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ANALYSIS OF BIO-RESOURCE UTILIZATION IN INTEGRATED AGRICULTURE-AQUACULTURE FARMING SYSTEMS IN ZOMBA DISTRICT, SOUTHERN MALAWI

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Abstract

A bio-resource flow analysis using participatory resource mapping was conducted in Chingale Area, west of Zomba District in southern Malawi. The analysis was aimed at providing the basis for designing an integrated agriculture-aquaculture system that would optimize utilization of on-farm resources for a cost effective aquaculture production system. Results showed that Chingale has over 18 crop species and five animal species that have potential for integration into the farming system. However, only 33% of the sampled farmers were integrating over 5 species (both crop and animal species) in agriculture systems resulting in low economic efficiency, low incomes to the farmers and low sustainability of farming systems. The availability of fertile land, water, and species, if properly designed, can reduce input costs thereby increase production which would result in sustainable higher incomes for the farmers.

Keywords: Bio-resource flow, Economic efficiency, Integrated Agriculture-Aquaculture, Income, Sustainability.

Introduction

Integrated Agriculture-Aquaculture (IAA) can increase rural fish supply and enhance whole farm productivity through improved on-farm resource recycling throughout the year (Brummett and Noble, 1995). The increased fish supply through IAA can help to release the pressure on capture fisheries. Specifically, aquaculture can increase household food supply and improve nutrition; increase household resilience through diversification of income and food sources; and strengthen rural economies by increasing employment and reducing food prices (FAO, 2000). At the same time, IAA can increase the sustainability and productivity of farming systems through resource recycling. A study on the impacts of WorldFish's research and development of IAA systems in Malawi by Dey *et al.* (2010) showed that IAA farms can produce more food than farms where IAA is absent. For example, fish production in small-scale fish ponds not integrated with agriculture was found to be about 800kg/ha/yr while in integrated aquaculture-agriculture farms, fish production was over 1800kg/ha/yr. For the maize staple, production in IAA systems ranged from 4-6 tons/ha/yr which is three times higher than that obtained on farms without IAA. Recognizing the important role IAA plays in food security and poverty alleviation, the Malawi Government incorporated fish farming development into its growth and development strategy (MGDS 2006—2011) and in the national policy on food and nutritional security (GoM, 2006). Aquaculture development has also been identified both by the New Partnership for African Development (NEPAD, 2005) and the Southern Africa Development Community (SADC, 2004) as a priority investment area for safeguarding the future contribution of Africa's fish sector to poverty alleviation and regional economic development.

Chingale Area of Zomba District in southern Malawi is one of the potential areas for aquaculture development. There are currently more than 2,045 farmers practicing aquaculture in 1,085 small earthen ponds that cover about 30 hectares. WorldFish and the Japanese International Cooperation Agency (JICA) through World Vision have in the past disseminated the IAA concept in the area using the community as an entry point for participatory aquaculture research, extension and development. However, fish productivity is still low averaging less than 1000kg/ha. One of the reasons for the low productivity is the rising costs of inputs (feed and fertilizers). Currently, farming practices are undergoing a shift from dependency on non-renewable inputs and from chemical-based intensification to forms of biological intensification and other emerging technologies that draw on biodiversity and natural resources to increase the productivity of ecosystem services. This paper analyzed the availability of local resources and how they are being utilized in order to design an integrated system that would optimize utilization of on-farm resources through input flows (bio-resource flow) within the farm to provide a cost effective source of nutrients that would enhance overall farm productivity and increase economic returns to the farmers.

Methodology

A structured questionnaire was developed to capture data on socio-economic characteristics of households; knowledge on bio-resource flows; general characteristics of the plots managed by the household (Natural

Resource Type); farm production and inputs used; and value and quantity of biological material flowing from one Natural Resource Type (NRT) or enterprise to another (Bio-resource inflows). A Global Position System (GPS) was used during the exercise in order to measure the area of the land cultivated per the NRT. Data was collected through participatory environmental assessments including the development of farm natural resources maps and transects walks involving farmers and researchers.

