seems more attractive to larger families/households than to small ones. For poor farming households with a small labour force who are already active in rice, cassava, sweet potato, fruits, maize and soybean cultivation, fish culture in rice fields is another opportunity to make ends meet. Farmers already relying much on hired labour in rice culture are expected to be more willing to introduce fish in their rice fields as the additional increase in costs will be less.

**Production**

Rice yields are higher in the rice-fish system than in the rice system, indicating that fish culture in a rice field can increase the production per hectare\(^2\). Rice-fish culture can thus provide an additional contribution to food security at household level and will also support the household income when part of the fish produced is sold. The reduction in insect pests and weeds is an important indirect benefit of cultivating fish in rice fields, and might be one of the reasons for this higher rice production. Recycling of nutrients by the fish may be another.

Individual fish growth levels are higher in the rice-fish production system than in the fish pond culture system as a result of better growing conditions. Bad experiences when trying other culture practices are causing high levels of non-acceptance of new techniques/practices by farmers, which influence the introduction and spread of rice-fish culture negatively.

**Risk**

Rice-fish culture seems to be a less risky activity than rice and/or fish culture alone as none of the rice-fish farmers interviewed incurred losses, in contrast to 30 percent of the rice-farmers and 20 percent of the fish farmers (Appendix 3). However, droughts and floods can cause financial disasters, as cyclone Gretelle showed in 1997, especially to the poorer part of the rice-fish farmers and to those who have just entered rice-fish farming and have invested a considerable part of their income in this activity.

Stocking a rice field that is not located next to the farm house with fish is risky, as rural poverty leads to fish theft (especially near harvest time) and jealousy-driven sabotage activities. Moreover, traditional cultural and social structures in farming communities and individual families cause skimming of the benefits and result in reduced opportunities for investments in, e.g., rice-fish culture.

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\(^2\) Editors’ note: An increase in rice yields on rice-fish farms in comparison to rice monoculture farms is often observed, and the reported increase is well within the range of reported yield increases from other parts of the world. However, the almost 80 percent lower seeding rate reported for rice-fish farming appears to be unusually low whereas the reported fertilization rates, both organic and inorganic, at three times the rate used in rice monoculture appear to be unusually high; these apparent contradictions unfortunately could not be examined in more detail.
Market prices of fish fluctuate considerably over the year. Harvests of different rice-fish culture farms entering the market more or less at the same time will most likely influence the price negatively. Farmers generally cannot postpone selling the fish once the dry season starts or when the fields need to be prepared for the next season, and therefore must accept the current market price. Fish pond operators are less susceptible to drought and therefore a bit more flexible in the timing of harvesting and marketing of their fish.

References


Appendix 2

Photographs of the three production systems in Madagascar: a) rice culture; b) rice-fish culture; and c) pond fish culture (all photos by Mr E. Randimbiharimanana).
# Appendix 3

A. Bio-economic data of ten rice culture farms in Madagascar, 2001

<table>
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<tr>
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## Main economic parameters

### Costs

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¹Kg per m² & per production cycle;  
²Months;  
³US$ per m² & per production cycle;  
⁴US$ per m²
## Appendix 3 (continued)

### B. Bio-economic data of ten fish culture farms in Madagascar, 2001

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$^1$Kg per m$^2$ & per production cycle;

$^2$Months;

$^3$US$\$ per m$^2$ & per production cycle;

$^4$US$\$ per m$^2$ (note: as the cost of pond construction is spread over 20 years the effect on total cost is minimal here)
Appendix 3 (continued)

C. Bio-economic data of ten rice-fish culture farms in Madagascar, 2001

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<td>0.60</td>
<td>0.59</td>
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<td>0.061</td>
<td>0.086</td>
<td>0.020</td>
<td>0.113</td>
<td>0.033</td>
<td>0.063</td>
<td>-</td>
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<tr>
<td>Weight at harvest (g/fish)</td>
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<td>250</td>
<td>125</td>
<td>375</td>
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<tr>
<td>Cost of feed</td>
<td>0.03</td>
<td>0.01</td>
<td>-</td>
<td>0.01</td>
<td>0.00</td>
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<td>Cost of in-organic fertilizer</td>
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<td>0.02</td>
<td>-</td>
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<td>Cost of organic fertilizer</td>
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<td>-</td>
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<td>0.03</td>
<td>0.04</td>
<td>0.00</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Total costs</td>
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<td>0.14</td>
<td>0.09</td>
<td>0.04</td>
<td>0.05</td>
<td>0.10</td>
<td>0.04</td>
<td>0.08</td>
<td>0.09</td>
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<td>Returns</td>
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<td>Gross revenue</td>
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<td>0.19</td>
<td>0.24</td>
<td>0.11</td>
<td>0.38</td>
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<td>Net revenue</td>
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<td>0.11</td>
<td>0.08</td>
<td>0.10</td>
<td>0.02</td>
<td>0.34</td>
<td>0.07</td>
<td>0.10</td>
<td>0.01</td>
<td>0.32</td>
<td>0.14</td>
</tr>
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1Kg per m² & per production cycle;
2Months;
3US$ per m² & per production cycle;
4US$ per m² (note: as the cost of field preparation is spread over ten years the effect on total cost is minimal here).
INTERNATIONAL RESEARCH SUPPORT FOR INTEGRATED IRRIGATION AND AQUACULTURE DEVELOPMENT

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Abstract

A brief review of the mandates of some international institutions dedicated to research and development on agriculture and natural resource management and interested in supporting research on integrated irrigation and aquaculture systems is given. The Food and Agriculture Organization of the United Nations (FAO), the International Programme for Technology and Research in Irrigation and Drainage (IPTRID), the International Water Management Institute (IWMI), the International Rice Research Institute (IRRI), the WorldFish Center (formerly known as ICLARM), WARDA (the Africa Rice Center), and the Inland Valley Consortium (IVC). All have specific agendas and specific approaches to achieve their missions, but all share the common goal of improved well-being for households and environmental sustainability across the globe and support integrated approaches to water management, implicitly supporting integrated irrigation-aquaculture development.

Introduction

To successfully promote and achieve integrated irrigation aquaculture (IIA) development, it is essential that international institutions working towards rural development, food security and poverty alleviation have complementary mandates and promote harmonized policies and coherent actions. Each organization follows a specific agenda towards poverty reduction, but they may diverge in the achievement of their objectives: improving irrigation efficiency or water productivity. The former can be carried out in the limited sphere of agronomists and irrigation/water management engineers, whilst the latter calls for an integrated multidisciplinary approach (economists, fisheries/aquaculture specialists, industrialists, etc.).

This section looks at the mandates and objectives of international agencies regarding irrigation water development, allocation and use to assess the strategic environment in which IIA will take place and its compatibility with current irrigation and aquaculture development policies.

FAO

The FAO recognizes the need to devise policies and laws to enhance water productivity at the individual, local and river basin levels and go beyond the "crop per drop" paradigm (i.e. irrigation efficiency) by increasing agricultural production per water unit, while creating jobs and incomes with limited water supplies (FAO, 2002a). To achieve this, the organization is promoting basin-wide integrated water resources management (IWRM) policies, which ensure that downstream water users are not penalized by upstream interventions (FAO, 2003a), and is calling for a "re-invention" of agricultural water management that increases productivity, promotes equal access to water and conserves the resource base (FAO, 2003b).

However, the contribution of irrigation to food security is crucial and what is also needed, according to the FAO, is "improved efficiency in the use of irrigation water" through the use of water saving methods such as drip systems and increased drainage that increase yields while reducing water-logging and salinisation (FAO, 2003c). Despite the potential for aquaculture development in saline areas, salinisation is a growing threat to the world's grain harvests and its prevention may lead to priority given to the use of sprinklers and drip irrigation methods (FAO, 2002b). Whilst the FAO's global aim supports integrated systems and multiple uses of water such as irrigation and aquaculture, it also suggests that IIA as an activity may not be suitable everywhere because of its requirements for irrigation.
development/rehabilitation in areas where water saving methods may be more adapted.

Specifically, IIA falls under the responsibility of the Land and Water Division in the Natural Resources, Sustainable Development and Technology Department and the Inland Water Resources and Aquaculture Service (FIRI) in the Fisheries and Aquaculture Department. The mandate of the Land and Water Division of the FAO is to provide "advisory and technical services to FAO Members to ensure a more productive and efficient use of land and water resources and plant nutrients in order to meet present and future food and agriculture demands on a sustainable basis".

In the Fisheries and Aquaculture Department, FIRI reviews and evaluates the use of inland water resources for fisheries, and promotes their better management; it promotes the use of improved techniques and systems for the culture of fish and other aquatic organisms in fresh, brackish and marine waters; and, it promotes sound environmental conservation practices in lakes and rivers. Its work is guided by the 1995 FAO Code of Conduct for Responsible Fisheries which maintains as a general principle that "States should consider aquaculture, including culture-based fisheries, as a means to promote diversification of income and diet. In so doing, States should ensure that resources are used responsibly and adverse impacts on the environment and on local communities are minimized" and more specifically that "States should produce and regularly update aquaculture development strategies and plans, as required, to ensure that aquaculture development is ecologically sustainable and to allow the rational use of resources shared by aquaculture and other activities." In this context, FAO has been assisting member countries in identifying and evaluating suitable IIA systems through studies and reports as well as several missions and workshops to evaluate and promote IIA since the early 1990s (see Coche, 1998; Halwart and Gupta, 2005; Moehl et al., 2001; Redding and Midlen, 1991; and several authors, this volume).

**IPTRID**

The mandate of the International Programme for Technology and Research in Irrigation and Drainage (IPTRID), a multi-donor trust-fund programme hosted by the FAO, is to "reduce poverty and enhance food security, while conserving the environment" through a "more efficient use of water in agriculture".

By identifying agricultural water management problems, IPTRID offers objective solutions and strategies adapted to each country's specific needs and priorities. This is exemplified in their *Field guide on irrigated agriculture for field assistants* in Malawi (Cornish and Brabben, 2001), which reviews objectively the advantages and disadvantages of each irrigation method to facilitate farmers' choices, and takes into account physical as well as socio-economic characteristics. In congruence with poverty reduction strategies, IPTRID promotes irrigation designs that are sensitive to environmental and societal conditions, and developments focused on smallholder schemes to benefit the poor (Hasnip et al., 1999).