Eighteen farmers were selected representing 37.5% of beneficiaries of the project: "Dealing with Major Challenges to Aquaculture Development in Malawi", funded through the Agriculture Research and Development Program (ARDEP). The project was testing the profitability of integrating two fish pond sizes - 200m^2 and 400m^2 sizes into the farming system. The bio-resource flow analysis of this project could therefore contribute to the designing of a profitable integrated fish farming system. The 18 farmers were randomly selected from each of the two pond size groups (200m^2 and 400m^2) equally (9 from each group). Five (5) respondents were female farmers representing 28% of the sample size while thirteen (13) respondents were male farmers representing 72% of the sample size.

A Research Tool for Natural Resource Management, Monitoring and Evaluation (RESTORE) software (Lightfoot *et al*., n.d) was modified to EXCEL without losing the link to qualitative and quantitative data analysis for bio-economic and ecological modeling. RESTORE provides a venue to efficiently restore, retrieve, process and analyze data resulting from farm inventories and monitoring. RESTORE outputs include economic and sustainability indicators of the farm's economic performance by NRT or whole farm system. Economic indicators among others include Gross income; Net income; Total costs; Net Cash Income; Total Non-cash costs and Total Cash costs. Through analysis of the data, four sustainability indicators were generated:

- Recycling - Flow of biological material from one enterprise or NRT to another.
- Diversity – number of species or cultivars managed or collected and utilized by the farm household.
- Capacity – Total biomass produced in tons per hectare.
- Economic Efficiency – Profit costs ratio.

Graphic summaries (kites) were produced for the individual farmers (ungroup summaries) as well as the average of all the farmers visited (group summaries) from four major economic and sustainability indicators presented in equations (1) to (4) below:

$$\text{Recycling (R)} = \sum_{n=1}^{k} R_{nk} \quad \text{.....................(1)}$$

Where (R) is a binary variable representing the flow of biological materials from one NRT to the other, k refers to the output (manure, crop wastes, water etc.) and n is the number of NRTs.

$$\text{Species (S)} = \sum_{n=1}^{k} S_{nk} \quad \text{.....................(2)}$$

Where (S) is a binary variable representing species (crops, livestock and fish) farmed, k refers to species (maize, cabbage, fish, sheep etc) and n is the number of species.

$$\text{Capacity (B)} = \sum_{n=1}^{k} B_{nk} \quad \text{.........................(3)}$$

Where (B) is the biomass (in tons) from each kth species and n is the number of species.

Economic Efficiency (E) = P/C .... (4)

$$\text{Where Profit (P)} = \sum_{n=1}^{k} I_{nk} - \sum_{n=1}^{k} C_{nk}$$

$$\text{and Total Cost (C)} = \sum_{n=1}^{k} C_{nk}$$

Economic efficiency (E) is the profit to cost ratio, where profit (P) is the total incomes (I) from each kth NRT on the farm subtracted by operating costs (C) for that NRT, whereas n is the number of NRTs

Results and discussion

Species diversity and utilization

Chingale is a good agricultural area with a climate that favors the production of many crops and livestock including fish due to its perennial running surface water. From the sampled farms, there were 18 crop species and 5 animal species (Table 1) being farmed that could be recycled.

Table 1: List of Species in Chingale by type

Legumes	Cereals	Livestock	Others
Groundnuts	Maize	Chicken	Vegetable
Pigeon peas	Sorghum	Goats	Fruits
Cow peas	Rice	Fish	Bananas
Soya	Millet	Ducks	Sugarcane
Common-beans		Sheep	Cassava
Velvet beans			Pumpkins
Ground-beans(Bambara)			Sweet - Potatoes

On average, each farm had a minimum of 5 species or enterprises. The practice of having many species on farm is common in Malawi mostly as a risk aversion strategy. Such farmers are known to be more resilient to droughts and/or harsh climatic conditions (WorldFish, 2003). The farm enterprises were however not systematically designed to ensure that one enterprise benefits from the other. From the sample, 39% of the farmers were recycling at least 2 species, and only 28% of the farmers were recycling more than 5 species (Fig. 1).