**IWMI**

The mission of the International Water Management Institute is to "improve water and land resources management for food, livelihoods and nature". Among the objectives of the institute are the identification of larger issues related to water management and food security, the promotion of management practices that can be used by governments and institutions to manage water and land resources more effectively and address water scarcity issues, and the clarification of the link between poverty and access to water.

While IWMI's earlier thrust was to improve irrigation management and efficiency, the institute has now moved towards improving agricultural water productivity (e.g. Guerra et al., 1998; Molden, 1997) to encompass multiple, including non-agricultural, uses of water (e.g. Renwick, 2001; Bakker et al., 1999). This was reflected in the recent change of the institute's name (from International Irrigation Management Institute) and currently by its strategic research priorities focusing on integrated water management for agriculture and competing uses of water in river basins and the institutional and policy implications of enhancing the productivity of water. However, IWMI is also working towards identifying and evaluating water and land use innovations for poor communities. Among these are water saving methods such as treadle pumps, bucket and drip irrigation and water-harvesting initiatives, not all suitable to support IIA activities.
IRRI

The goal of the International Rice Research Institute is to "to improve the well-being of present and future generations of rice farmers and consumers, particularly those with low incomes" by "generating and disseminating rice-related knowledge and technology of short- and long-term environmental, social, and economic benefit and helping enhance national rice research and extension systems". An International Platform for Saving Water in Rice (IPSWAR) was created in April 2002 and IRRI's scientists have carried out experimental work to develop field methods to reduce water use (Tabbal et al., 2002) and to assess the effect of irrigation savings on rice production (Bouman and Tuong, 2001).

However, concerned with growing demand for rice, the same scientists did not advocate irrigation saving methods at all cost (Bouman and Tuong, 2001). They found that, although water productivity (rice produced per unit of water applied) was increased, land productivity (rice yields) was reduced, and unless the water saved was used to irrigate previously un-irrigated land, field-level water savings could potentially threaten global rice production. Tabbal et al. (2002) pointed out that field-level water savings do not necessarily lead to water savings at the system level as downstream water can be re-used for irrigation or other purposes, and that the massive adoption of water saving methods in rice farming could result in drops in groundwater tables and increased percolation losses. In the past, IRRI together with the WorldFish Center and national partners has supported integrated irrigation aquaculture through the Asian Rice Farming Systems Network.

WorldFish Center

In the face of depletion of natural fish stocks and the reliance of populations on fish for food and employment, the WorldFish Center's (formerly known as ICLARM) mission is to "reduce poverty and hunger by improving fisheries and aquaculture" by being the "science partner of choice for delivering aquaculture and fisheries solutions in developing countries". This can be carried out through increases in productivity of fisheries and aquaculture systems, protecting the aquatic environment, saving aquatic biodiversity and improving policies for the sustainable development of aquatic resources. Research is carried out on the integration of freshwater fisheries and aquaculture in land and water management practices. The promotion of community-based rice-fish culture on the floodplains of South and Southeast Asia has been a success and has benefited the landless poor (WorldFish Center, 2001a; 2001b). Fishponds used to irrigate vegetables were also developed in Malawi through farmer-scientist research partnerships (WorldFish Center, 1999). A new programme for Africa and West Asia was set up in April 2001 targeting the fisheries of three priority aquatic production systems (rivers and floodplains, lakes and reservoirs and coastal areas) and aquaculture (WorldFish Center, 2001c).

WARDA

WARDA is the Africa Rice Center. Its mission is to "contribute to poverty alleviation and food security in Africa, through research, development and partnership activities aimed at increasing the productivity and profitability of the rice sector in ways that ensure the sustainability of the farming environment". With its rainfed rice, irrigated rice and rice policy and development programmes, WARDA's research aims to increase the sustainable productivity of intensified rice farming systems in the arid, semi-arid, warm sub-humid and warm humid tropics of West Africa.

West African farmers in rainfed areas cannot grow the semi-dwarf rices, which were developed by IRRI and have revolutionized production in Asia, because they are not adapted to local conditions. The development of new rice varieties by WARDA in the 1990s lead to the release of the "New Rice for Africa" (NERICA), a crossing of indigenous African rice with exotic Asian rice, resistant to diseases, drought and soil iron toxicity. Its adoption is spreading fast across the drylands of the African continent through the African Rice Initiative. WARDA is, in collaboration with IWMI, part of the System-wide Initiative on Malaria and Agriculture (SIMA), which aims to develop and promote methods and tools for malaria control through improved agricultural practices and proper management and utilisation of natural resources. This includes, for example, the use of intermittent irrigation to reduce mosquito breeding in flooded rice, or the use of crop pest predators as an integrated pest management technique. At the same time WARDA is interested in exploring the potential...
of integrating aquaculture into irrigated rice production systems (FAO/WARDA, 2005).

**IVC**

The Inland Valley Consortium (IVC) is a research consortium hosted by WARDA. It is "a platform for regional cooperation to promote the sustainable development of inland valleys" and "a partnership of diverse institutions to create critical mass and jointly plan and implement an integrated research program of common interest". Consortium members work towards the characterisation of the constraints and technical needs for inland valley development, development of low-cost water management systems and testing of agronomic technologies.

**For or against IIA?**

None of the above organizations has developed specific policies nor carried out research specifically related to the development of integrated irrigation and aquaculture activities. If each has its own agenda and specific approaches to achieve its mission, they nonetheless all share the common goal of improved well-being for households and environmental sustainability across the world. This supports the current call for integrated approaches to water management. Regardless of how irrigation is practiced, its development is no longer seen in isolation from other issues but in conjunction with broader perspectives of increased food production, environmental sustainability and poverty alleviation. While some institutions are focusing on water and its management, others are emphasising its specific uses (e.g. irrigation for rice production), which, if taken narrowly, could conflict with the promotion of multiple water use policies in irrigated rice growing areas.

However, no mandate stands against the promotion of IIA: the limitation of water savings in farming is acknowledged and multiple water users platforms are promoted to overcome single purpose management of irrigation systems (Meinzen-Dick and Bakker, 1999). Local contexts have to be taken into account to determine opportunities for irrigation and aquaculture. In areas where, for example, markets for fish and fish products are strong, and demand high, water saving irrigation technologies may be less appropriate than the promotion of IIA activities. In addition, IIA may not be contradictory to irrigation control methods as water from fish ponds can be used in irrigation drips, as illustrated in Prinsloo et al. (2000).

**REFERENCES**


Summary

Using a sustainable livelihoods approach (SLA) and the Code of Conduct for Responsible Fisheries (CCRF) as tools, the Sustainable Fisheries Livelihoods Programme (SFLP) stresses community participation to ensure holistic and sustainable development that will favour strategic, technical and financial partnerships. Programme activities, which could have a direct link to integrated irrigation and aquaculture, were conducted as part of poverty-profile studies, and were based on a strategy for the sustainable development of fisheries in Burkina Faso. Poverty-profile studies were conducted as part of a pilot project on fisheries co-management in inland waters. These studies were conducted within fisheries communities along the Bagré and Kompienga reservoirs in Burkina Faso, Lake Kossou in Côte d’Ivoire, Lake Volta in Ghana, and the Sélingué reservoir in Mali, where fisheries and irrigated agriculture are practised. These systems cover vast areas that could offer riverine communities the opportunity to diversify their livelihoods through the integration of aquaculture and irrigation. By linking these activities to a strategy for the development of enhanced fisheries, it would appear there is a need for an approach that will integrate government agriculture policies with small-scale irrigation, fisheries (including aquaculture), food security, land tenure, and poverty reduction efforts. Given this situation, it is necessary to prioritise: (i) the creation of a body to oversee the management of local-level water body resources; (ii) strengthening organizational and technical capacities to improve participation in planning, resource management, and local development; and (iii) the development of an effective information system to facilitate the collection of useful data to be disseminated to both professionals and policy makers.
INTEGRATING AQUACULTURE INTO AGROECOSYSTEMS IN WEST AFRICA: THE ROLES OF WARDA – THE AFRICA RICE CENTER AND THE INLAND VALLEY CONSORTIUM

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Abstract

WARDA – The Africa Rice Center is an international research center working on food security in Africa through collaborative research on rice farming systems. Among the networks hosted by WARDA is the Inland Valley Consortium (IVC) which aims at developing suitable technologies and knowledge bases for integrated agricultural land use management and operational support systems for sustainable use of inland valleys in Africa. Integration of aquaculture into rice-based farming systems in Africa fits into the strategies of WARDA and the IVC's which makes them valuable partners for potential integrated irrigation–aquaculture initiatives.

Introduction: WARDA and the IVC

WARDA - The Africa Rice Center is one of the 16 international agricultural research centers supported by the Consultative Group on International Agricultural Research (CGIAR). However, WARDA is also an autonomous intergovernmental research association of African member states, a fact that distinguishes WARDA from her sister organizations. WARDA's mission is to contribute to poverty alleviation and food security in Africa, through research and development activities and partnerships aimed to increase the productivity, efficiency and profitability of the rice sector in ways that ensure the sustainability of the farming environment.

The modus operandi of WARDA is partnership at all levels. WARDA’s research and development activities are conducted in collaboration with various stakeholders — primarily the national agricultural research systems (NARS), academic institutions, advanced research institutions, farmers’ organizations, non-governmental organizations and donors — for the benefit of African farmers, mostly small-scale producers, as well as the millions of African families for whom rice means food.

WARDA hosts three major networks: first, the just mentioned African Rice Initiative (ARI), secondly, the Regional Rice Research and Development Network for West and Central Africa (ROCARIZ), and last but not least the co-organizer of this workshop: The Inland Valley Consortium (IVC).

WARDA has its headquarters in Côte d’Ivoire and regional research stations at St-Louis in Senegal, at the International Institute for Tropical Agriculture (IITA) in Ibadan, Nigeria, and at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) research station at Samanko, just outside Bamako.

Inland Valley Consortium (IVC)

The Inland Valley Consortium (IVC) was established in 1993 to respond to social and environmental challenges in West Africa, related to poverty and food security on the one hand and degradation of the natural resource base on the other. Membership grew gradually to a total of 10 West African countries (Benin, Burkina Faso, Cameroon, Côte d’Ivoire, Ghana, Guinea, Mali, Nigeria, Sierra Leone and Togo). Eight international research and development institutions are involved in IVC: Conference of Agricultural Research Directors in West and Central Africa (CORAF); Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), France; United Nations Food and Agriculture Organization (FAO); International Institute for Tropical Agriculture (IITA); International Livestock
Research Institute (ILRI); International Water Management Institute (IWMI); The Africa Rice Center (WARDA) and Wageningen University and Research Center (WUR), the Netherlands. The Consortium is one of the seven ecoregional programs of the CGIAR and is convened by WARDA. The second phase of the Consortium started in 2000.

The overall goal of the Inland Valley Consortium is to develop, in concerted action and using an agro-ecological approach, suitable technologies and knowledge bases for integrated agricultural land use management and operational support systems for intensified but sustainable use of inland valleys in Africa, through a combined effort of national and international agricultural institutions, development agencies and other stakeholders.

During Phase I of the IVC (1994-1999) extensive biophysical and socio-economic characterisation work was done in all countries and at 18 key sites. Research objectives in Phase II (2000-2004) focus on four main themes:

• Characterisation of inland valley land use dynamics;
• Development and evaluation of technologies for improved production systems and natural resources management;
• Socio-economic and policy aspects of improvements in inland valley land use systems; and
• Technology dissemination processes and impact pathways for inland valley development.

**WARDA and IVC's roles in developing integrated irrigation-aquaculture (IIA) systems**

The topic of this workshop ties well with WARDA’s mission statement of alleviating poverty through increasing food security and productivity. Incorporating aquaculture into rice-based systems increases productivity as well as output diversity, and also contributes to income generation. The workshop also connects very well to WARDA’s modus operandi. WARDA works through partnerships, and especially through its networks. The FAO has been a member of IVC since 1997. The fact that WARDA was established as a regional, inter-governmental association meant that partnership, collaboration and capacity building were, from the beginning, at center stage. The basic proposition was, and remains, that faced with a set of common problems, and with constrained human and financial resources, significant benefits can be derived from effective regional collaboration.

These benefits take several forms. In terms of the researchers themselves, the collaborative model can help break the intellectual and professional isolation that often comes with being the only rice breeder, agronomist, irrigation or aquaculture specialist at a particular research station or in a national program. Being a member of a functional research network is an important factor in motivating researchers to analyze, write-up and present their work to their peers. For the national research systems, regional collaboration provides access to ideas, funding opportunities, research outputs and lessons that might otherwise remain out of reach.

The main research effort in Phase I of IVC was targeted on agro-ecological characterization. A common multi-scale characterization methodology has been developed and adopted by the IVC partners to conduct reconnaissance, semi-detailed and detailed characterization studies. All IVC member countries have completed the agro-ecological characterization.

Over 100 research activities has been funded by the Consortium through small research grants (US$ 3 000 to 25 000 per activity). These small projects not only covered the full range of IVC’s research themes, but also a number of more-specific studies were implemented, such as the testing of DIARPA (a rapid diagnostic appraisal system for water management), the role of female farmers in inland valley cultivation, costs of water management systems, evaluation of existing water management systems, indigenous knowledge on soil conservation, functions of natural vegetation in inland valleys, etc.

All countries have completed national state-of-the-art studies on inland valley research and development. The main goal of these studies is the inventory of technologies available at the national level. An overall synthesis is being compiled, in the form of a catalogue of technologies from which partners may choose the appropriate technologies for testing in the key sites.

IVC's characterization studies conducted so far have considerably increased the understanding of the characteristics and dynamics of inland valley agro-ecosystems. Also, IVC activities in member countries have contributed towards increased awareness at the scientific and policy level about the agricultural potentials of inland valley agro-ecosystems.
THE WORLDFISH CENTER AND ITS RELEVANCE FOR INTEGRATED IRRIGATION AND AQUACULTURE

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Abstract

The WorldFish Center (formerly known as ICLARM – the International Center for Living Aquatic Resources Management) was established in 1977 and since the mid 1980s has conducted research on rice-fish systems which are an essential part of integrated agriculture-aquaculture (IAA), and more specifically, integrated irrigation-aquaculture (IIA) farming systems. Its current mandate is to strive for more equitable distribution of the benefits derived from fishing and aquaculture, general improvements in the livelihoods of fishing and fish farming households; access to fish at affordable prices for poor consumers; reduced environmental impacts of fishing; increased number of fish farmers; and the protection of aquatic biodiversity. The strategic plan 2000-2020 places a high priority on the development of freshwater pond aquaculture, including rice-fish farming in irrigation systems and in fenced-in enclosures in agricultural lands. Although more widely developed in Asia, previous studies on rice-fish culture activities took place in Africa (Malawi and Ghana). The number of initiatives by the WorldFish Center and collaborative partners related to IIA (rice-fish farming in large-scale and small-scale irrigation systems, community-based fish culture) are being increased to monitor the technical feasibility and household adoption of IIA activities in Africa.

Mandate

The WorldFish Center was established by the Rockefeller Foundation in 1977 as the International Center for Living Aquatic Resources Management (ICLARM) with a mandate to conduct strategic research on issues relevant to the poor in tropical developing countries. In 1992 the Center became one of 16 international centers (also referred to as “Future Harvest Centers) under the Consultative Group on International Agricultural Research (CGIAR). The goals of the Center are to strive for more equitable distribution of the benefits derived from fishing and aquaculture, general improvements in the livelihoods of fishing and fish farming households; access to fish at affordable prices for poor consumers; reduced environmental impacts of fishing; increased number of fish farmers; and the protection of aquatic biodiversity.

The main foci of technical research have been on aquaculture of freshwater and coastal organisms and the assessment and management of coastal and continental fisheries. In addition, research is conducted on the genetic improvement of cultivated fish species, such as tilapia and carp, and the management of aquatic biodiversity. Overarching, and closely involved in all technical fields, is policy research, legal and institutional governance and impact assessment and priority setting. In recent years, the latter research has developed into the largest programme.

The WorldFish Center presently has nine country offices with posted staff in the Pacific, Asia, Africa and the Caribbean, including its headquarters in Penang, Malaysia. As of 2003, the Center has ongoing projects through formal agreements with around 250 partners in 51 countries (WorldFish Center, 2003a). The Center’s core competencies (WorldFish Center, 2003b) are:

- Facilitating research;
- Stock assessment of coastal fisheries;
- Culture and stock enhancement of coral reef invertebrates;
• Global databases for managing aquatic resources;
• Methods for developing improved fish strains;
• Smallholder aquaculture development;
• Watershed approach to aquatic resource management;
• Socioeconomic research including institutional and governance analysis of the fisheries sector in developing countries.

As a key mode for the operation and implementation of its mission, the Center engages in formal partnerships with numerous types of stakeholders, for which it has a formal partnership policy. The Center has numerous multi-partner projects, and several multi-country, multi-disciplinary projects. It is in the process of adopting a focus on impact pathways for research, and expects that in the future, partnerships and networks will change to include more non-research partners to improve uptake and dissemination, including a wider range of disciplines. The partnerships are grouped into:

• National Agricultural Research and Development Systems (NARS in the CGIAR lexicon);
• Non-Governmental Organizations (NGOs);
• Individual scientists/researchers;
• Regional and international organizations;
• Advanced Scientific Institutions (ASIs) usually located in industrialized countries;
• Farmers and fishers.

**Strategic plan**

The WorldFish Center’s Strategic Plan for 2000-2020 (ICLARM, 1999) places a high priority on the improvement of freshwater pond aquaculture, which includes rice-fish cultivation in irrigation systems and fenced-in enclosures in temporarily flooded agricultural lands.

**Freshwater pond aquaculture**

Total aquaculture production from tropical developing countries and East Asia in 1994 amounted to 15.1 million tonnes of which approximately 10.4 million tonnes were derived from freshwater aquaculture in ponds. Tilapia production doubled between 1988 and 1994 whilst carp production is suggested to have risen seven fold. Farmers can usually exercise rights over ponds and they are the most easily “manageable” of the production systems currently in use. New technology, if made available and applied to fish of value to the poor, can increase production efficiency so that further growth in output is likely. The main constraint to improved adoption in the smallholder sector is low yields due to lack of appropriate management methods and high feed costs. Higher levels of intensification suffer from lack of a systems approach, high disease incidence and inequity in the distribution of benefits. The WorldFish Center will concentrate on:

• Development of appropriate combinations of technologies for improved management, i.e. nutrition and reproduction, with an emphasis on genetic enhancement of food fish species;
• Integration of aquaculture methods into farming systems;
• Ex-ante estimation of the socio-economic impacts of aquaculture that might influence adoption and the marketable supply of improved fish.

The WorldFish Center will conduct its strategic genetic enhancement research increasingly through its Egyptian aquaculture facility. Other research will focus on field-level assessment and introduction of integrated aquaculture systems (including rice-fish) to those countries in Asia and sub-Saharan Africa with high concentrations of poor people and high potential for aquaculture development. Over the 20-year strategic planning period, the WorldFish Center will also evaluate the development of aquaculture systems with a focus on maximizing benefits accruing to poorer sectors of society, including both consumers and producers. These will be largely in the form of increased production, improved nutrition and better income for farm households, and affordable high-quality protein for consumers. Additional impacts are expected from improved efficiency of land and water use through integration.

**Streams, rivers and floodplains**

Lotic ecosystems represent a new area of work for the WorldFish Center (Dugan 2003). New knowledge about the importance of streams, rivers and floodplains show that large numbers of poor people depend upon these highly variable resource systems to support complex livelihood strategies. Our analysis suggests that
total productivity from lotic ecosystems in developing countries increased from approximately 3.5 million tonnes to 4.3 million tonnes in 1994. It is widely accepted that these may be large underestimates due to having left out the subsistence catch. Threats to this resource system include reduction in catches, and loss of biodiversity through habitat alteration. There is a generally weak knowledge base about access rights and the potential for enhancing production within floodplain systems, resulting in inappropriate policies and weak institutional support.