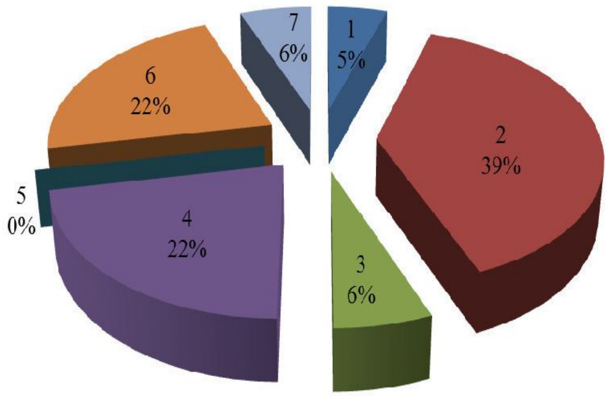


Figure 1. Percentage of farmers and the respective number of species integrated on the farms

There were also observations on indirect recycling in the form of mixed cropping especially those of legume and cereals. The study also found that there is little knowledge among farmers on the benefits of bio-resource flows. For example, over 50% of the farmers do not know that animal manure can reduce seepage in fish ponds; that mud dredged up from fish ponds can considerably increase vegetable yields; and that fish and other animals act as bio-converters of wastes on the farm.

Economic efficiency

It was observed that majority of farmers (>50%) farmers knew many production technologies and practices but these were either not followed or were used inconsistently. Production was therefore very low. The average total farm biomass production was 3 metric tons (MT) with the highest reaching 12 MT (Table 2).

Average productivity was 1.6MT/hectare. Fish productivity in particular was 1.2MT/hectare. This is not very different from fish productivity quotes by the National Aquaculture Strategic Plan (2005) and the Presidential Initiative on Aquaculture Development (Department of Fisheries, 2006). The average production cost for the sampled farmers was about MK28,000 (Table 2) with economic efficiency of about 4 (Fig. 2).

Table 2 : Calculated economic indicators for total farm biomass (crops and livestock) production

Indicator	Minimum Value	Maximum value	Mean Value (n=18)
Area under cultivation (Ha)	0.77	4.85	1.97
Fish pond area (m^2)	150	2800	545
Total production (MT)	0.79	11.62	3.09
Total Fish production (kg)	0	363	48
Total Non-cash costs (MK)	2,800.00	61,550.00	19,797.00
Total input Cost (MK)	800.00	27,750.00	8,523.00
Total costs (MK)	11,350.00	76,150.00	28,320.00
Net Cash Income (MK)	5,889.00	409,367.00	71,667.00
Net Cash profit (MK)	2,889.00	384,617.00	63,383.00

*MK—Malawi Kwacha based on 2010 prices

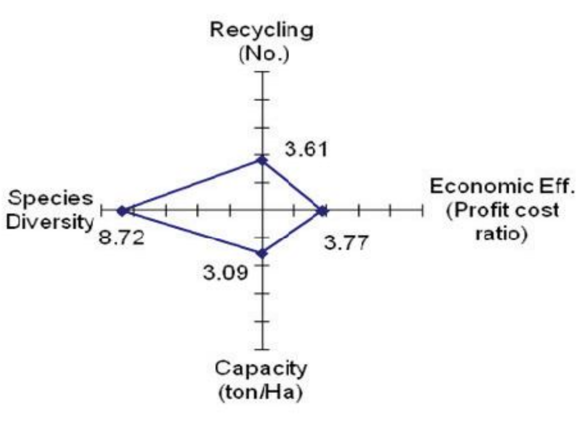


Figure 2. Summary of the sustainability indicators based on sample averages

This indicates that the return on investment for a single investment in agriculture is 4 on average. The concept of economic efficiency relates to the question of whether a firm uses the best available technology with minimal costs in its production process (Sullivan and Sheffrin, 2003). Economic efficiency in this case goes beyond technical efficiency. It reflects whether a technically efficient firm produces at the lowest possible cost. In Chingale, production costs are either funded through battering of farmers' own time and labour (non-cash costs) or funded through cash payments (cash costs). Recycling of biological resources (wastes and by-products) can improve farm production at low cost thereby improving economic efficiency which translates into high profits.