Focusing on the resources and the people who use them, WorldFish will seek to arrest loss in biodiversity, increase per capita fish production, and develop the research methods and data needed to improve policy and build an adequate institutional framework to support sustainable resource management. Improved access to and use of floodplain resources are anticipated to have relatively high gender benefits.

Activities under the Strategic Plan will concentrate on the development of appropriate ecological-economic models (including people as an integral part of the ecosystem analysis) and integration of ecological, institutional and policy analyses. Central to this work will be the valuation of resources, development of action plans to mitigate threats, and the elaboration of technical, policy and legal frameworks under which access can be allocated among competing resource users.

Medium term plan 2003-2005

During the Medium Term Plan (MTP) period (WorldFish Center, 2002) "..., a new research initiative into the improvement of fish production (naturally occurring and stocked) in seasonally fenced areas will be implemented. ... In collaboration with the national partners ..., trials will be conducted on community-based fish culture in seasonally flooded and fenced areas, following the achievements and experiences gained from recent work in Bangladesh and Viet Nam” (WorldFish Center, 2003c).

During the MTP period, social science studies will examine the adoption patterns and agreed institutional arrangements among communities already implementing the community-based fish culture approach. The expansion of this community-based aquaculture approach in Bangladesh and Viet Nam will be monitored.

Past and ongoing activities by research programmes

The publications produced by the Center on Integrated Agriculture-Aquaculture (IIA) since 1990 include outputs (articles, reports, reviews, conference and workshop proceedings) of research on rice-fish culture and floodplain aquaculture.

A large project on Community-Based Fisheries Management (CBFM) in Bangladesh is studying, on a large scale, the different approaches to community and policy and the policy and legal environment required to enable its sustainability (e.g., Sultana and Thompson, 2003; see also numerous other contributions). Management of dry-season refuges or protected areas, and restocking of selected waterbodies are areas related to IIA.

Activities in Africa: past, ongoing and planned IIA

In early 2003, the Center released its plan for work in Africa (Dugan, 2003; WorldFish Center, 2003d), which includes initiatives for increased utilization of existing perennial and seasonal waterbodies and of traditional and more technical water management systems, such as irrigation.

In Malawi, Chikafumbwa (1994) studied the rice-fish culture activities of around 1 500 farmers, and the opportunities for their expansion, and pointed out the importance of taking an holistic view of the farming system so as to identify opportunities for integration. Indeed, working with farmers to understand the role that aquaculture plays on small-scale farms has now become a key aspect of the Center’s work in Africa (Brummett & Noble 1995). As part of a research project by the Water Research Institute and the WorldFish Center on the potential of IIA to enhance traditional smallholder farming systems in Ghana, a trial was conducted on the feasibility of rice-fish culture in a large irrigation scheme of the Irrigation Company of the Upper East Region, ICOUR (Kumah et al., 1996).

A project implemented by FAO with support from IFAD on introducing IIA in smallholder irrigation schemes in southern Africa (Malawi, Zambia and Zimbabwe) will have inputs by the WorldFish Center at the Malawi site on monitoring of household level impact of such technology introductions.

Recently, the WorldFish Center established
a new approach to community-based fish culture (Dey and Prein, 2000; 2003; in press). As part of a possible new project under the CGIAR Challenge Program Water and Food, the approach is planned to be expanded in four countries in Asia (Viet Nam, Cambodia, Bangladesh and India), and possibly Mali as a first site in Africa.\(^1\) Other sites in Africa are under consideration, e.g. eastern Guinea and northeast Nigeria.

References


WorldFish Center. 2003b. Our commitment and capabilities. Penang, Malaysia.


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\(^1\) Editors’ note: This proposal has been approved by the CGIAR and the project has become operational in 2005 and the WorldFish Center has teamed up with WARDA-IVC and FAO to assess the opportunities for implementing the approach in Mali.
WAGENINGEN UNIVERSITY AND RESEARCH CENTER’S NETWORKS AND THE FUTURE ROLE OF INREF-POND IN INTEGRATED IRRIGATION AND AQUACULTURE IN WEST AFRICA

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Abstract

Wageningen University and Research Center (WUR) aims at contributing to international development through collaborative projects with partner institutes and networks in the South. The Interdisciplinary Research & Education Fund supports six research programmes with about 50 PhD projects. In West Africa, there are projects in Burkina Faso, Ghana and Benin. WUR is also involved in the Inland Valley Consortium and in research projects on sustainable management of inland valleys and wetlands. A project with particular relevance for integrated irrigation and aquaculture is the INREF-POND project which focuses on developing fish breeds and optimizing nutrient flows for integrated aquaculture systems.

Introduction

Wageningen University and Research Center (Wageningen UR) consists of Wageningen University; the Dutch Agricultural Research Institutes, Laboratories, and Centers; and the International Agricultural Center. This last institute includes the newly-created North-South Center that promotes collaboration between Wageningen UR and partner institutes and networks in the South. This last institute is part of Wageningen UR’s commitment to mobilise its knowledge and expertise in assisting the South to develop and improve livelihoods sustainably. One of the North-South Center’s means to attain this overall goal is the Interdisciplinary Research & Education Fund (INREF). Currently INREF supports six research programmes with about 50 PhD projects.

Through education and research Wageningen UR intends to contribute to the development of Integrated Irrigation-Aquaculture (IIA) and Integrated Agriculture-Aquaculture. The major network of Wageningen UR consists of its MSc and PhD graduates. However, the best possibility for future support is through collaborative research projects. This paper lists the contacts of Wageningen UR in West Africa through projects and networks, presents the objectives and research-projects of INREF-POND and clarifies its future link to West-Africa.

Contacts of Wageningen UR in West Africa

At present Wageningen UR has contacts in West Africa through three bilateral research/education projects and three collaborative research networks. Some of these are related to the topic of IIA. Two of these bilateral research projects are INREF-funded from 2002 to 2006. In 2004, INREF-POND plans to start research in Cameroun. Details on the project can be found on the website of the North-South Center (www.north-south.nl).

Currently Wageningen UR participates in the projects:

1. “Food technology and human nutrition” and “Centre d'études pour l'aménagement et la protection de l'environnement”, which are carried out with the University of Ouagadougou and funded through NUFFIC (Netherlands University Fund for International Collaboration).
2. "Convergence of Science", an INREF project that is a co-operation between two Wageningen Graduate Schools and various partners in Ghana (a.o. University of Legon, FAO, World Vision, and others) and Benin (Université National de Bénin, Institut National des Recherches Agricoles du Bénin (INRAB), IITA, and others).

3. "From natural resources to healthy people", an INREF project conducted in Burkina Faso, Ghana, and Benin. This project is a co-operation between two Wageningen Graduate Schools and various partners in the region, for example Université National de Bénin, University of Development Studies in Ghana, and the Universities of Ouagadougou and Bobo Dioulasso in Burkina Faso.

At present Wageningen UR participates in the following networks:

1. The Inland Valley Consortium, which is a regional partnership of ten countries in West Africa and seven international research institutions, including Wageningen UR. This programme is financed by the Dutch and the French Governments from 2000 to 2004.

2. "Sustainable use and conservation of the Wetlands of Mali, with a special focus on the Inner Niger Delta", which is a project of Wetlands International and the Ministère de l’Equipement, de l’Aménagement du Terroire, de l’Environnement et l’Urbanisme (Mali). Some of the other partners are: Institut d’Economie Rurale (Mali), IUCN and Wageningen UR (Alterra).

3. VINVAL, which focuses on the ecological and production functions of natural and fallow vegetation in inland valleys. It is funded by the European Union and the Dutch Ministry of Agriculture from 2001 to 2005. The project is carried out in Ghana and Burkina Faso. Partners involved are Alterra and LEI from Wageningen UR, and several institutes from Germany, Italy, Ghana and Burkina Faso.

The INREF-POND project

Available improved fish breeds and fish feeding strategies were mostly developed for high-input aquaculture systems. These feeding strategies are too expensive for small farmers and it is doubtful whether the improved fish breeds can perform optimally in low-input integrated farming systems using waste inputs. The INREF project "Program for Optimisation of Nutrient Dynamics" (INREF-POND), intends to contribute to the development of more sustainable integrated livestock–fish–crop farming systems in order to improve farm household livelihood and well-being. More specifically its goals are to:

1. Quantify nutrient dynamics in such integrated agriculture-aquaculture farming systems, using fish breeds especially selected for high and low input environments.

2. Identify the most optimal combination of components that contributes optimally to improved systems' resilience and ecologic, economic, and social sustainability.


The partners in this program are the WorldFish Centre, through its Regional Center for Africa and West Asia in Egypt and the College of Agriculture, Can Tho University, Viet Nam. From Wageningen University the groups of Aquaculture & Fisheries, Animal Production Systems and Animal Breeding & Genetics from the Department of Animal Sciences, and the Laboratory of Soil Science and Geology from the Department of Environmental Sciences participate. At present five PhD projects are running:

1. Selection of Tilapia (*Oreochromis niloticus* L.) in high and low input environments;

2. Effect of partner choice on reproduction in natural mating systems;

3. Quantification of the effect of high and low input systems on the nutrient cycle;


5. Oxygen as a determinant of fish production in aquaculture systems.

Two other projects recently started. The first will study the socio-economic context of aquaculture development in Egypt. The study on the adoption process of integrated livestock–fish–crop farming systems just started and plans to work in Viet Nam as well as in Cameroon. The work in Cameroon is the bridge of INREF-POND to sub-Saharan Africa.
THE UNESCO-IHE INSTITUTE FOR WATER EDUCATION: CAPACITY BUILDING AND RESEARCH IN INTEGRATED WATER RESOURCES MANAGEMENT

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Abstract

UNESCO-IHE in Delft, The Netherlands is an international institute for capacity building and training in water and environmental management and infrastructure. Its activities include implementation of education and research programmes and development of partnerships and networks of institutions and professionals involved in the water sector. UNESCO-IHE's international postgraduate programme consists of MSc, PhD, short courses and tailor-made training. Collaborative research programmes often contribute to capacity building of partner institutions through integration with MSc and PhD training.

UNESCO-IHE was established in 1957 as an international institute for training hydraulic engineers, funded by the government of The Netherlands. In 2001, it was established as the UNESCO-IHE Institute for Water Education with a mandate to strengthen and mobilise the global educational and knowledge base for integrated water resource management and to contribute to meeting the water-related capacity building needs of developing countries and countries in transition. UNESCO-IHE's mission therefore is to contribute to the education and training of professionals and build the capacity of knowledge centres and other organisations in the fields of water, environment and infrastructure.

To achieve this, UNESCO-IHE works with partners to do research in the context of integrated water resources management and aims at global dissemination and knowledge sharing. Activities include: (1) implementation of education, training and research programmes; (2) establishing and fostering partnerships between academic centres and professional organizations that offer education, training and research programmes at the local or regional level; (3) developing and maintaining global networks of collaborating institutes, and encouraging active participation in these networks of all professionals involved in the water sector.

UNESCO-IHE counts five academic departments: Water Engineering, Environmental Resources, Municipal Infrastructure, Management and Institutions, and Hydro-informatics and Knowledge Management. Currently the number of academic staff is about 90. The institute is based in Delft, The Netherlands.

The UNESCO-IHE Alumni network counts more than 12 000 alumni representing more than 120 countries. Shortly, UNESCO-IHE will launch its Virtual Alumni Community portal, which will be a knowledge platform for water professionals. Among the networks initiated by UNESCO-IHE is the PoWER (Partnership for Water Education and Research) network through which partnerships of international and national organizations and institutions active in water resource management are initiated and supported.

The international postgraduate programme consists of an international Masters programme (18 month MSc), a PhD programme, short courses and tailor-made training. There are four international Masters programmes, each with a number of specializations: Water Management, Water Science and Engineering, Environmental Science, and Municipal Water and Infrastructure.

UNESCO-IHE's research projects contributes considerably to training and capacity building of the partner institutions.
E.g., in the Fingerponds project (Chapter 11, this volume) two research assistants in the African partner countries are registered as PhD-students at UNESCO-IHE. In addition, several MSc-projects are being carried out under the project (see Table 1).

UNESCO-IHE is involved in a number of networks in the area of integrated water resource management. It has recently received a small grant to set up an internet-based knowledge platform for wetland professionals, in collaboration with the Wetlands Advisory and Training Centre (WATC) of the Netherlands Ministry of Transport, Public Works and Water Management, Wetlands International and the Netherlands Water Partnership (www.wetlandprofessionals.org). This platform will facilitate communication between wetland researchers and managers and promote learning and the flow of wetland knowledge. The partners in the Fingerponds and Ecotools (another EU-funded wetland research project in East Africa) projects will use the platform to exchange information about the project and share results with other wetland professionals.

Table 1. PhD and MSc-projects carried out under the auspices of the Fingerponds project (2003).

<table>
<thead>
<tr>
<th>Project title</th>
<th>Name of student</th>
<th>Degree type, end year, institution</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>Utilization of wetlands through integration of fingerponds into riparian farming systems in East Africa</td>
<td>Julius Kipkemboi</td>
<td>PhD, 2006, UNESCO-IHE</td>
<td>Kenya</td>
</tr>
<tr>
<td>The dynamics and importance of manure nutrient applications on phytoplankton and periphyton communities in an integrated aquaculture system in Uganda.</td>
<td>Rose Kaggwa</td>
<td>PhD, 2006, UNESCO-IHE</td>
<td>Uganda</td>
</tr>
<tr>
<td>Fish stocks and comparative yields from East African self-stocked fingerponds</td>
<td>Hieromin Lamtane</td>
<td>PhD, 2006, King's College, London</td>
<td>Tanzania</td>
</tr>
<tr>
<td>Performance of substrates in periphyton production in fingerponds</td>
<td>Deborah Kasule</td>
<td>MSc, 2004, Makerere University, Kampala</td>
<td>Uganda</td>
</tr>
<tr>
<td>Effects of organic manure on sediment characteristics, nutrient dynamics and benthic macroinvertebrates composition in Lake Victoria fingerponds</td>
<td>Cyrus Kilonzi</td>
<td>MSc, 2003, UNESCO-IHE$^a$</td>
<td>Kenya</td>
</tr>
<tr>
<td>The phytoplankton primary productivity, biomass (Chlorophyll a) and species composition in the fingerponds (Uganda)</td>
<td>Grace Ssanyu</td>
<td>MSc, 2003, UNESCO-IHE$^a$</td>
<td>Uganda</td>
</tr>
<tr>
<td>Extent of plankton colonisation (spatial and temporal) in fingerponds. Case study of Uganda fingerponds</td>
<td>Austin Mtethiwa</td>
<td>MSc, 2003, UNESCO-IHE</td>
<td>Uganda</td>
</tr>
</tbody>
</table>

$^a$In collaboration with Institute of Limnology, Mondsee and University of Natural Resources and Applied Life Sciences, Vienna, Austria.
DEVELOPMENT OF INTEGRATED IRRIGATION AND AQUACULTURE IN WEST AFRICA: THE WAY FORWARD

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Abstract

This chapter provides an overview of critical elements for the promotion of integrated irrigation-aquaculture (IIA) in West Africa. It emphasizes that IIA should be interpreted more broadly than merely in terms of aquaculture in irrigation schemes. Options for integration of fish production (capture fisheries and aquaculture) with production of crops exist in a wide range of environments, from river floodplains and lake basins to inland valleys and irrigation systems. The constraints for development of IIA are different for these different environments and also depend on local conditions. Many detailed constraints for countries in the West Africa region were mentioned in the preceding chapters. Some key factors for successful adoption of IIA across a wide range of environments are reiterated. Participation and empowerment of the resource users (farming and fishing communities) in development of new technologies is crucial for ensuring relevance and making use of existing knowledge about resource use. Cross-sectoral, multi-disciplinary collaboration is needed to bring together the various agencies involved (water, agriculture, environment, fisheries, etc.) at local, national and regional levels. Improved knowledge management is needed to ensure the generation, storage and sharing of knowledge and information on IIA. Innovative ways of working together and modern information and communication technology should be used to support this process through networking.

Integrated irrigation and aquaculture development potential: a synopsis

The results of various meetings and workshops on IIA (Moehl et al., 2001; FAO/WARDA, 2005) and the contributions in this book show the general agreement on the significant potential for developing integrated aquaculture activities in irrigation networks. This potential should be explored, particularly in irrigated systems dominated by rice production. But why is the technology not spreading like wildfire when it has so much potential and so many obvious advantages?

In most studies and reviews, IIA has been interpreted as a combination of aquaculture in irrigation schemes. However, there is a range of environments in which people grow crops or produce fish, and fish production can be enhanced in all these environments ranging from floodplains, lake basins and inland valleys without formal governance arrangements to large-scale irrigation systems with official management authorities. In between, a variety of crop production systems can be found, from different forms of flood-recession agriculture in wetlands through rainfed upland agriculture to irrigated crops. Likewise, fish production can range from unregulated capture fisheries, through different forms of management and enhanced fisheries, to aquaculture with fully controlled culture cycles and clearly defined ownership of stocks. The contributions in this volume show that IIA development efforts should not be limited to “formal” aquaculture in “formal” irrigation systems. A lot of the potential increases in crop and fish production in West Africa lies in enhancing production from extensive, seasonal wetland agriculture and fisheries. Technologies for enhancing such traditional systems should be developed further, building on valuable local knowledge and incorporating concepts from other parts of the world. IIA in this wider sense is a set of technologies for integration of fish production into crop production systems. IIA then becomes part of a natural resources management approach in which water and nutrients are managed wisely for the benefit of the resource users and without detrimental effects on the environment.
Many of the constraints that have been listed for the various environments are not particular to IIA but rather to the development of aquaculture and agriculture in general. The recent recommendations for aquaculture development in sub-Saharan Africa (Moehl et al. 2005) are therefore also valid for IIA development. Many recommendations for dissemination of integrated agriculture-aquaculture in Asia contain valid points for IIA development. Many recommendations for the various environments are not complete. An approach to fish farming development at the irrigation system level has been proposed, as this will alleviate constraints that are inevitably encountered if aquaculture is developed in only one irrigation system component (Fernando and Halwart, 2000, 2001).

For individual countries, IIA development requires a sequence of developing a national strategy, identifying high potential areas, identifying suitable production systems, ensuring an adequate number of development participants in a specific zone, and targeting well-focused participatory extension services to these selected groups regularly and over a substantial period of time. It also requires efforts in data collection and documenting successful examples so that suitable technologies can be scaled up, preferably with the involvement of the early adopters. Advice and support mechanisms will be needed at local, national and sub-regional or regional levels so that communities and countries can benefit from each other’s knowledge and experience. The recent developments initiated in the Committee for Inland Fisheries of Africa (CIFA) for the establishment of an organization for Africa similar to the Network of Aquaculture Centers in Asia-Pacific (NACA) in Asia will be critically important in successful networking.

Specific recommendations for IIA development by key environment (irrigated systems, floodplains, inland valley bottoms) and the type of constraint/intervention (technical, institutional, economic, social, environmental) have been put forward (FAO/WARDA 2005). It is obvious that technical difficulties make up only a small portion of the constraints that have to be overcome. Much can be done to create an enabling environment for IIA development particularly on the institutional side, and governments, non-governmental organizations and the private sector should work together in this direction. The following paragraphs provide an overview of critical elements that need to be considered in the promotion of IIA based on FAO/WARDA (2005) and contributions in this volume. Three main issues are highlighted, roughly corresponding to the local, national and (sub-)regional levels: locally, the need for participation of targeted communities and support for their efforts; at a national level, the need for an integrated, multisectoral approach; and at a (sub-)regional level, the need for networking and knowledge management.