The contribution of input costs to production averaged about MK9, 000 mostly from chemical fertilizers. This means that through recycling farmers can reduce about MK9, 000 at the same time improve biological properties of the soils and the environment to create a platform for increasing economic efficiency. Although the input costs comprise only 30% of the total farm costs, its replacement through recycling brings more economic returns. Lightfoot *et al*., (1993) showed that compost materials can replace basal applications of

Nitrogen, Phosphorus and Potassium (NPK) fertilizers and reduce fertilizer costs by up to 50% and that the value of all recycled materials can be up to 40% of gross farm income. Jamu (2003) also found out that IAA reduces soil erosion and increases soil nutrient use efficiency by 50% through increased ground cover. The recommended bio-resource flow model (Fig. 3) in the later sub-section deals with enhancement of such intra-farm biological synergies.

Sustainability indicators

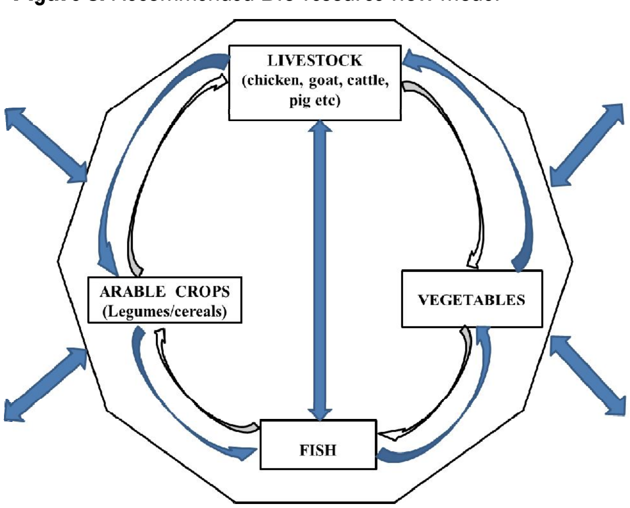
In the study, sustainability was measured by: Species diversity, Recycling, production (capacity) and economic efficiency. The group indicator summaries have been presented on a kite (Fig. 2).

The kite is skewed to the left (species diversity) with low rates on capacity (3), recycling (4) and economic efficiency (4). The results indicate that the farming system in Chingale has the potential of being sustainable if recycling and capacity are improved which would subsequently result in a more economic efficiency. Recycling would mean reducing investment in external inputs, which is ideal in capital constrained situations typical of most rural farmers. Lovell (1992), argued that if growth is propelled by improvements in production efficiency, by reducing external inputs, it is more likely to be sustained and to withstand economic shocks.

Recommended Bio-resource Flow Model

The high species diversity in Chingale presents an opportunity for developing enterprises that can turn crop and livestock residues and by-products into feeds and fertilizers for other enterprises as recommended in Figure 3.

Figure 3. Recommended Bio-resource flow model



The availability of fertile land, water, and species, if properly designed, can reduce input costs at the same time increasing production hence more money for the farmers. The recommendation from Figure 3 is based on the premise that resource flows from arable crops, vegetables, livestock and fish produce positive environmental benefits that enhance overall farm sustainability. The figure above indicates resource flows from the main species found in Chingale i.e. fish, livestock, arable crops and vegetables. For example, earthen fish ponds act as water reservoirs necessary during the dry season to grow crops including vegetables and generate incomes through sales of crops and fish. On the other hand, wastes from crops and livestock are used as food for the fish. The nutrients generated in the pond from the crop and livestock wastes will be used as fertilizers for growing crops, which reduces the need for off-farm inputs. The cyclic movement of the farm resources increases both the technical and economic efficiency translating into higher per capita income. Double pointed arrows outside the polygon represent linkages between the integrated farming system and external inputs, which can be avoided if the bio-resource flow is optimized as represented by the closed polygon.

Conclusion

The analysis bio-resource flows in Chingale demonstrated that farmers grow a diverse number of arable crops ranging from cereals and legumes to vegetables. Livestock production especially chickens; ducks, goats are also common in the area. However, these resources are not optimally combined to produce high yields. As a result, farm productivity, economic efficiency and sustainability are low. A bio-resource flow model has been recommended as a basis for designing sustainable IAA systems. The model is based on utilization of species diversity to offset external input costs, which would sustainably enhance bio-resources flow (recycling) and subsequently increase production capacity and economic efficiency on IAA farms.

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