Participation and institutional support for local development

IIA development should take a participatory approach, involving the target communities who are expected to adopt IIA technology right from the start of the process in identifying promising technologies and culture systems, developing and adapting technology to local conditions, incorporating local and traditional knowledge into innovative techniques, and disseminating successful approaches to other prospective adopters. Choosing the right target groups is essential. Prevalence of local customs, attitudes to work and innovations, and ethnic origin are factors that can influence the success and uptake of IIA activities. Understanding and sensitivity to these differences and their influence on perception of IIA is a prerequisite. Inter-ethnic relations are equally important and will condition the long-term success of IIA, especially in areas where land is shared by several ethnic groups and rises in land value following the introduction of aquaculture could lead to possible conflicts.

The potential role of farmers in dissemination of IIA technology in West Africa is not completely clear. Farmer-to-farmer training can be inefficient in sub-Sahara Africa because of the long distances travelled and the low number of participants. Conversely, group training was more appropriate and well received (Harrison et al. 1994). Extension of IIA should focus on the groups and systems in high priority areas as identified in the national aquaculture development strategy. Trainers need to spend a considerable amount of time with the farmers, usually at least once a week over a whole season. Also, considerable time is required for farmers/households to become familiar with IIA innovations and new land and water management techniques. A Farmer Field School curriculum that combines integrated pest
management, aquaculture and rice farming is urgently needed. Organized support for farmers at the local level is extremely important. Multi-stakeholder partnerships, consisting of farmer’s groups, government agencies (e.g., agricultural and fisheries extension, environmental agencies, research institutes and universities) and non-governmental organizations should be established to assist farmers in development and adaptation of new approaches. Management committees representing all local water users should be established or strengthened. Extension services should be sufficiently funded, and the technical capacity of all stakeholders should be increased with the training of technicians and the strengthening of producers’ capacity for the organisational, technical and financial management of IIA activities.

Technically, production technology is important but the rest of the production chain (fingerling and feed production, processing and marketing) and general management aspects should also receive attention. Low-cost systems using locally available materials have more promise of success than intensive, high-input systems. Extensive aquaculture in irrigated rice areas of inland valley bottoms is more suitable than semi-intensive aquaculture in which fish areas are smaller and require more inputs (Coulibaly, 2000). Special consideration needs to be given to marketing issues and prices for fish since rice-fish farmers have less flexibility about timing of harvest and selling the fish than farmers with ponds. Private fingerling production and distribution should be promoted. Wild seed collection and stocking methods for fish to be raised in command areas should be developed. Farmer Field Schools would consider all aspects of production and post-harvest issues leaving flexibility to incorporate farmers’ needs.

Agricultural extension staff should be trained in aquaculture and in participatory development approaches (Halwart & Gupta, 2004). These ideas are currently put into practice in a regional Technical Cooperation Project in Guyana and Suriname with considerable success. The extension support should be delivered by a small and well-trained group of extension agents. This group would provide the core trainers who will train others. The extension approach should be participatory in nature giving special attention to gender issues as has been done in the Farmer Field Schools which have so successfully introduced the concept of Integrated Pest Management to Asian and African farmers.

**Integrated, multisectoral, collaborative approach within an IWRM framework**

Although the more efficient utilization of scarce water resources is one of the objectives of IIA development, IIA systems will be competing with other water uses. IIA development should therefore be part of an integrated water resources management (IWRM) or integrated watershed or river-basin management approach and be on the agenda of river and lake basin management authorities. Necessary precautions to limit the negative impacts of IIA activities and to strengthen environmental protection should be taken. Potential conflicts between different user groups (e.g. irrigation, fishers, drinking water) can only be resolved at high levels. Caution is needed as multisectoral integration is difficult and requires strong mediation skills. A "sustainable governance" approach to IIA development should be adopted. The governance concept implies the involvement of both public and private actors who share an interest in resource management. Apart from the actor level where most of the resource-use problems and conflicts become visible, institutional arrangements and structures (organizations involved, laws, agreements etc.) as well as shared norms and principles are important. Research for IIA should focus not only on exploitation of the natural and agricultural resources but must include the context in which the exploitation takes place (Giampietro, 2003; Kooiman and Bavinck, 2005).

Most of the environments in which integrated production of fish and crops take place are multi-functional ecosystems (often wetlands) that serve a variety of sectors and stakeholders. However, they are often subject to uni-sectoral planning and as a result, their multiple values are frequently ignored. Fisheries and aquaculture are often separated institutionally, which does not help their integrated development. Many other sectoral agencies are involved, such as environment (wildlife), water and infrastructure departments. Considering aquaculture as a branch of agriculture could be an initial step towards the more consistent promotion of integrated aquaculture and IIA. This should facilitate its integration into agricultural development programmes linked to irrigation use as well as its promotion to farmers by agricultural
extension agents. This will only be possible with a strengthening of interdisciplinary collaboration amongst institutions and cross-sectoral partnerships encompassing the multiple interests at stake: water for rice and other crops, irrigation, fish and other uses. Links should be established with the environment and development sectors to look for common objectives of environmental protection and poverty eradication. National IIA strategies should be part of agricultural development strategies. Such an integrated approach can also help states to fulfill their obligations to international conventions such as the Convention on Biological Diversity (CBD), the Ramsar Convention on Wetlands or the Code of Conduct for Responsible Fisheries (CCRF). Organizations that are traditionally concerned primarily with protection of wetlands in relation to waterfowl and migratory birds are now seeking collaboration with development agencies and try to develop "wise use" approaches that link the livelihoods of wetland communities to the conservation of ecosystem integrity (see e.g., Ramsar, 2005; Wetlands International, 2005). IIA may facilitate collaboration between wetland and agricultural sectors and provide opportunities to enhance the direct use values of wetlands without destroying their ecological services and functions.

Agricultural services should take the lead in implementation but participation should include other interest groups and the private sector. Rice-fish farming development should be included in national rice production strategies (Halwart & Gupta 2004). Such action is supported by the policy recommendations made to the 61 member countries of the International Rice Commission at its last session in Bangkok in 2002, both on enhancing aquatic biodiversity in rice fields as well as the deliberate farming of fish in rice fields (Box 1). In each country, a multisectoral entity coordinating the development of IIA should be created. This new entity should be financed from existing resources in the participating agencies. Such a body would be instrumental in facilitating the formation of farmer associations and facilitation of credit. Projects on irrigation development and rehabilitation would be screened by this entity ensuring that due consideration is given to the various aquaculture systems in these irrigation systems at the earliest stage, if possible already at the planning or design phase.

A supportive legal and regulatory framework for IIA development should be created, including an updating of regulatory

Box 1. Recommendations of the 20th Session of the International Rice Commission, 23-26 July 2002, to its 61 member countries.

The FAO’s International Rice Commission is the forum where senior policy makers and rice specialists from rice producing countries review their national rice research and development programmes. Its objective is the promotion of national and international action in matters relating to the production, conservation, distribution and consumption of rice. With regard to the presentation on “Recent initiatives on the availability and use of aquatic organisms in rice-based farming” the Commission made the following recommendations:

1. Member countries should promote the sustainable development of aquatic biodiversity in rice-based ecosystems, and policy decisions and management measures should enhance the living aquatic resource base. In areas where wild fish are depleted, rice-fish farming should be considered as a means of enhancing food security and securing sustainable rural development.

2. Attention should be given to the nutritional contribution of aquatic organisms in the diet of rural people who produce or depend on rice.

Source: FAO (2002)

texts on the management of command areas and a revision of land tenure arrangements. Priority zones of intervention need to be identified based on an inventory of all resources and infrastructures to identify IIA potential. Target groups need to be identified, in particular rice farmers and beneficiaries from integrated pest management (IPM) programmes in rice farming. Participatory identification of IIA systems according to the means and characteristics of target groups should be initiated or continued. In this context, better acknowledgement of traditional resource management and enhancement systems is an essential component of a more appropriate and effective approach to inland fisheries and aquaculture development (COFAD, 2001). The needs for and access to credit for the adoption of IIA technologies should be evaluated and facilitated, micro-financing schemes should be reviewed to negotiate preferential rates for IIA producers. The local availability of inputs for IIA should be assessed. Introduction of IPM and reduced pesticide use leads to cleaner aquatic environments and should be stimulated.
**Knowledge management and networking**

A large body of knowledge and information on IIA is available. Valuable traditional knowledge about fish and crop resources and their management is present among the proposed target groups for IIA development (farming and fishing communities). More formal knowledge about fisheries management, aquaculture, agronomy (including irrigation), environmental impact, marketing, processing and other relevant fields is available in national institutions (universities, government research institutes) and in international agencies. A conscious knowledge management approach should be followed to mobilize, store, organize and exchange knowledge on IIA.

The impact of research on development should be increased. Formulation of research questions should be based on the identification of problems by stakeholders (resource users/farmers and policy/decision makers) in the field. A better communication between researchers and the “consumers” of knowledge will increase the impact of research on development. At a local level, multi-stakeholder partnerships can facilitate this process, but it should also be pursued at national and regional levels to ensure rapid dissemination of successful approaches and prevent duplication of research efforts. Highly successful initiatives, such as the preparation of the resource book on the utilization of different aquatic resources for livelihoods in Asia (IIRR et al., 2001) should be repeated in Africa. Collaborative and integrative learning approaches should be explored to achieve more rapid and effective upscaling of stakeholder-driven innovation processes. An example are Learning Alliances, a series of linked platforms at community, district and national levels that bring together stakeholders in an area of common interest, such as IIA (Lundy et al., 2004; Moriarty et al., 2005). IIA development should be periodically evaluated based on participatory monitoring programmes in the field. Farmers can be involved in monitoring of IIA activities. This would help to evaluate in a comprehensive and inclusive manner the social, economic, environmental and institutional sustainability of IIA systems.

Networking for information exchange and harmonization of approaches should be stimulated at all levels of involvement (policy and decision-making, research, extension, inter-sectoral). Existing national and international networks should be used to enhance the flow of IIA information and knowledge. Knowledge of a wide range of systems and environments is available from all over the world. Information and communication tools should be used to store, organize and mobilize knowledge on IIA.

**Need for action**

It is high time that the conclusions and recommendations of the wide range of experts who participated in the IIA Workshop in Bamako in 2003 and contributed to this volume are now taken up and implemented. Most countries have the necessary knowledge and other prerequisites to start with small “seed” activities that can demonstrate to policy makers and donors that investing into the scaling up of IIA will be a wise decision with high returns on the food security and poverty alleviation agendas.

At the same time, there are mechanisms available to assist countries in initiating activities on IIA. Besides the bilateral as well as various multilateral opportunities, the Telefood anti-hunger campaign of the FAO can be approached for small-scale projects (FAO, 2005a). Several authors have highlighted the importance of the National Special Programmes for Food Security. Through projects in over one hundred countries worldwide the SPFS promotes effective and tangible solutions to the elimination of hunger, undernourishment and poverty (FAO 2005b). The SPFS strongly promotes national ownership and local empowerment in the countries in which it operates, and it is in the countries’ best interest if they make IIA a pillar of their national agricultural development work. Yet another opportunity is through FAO’s Technical Cooperation Programme which supports the FAO Member Nations through small projects which address specific problems in the agriculture, fisheries and forestry sectors (FAO, 2005c).

The successful development of IIA in West Africa will need to take place incorporating various components at local, national and regional levels. A regional programme will be necessary to support development efforts, and in fact a programme proposal on integrated inland water resources management in drought-prone West African countries through development of IAA has been prepared and presented to the Committee for Inland Fisheries of Africa (CIFA) at its 11th session in Abuja, Nigeria in October 2000. The Committee unanimously endorsed this regional programme (FAO, 2001). Some time has passed, but with the recent advancement of our knowledge on the concepts, practices and potential of IIA the proposed programme has become even more
relevant. It is elaborated in detail in the next chapter, for reference, and in the hope that funds can be secured for its timely implementation.

References


PROPOSAL FOR A PROGRAMME OF INTEGRATED INLAND WATER RESOURCES MANAGEMENT IN DROUGHT-PRONE WEST AFRICAN COUNTRIES

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Abstract

A proposal is presented for a programme on integrated inland water resources management that will contribute to improved food security in drought-prone West African countries through development of integrated irrigation-aquaculture (IIA). The main beneficiaries of the programme are irrigation management committees, small-scale farmers involved in irrigated rice, vegetable and pasture production as well as small-scale farmers involved in fish culture, including women’s groups involved in processing, preservation and marketing activities of agricultural products and fish. Specific objectives of the programme include: (1) strengthened national capacities to assess IIA potential and improve IIA production techniques and practices; (2) financially and ecologically viable, socio-culturally acceptable IIA systems that improve land and water productivity as well as irrigation efficiency, managed by farmers/fishers; (3) improved processing, preservation and marketing of agricultural and fishery products through women’s groups; (4) regional cooperation and information exchange on IIA research and development through an IIA network. After an analysis of sectorial, technical, institutional, socio-economic and post-harvest constraints, and of the opportunities for IIA, the institutional framework and expected results are elaborated in detail.

Background of IIA

Several regional and international meetings have proposed frameworks for programmes for integrated inland water resources management in water-scarce regions. Among these frameworks, Integrated Irrigation and Aquaculture (IIA) is an innovative strategy to improve agricultural productivity from every drop of water used while improving the financial sustainability of investments in irrigation. Adopting IIA through a programme of Integrated Inland Water Resources Management (as proposed in this chapter) will contribute to improved food security in drought-prone West African countries.

This project proposal has been originally proposed to the eleventh Session of the Committee on the Inland Fisheries of Africa (CIFA) in October 2000 where it was endorsed by country delegations (FAO, 2001). Participating countries originally included Mali, Niger, Burkina Faso and Côte d’Ivoire. Subsequently, Senegal joined the IIA group\textsuperscript{1}. Parts or all of the territories of the participating countries belong to the Sahelian Zone which is characterised by an arid tropical climate. This area is bordered on the north by the Sahara Desert and to the south by the Sudanese agro-ecological zone, corresponding to mean annual precipitation of 100 mm and 600 mm, respectively. Water constitutes the principal ecological constraint in the Sahelian Zone.

IIA offers one strategy to mitigate the severe effects of chronic water shortages. IIA represents a true integration of two different but related agricultural production systems; irrigation and aquaculture. As a true integration,

\footnote{1 A request was received from the Ministry of Agriculture, Rural Water Supply and Food Security in Senegal to consider Senegal as an additional project country. This led to the assessment and (positive) evaluation of IIA opportunities in Senegal (Peterson et al., Chapter 8, this volume).}
there are tangible synergies, with the whole greater than the sum of the parts.

Limited trials on IIA systems have been initiated in the sub-region and different technologies are known in various countries. One of the best known systems is rice-fish production. Trials in rice-fish culture had been undertaken in the past but were abandoned for various reasons (exclusion of socio-economical aspects, lack of expertise, theft, etc.). Other models of integration are less well known. These models are often based on indigenous technology implemented spontaneously by users without planning and/or monitoring, often with lack of necessary preliminary studies.

Constraints to IIA

Sectorial constraints

West Africa is classified as economically water–scarce, all countries facing severe financial and capacity difficulties in meeting their water needs. Expanding populations in arid areas means there is a rapidly growing demand for food with an urgent requirement to increase the number of irrigation schemes. However, the financial means to establish these new schemes are increasingly less available from the states and donors. With high competition for dwindling financial resources local assets and increased financial participation from the beneficiaries have to be mobilized. In this context, over the past several years governments have been adopting a policy of transferring the management of former public sector irrigation schemes to the beneficiaries. Unfortunately, these new managers often lack adequate support and extension services to enable them to strengthen their technical and financial management capacities. They remain little involved with the design of water delivery systems which are consequently often poorly adapted to local conditions.

Concurrently with the shift in operational responsibility for many irrigation schemes and the need to expand production, inland capture fisheries in the region are stagnating or declining, further exacerbating the overall food supply shortage. Although efforts have been made to develop fish culture in the Sahelian zone, these remained generally unsustainable. The main reasons for this poor success were identified as being pan-African in nature and include the lack of quality seed, feed capital, and information combined with poor access to necessary markets (FAO, 1999). These overarching constraints were highlighted and expanded upon during a recent Expert Workshop organized in 2004 by the FAO and the WorldFish Center (Moehl et al., 2005). These included inter alia:

- Lack of knowledge on the socio–economical aspects;
- Inefficient co-ordination of research and development;
- Lack of effective evaluation processes.

Technical constraints

Certain technical constraints are specifically related to the development of IIA. In addition to the ubiquitous requirements of satisfactory inputs and markets, IIA systems but technically interface to the benefit of the two systems. This requires developing water delivery, management and harvesting strategies that are hopefully mutually beneficial and certainly not mutually detrimental. Lack of better understanding and characterization of these IIA models presently hinders their wider use.

Institutional constraints

In all the countries, an interdisciplinary organizational structure is missing to harmonize IIA interventions and identify the roles of stakeholders involved with IIA research and development. Until now, adequate attention has not been devoted to monitoring/evaluation activities and identifying lessons learned. The prerequisite regulatory and legal frameworks also remain incomplete for land reforms. It is not unusual in Mali and Côte d'Ivoire to note a lack of title to land in irrigation schemes as well as conflicts between civil and traditional ownership practices.

Socio-economic constraints

In the context of the development of irrigation schemes and IIA models, problems include poor access to inputs (little access to credit facilities, lack of inputs, etc.) as well as competition between different farming systems for the use of available inputs (by-products and
manpower). High capital costs have made many irrigation schemes very expensive ventures and some proponents of IIA view this as a mechanism of spreading the costs to establish a more profitable firm.

**Environmental constraints**

Among environmental constraints, pollution of water draining irrigation schemes by the inappropriate application of pesticides hinders the recycling potential of these waters through the development of downstream aquaculture.

**Post-harvest constraints**

Concerning marketing, there can be competition with fish and fishery products from other sources. There are existing traditions product paths which can involve a high degree of inequity as well as high post harvest loss. A similar situation exists for rice where the women who are primarily responsible for processing and marketing lack the necessary post-harvest skills.

In the framework of increasing aquaculture production (essentially fish culture) as well as promoting irrigated crops, the programme will seek to demonstrate in a participatory manner appropriate IIA techniques and practices aiming to alleviate the main technical, economical, socio-cultural, institutional and environmental constraints which have been previously identified.

**IIA beneficiaries**

The main beneficiaries of the programme are irrigation management committees, small-scale farmers involved in irrigated rice, vegetable and pasture production as well as small-scale farmers involved in fish culture. The target groups include women’s groups involved in processing, preservation and marketing activities of agricultural products and fish. The indirect beneficiaries are planners and decision-makers, civil servants and researchers from national development and research institutions, extension workers of local support institutions, managers of the Public Sector and Civil Society (NGOs) and farmers' associations (Fish Farmer Associations, Co-operatives of rice producers, etc.).

**IIA Opportunities**

Recent missions carried out by FAO have highlighted significant opportunities for the development of IIA in the sub-region. These include:

- Potentially important unexploited land and water resources and the high demand for irrigation schemes which remains unsatisfied due to their high costs;
- High priority given by governments to food security issues;
- Current policies for transferring management responsibilities of irrigation schemes to beneficiaries along with the adoption of participatory and gender-sensitive approaches to development by support services;
- Policies for diversification being undertaken by governments which are better adapted to the new economical environment and which offer more possibilities for small-scale farmers to choose enterprises for optimal development of the irrigation sites;
- Existing tradition of practising irrigation (farmers having necessary technical skills for producing irrigated crops such as rice and vegetables) combined with the high motivation of producers (rural communities and private entrepreneurial sector) and an interest on the part of donors in the development of the sector;
- Awareness of government officials of the decline of fish production;
- Establishment of statutory measures such as those in Côte d’Ivoire allocating specific areas upstream of irrigation schemes for aquaculture;
- Good local markets for rice and fish as well as good prospects for creating regional markets.

Trials conducted by FAO in Asian countries have shown that fish farming in irrigated plots increases substantially the fish production. The West African region has still an underutilized potential as demonstrated by the following:

- The area has an important potential in land and water resources. The total surface water potential is assessed to more than 97 billion m$^3$ while the total groundwater potential is estimated to more than 3 000 billion m$^3$. 
The irrigation potential comprises an area between 3.3 and 5.1 million ha while the total area under irrigation is approximately 0.33 million ha, i.e. one tenth of the irrigation potential. If one only considers the area allocated to surface irrigation, there would be a potential of:

- 117 000 ha of surface irrigation schemes suitable for IIA development (e.g. rice-fish farming, fish culture in canals);
- 153 000 ha of “complete” control schemes suitable for IIA development (excluding fish ponds);
- 66 000 ha of inland valleys suitable for IIA development (excluding small-scale fish reservoirs of 0.3 to 1 ha associated with cultivated plots in the area downstream and on the slopes).

Therefore, there is a conducive environment and real potential to increase agricultural and aquaculture production in West Africa through the promotion of sustainable integrated systems of irrigation and aquaculture.

**FAO and its IIA technical expertise**

The SIFR Expert Consultation in 1992 (FAO, 1993) identified nine research programmes for the promotion of aquaculture in sub-Saharan Africa. Amongst these programmes, the integration of aquaculture in irrigation schemes was considered as a rapid means to increase fish production in the region.

Moreover, during its meeting in 1997, the Sub-Committee for the Protection and the Development of Inland Fisheries in the Sahelian Zone recommended (FAO, 2000):

- An inter-regional network be put in place to exchange information and avoid duplication of effort;
- Aquaculture development be based on better management and improved yield from irrigation “basins” through enhanced stocking and post-harvest techniques;
- FAO act as facilitator for networking and information exchange at the regional level.

**IIA PROPOSAL**

**Institutional framework**

The institutional arrangements of the proposed intervention will have a two-tiered approach.

The first tier consists of a core of five countries (Mali, Niger, Côte d’Ivoire, Burkina Faso and Senegal) which will be actively involved in IIA research and development (demonstration activities). Each country will establish a national network to ensure free flow of information and skills, co-ordinated by a designated lead institution. The national network will be made up of irrigation and fisheries institutions, associations of fishers, irrigation management committees, research and/or training institutions, institutions of environmental protection, NGOs, consultants’ firms and other beneficiaries. IIA development activities that will be demonstrated in each of the country will be coordinated by a National Coordinator with the support of a multidisciplinary team.

National networks will subsequently be linked to a sub-regional network with WARDA (the Africa Rice Center, Conacry, Guinea) as possible Regional Coordinator. This operational framework would enable the programme to have important links with regional research networks that are already located at WARDA, such as the Inland Valley Consortium (IVC) and the Regional Network on Rice Research.

The second tier would become active as IIA technologies are demonstrated and the sub-regional networking is fine-tuned. This would include countries or other stakeholders from the region outside the core who would wish to participate in the network.

**Related issues**

The programme would offer possibilities for university cooperation on integrated water resources management. This would facilitate the development of national research and development projects.

In the context of strengthening national capacities and setting up a regional training programme for the training of national trainers in IIA, a TCDC expert from Asia would be recruited.
**Links with partners and existing programmes**

The programme would build up a regional network based on existing regional networks (the Inland Valley Consortium, IVC; the Regional Association for Irrigation and Drainage, ARID; the Eco-regional Programme for Humid and Sub-Humid Tropics of Sub-Saharan Africa, EPHTA) and would create synergy with research institutions belonging to the CGIAR Group (WARDA; the International Institute for Tropical Agriculture, IITA; and the WorldFish Center) in order to avoid duplication of effort, to promote complementarity and to maximize the utilization of resources. It would benefit from the lessons learned from past and on-going programmes/projects (ALCOM, IIA/IFAD, SPFS country programmes, etc.).

**Links with SPFS**

The programme would strengthen the integration of the "water control" and "diversification" components of the Special Programme for Food Security (SPFS) through the introduction of IIA activities at pilot sites in all concerned countries. SPFS demonstration sites would be used for the promotion of improved IIA techniques and practices or the transfer of newly adapted IIA techniques and practices. It would also offer opportunities for undertaking IIA constraints analyses through the steering committees and SPFS Monitoring Committees at national, regional and local levels.

**Objectives**

**General Objective**

The programme of inland water resources management will contribute to improved food security in drought-prone West African countries, in particular Mali, Niger, Burkina Faso and Côte d’Ivoire.

**Indicators:** Twenty-five percent increase in agricultural and fish production through integrated irrigation and aquaculture systems; 20 percent reduction in post-harvest losses for both fish and irrigated crops (rice and horticultural crops); and 20 percent increase in global income for members of women groups responsible for the processing, preservation and marketing of agricultural and fish products.

**Specific objectives**

The programme has the following specific objectives:

SO1 Strengthened national capacities to assess IIA potential and improve IIA production techniques and practices by the end of year two;

SO2 Established integrated irrigation and aquaculture systems, financially and ecologically viable, socio-culturally acceptable, improving land and water productivity as well as irrigation efficiency, managed by the farmers/fishers by the end of year five;

SO3 Improved processing, preservation and marketing of agricultural and fishery products through women’s groups by the end of year five;

SO4 By the end of the fifth year, regional co-operation, information and skills exchange on IIA research and development strengthened, through a functional IIA network;

**Expected results**

The list of expected results for each of the specific objectives follows:

For SO1 (strengthened national capacities to assess IIA potential and improve IIA production techniques and practices by the end of year two):

Strengthened national capacities to assess IIA potential

R1.1 20 national statisticians (5 per country) trained to collect statistical data on irrigation and inland fishery;

R1.2 A regional office of statistical analysis and mapping (GIS) operational;

R1.3 IIA national maps and IIA regional map produced.

These maps will allow for the characterization of the IIA physical potential in order to promote
the regional transfer of appropriate IIA technologies and sensitize decision makers on the potential contribution of IIA to increased agricultural and aquaculture production.

Strengthened national capacities to improve IIA production techniques and practices

R1.4 12 IIA specialists from the Public Sector and Civil Society (NGO) completed long-term scholarship programmes and returned to assist the programme;

R1.5 An IIA training curriculum developed during a regional workshop (the development of the training curriculum implies the preparation of training modules for each IIA model);

R1.6 20 national trainers (5 per country) of technician-extension worker level trained at regional level in a participatory manner on IIA technologies.

For SO2: (established integrated irrigation and aquaculture systems, financially and ecologically viable, socio-culturally acceptable, improving land and water productivity as well as irrigation efficiency, managed by the farmers/fishers by the end of the fifth year):

Techniques and practices of existing local IIA models improved and new IIA techniques and practices of introduced IIA models adapted.

R2.1 An inventory report elaborated on local IIA models as well as on IIA research studies conducted in the sub-region;

R2.2 Multidisciplinary feasibility studies (technique, financial and economical, socio-cultural, environmental and sanitary) carried out for the selected IIA models (to be promoted in the sub-region);

R2.3 A Research Master Plan elaborated, enabling the formulation and the implementation of national research programmes by country and a regional research programme with the research institutions of the CGIAR Group (the research master plan is based on the IIA constraints identified at national level in a participatory manner. It will include the identification of key indicators for the monitoring-evaluation process);

R2.4 Demonstration protocols elaborated for the selected IIA models.

Improved IIA techniques and practices of local models and newly adapted IIA techniques and practices of introduced models (production) demonstrated.

R2.5 40 IIA demonstration sites, covering a total area of at least 400 ha developed for improved water control with the participation of beneficiaries;

R2.6 40 Water User Associations (10 per country) established/strengthened for the development and management of water control structures;

R2.7 1200 farmers/fishers trained in a participatory manner in the technical and financial management of integrated irrigation and aquaculture systems (including water management);

R2.8 Improved and newly adapted IIA production techniques and practices demonstrated at the 40 sites.

For SO3: Improved processing, preservation and marketing of agricultural and fishery products through women’s groups by the end of year five;

R3.1 A market study of IIA related products (analysis of constraints and opportunities) carried out for each production zone;

R3.2 40 women’s groups (10/country) established/strengthened and organized. The organization of women’s groups will aim to ensure access to and control over post-harvest equipment, credit, etc.;

R3.3 The members of 40 women’s groups are trained on post-harvest techniques and practices as well as self-management;

R3.4 Improved techniques and practices of processing, preservation and marketing are demonstrated to the 40 women’s groups;

R3.5 Local market infrastructure and structures put in place and/or improved.

For SO4: By the end of the fifth year, regional co-operation, information and skills exchange on IIA research and development strengthened through a functional IIA network;
R4.1 The Office of the Regional Co-ordination established and operational;
R4.2 4 National Co-ordination Units established and operational;
R4.3 A Multidisciplinary Steering Committee established and operational;
R4.4 A Pan-African Workshop “Review of IIA National Experiences” conducted. This Pan-African workshop will enable new stakeholders to take part in the network;
R4.5 IIA communication tools developed (quarterly liaison bulletin, video cassette on IIA technologies demonstrated in the sub-region, WFD, etc.);
R4.6 Study tours organized for 10 trained extension workers.

References


This volume contains background documents and papers presented at the FAO/WARDA Workshop on Integrated Irrigation Aquaculture (IIA) held in Bamako, Mali, from 4 to 7 November 2003, as well as the findings of FAO expert missions on IIA in the West Africa region.

The rationale for IIA development lies in its potential to increase productivity of scarce freshwater resources for improved livelihoods and to reduce pressure on natural resources, which is particularly important in the drought-prone countries of West Africa where water scarcity, food security and environmental degradation are priority issues for policymakers.

Irrigated systems, floodplains and inland valley bottoms are identified as the three main target environments for IIA in West Africa. Many examples of current practices, constraints and potential for development of IIA are provided. The conceptual economic analyses of IIA are reviewed, and an overview of regional and international research institutions and networks and their mandates as they relate to IIA is given. Key factors for successful adoption of IIA – participation of stakeholders and support for local development, an integrated, multi-sectoral approach to IIA and improved knowledge management and networking – indicate the way forward and are reflected in a proposal for IIA development in West Africa.