Abstract

Rapid population growth in developing countries has resulted in increased demand for food, leading to increased pressure to extend land under cultivation and to intensify food production. Because most of the arable land has already been utilized, further intensification of agricultural production has involved conversion of marginal lands such as forest reserves, communal grazing land & and fragile areas such as river banks and steep hill slopes. Intensified crop production on marginal lands enhances the risk for soil degradation, like soil fertility decline. In many situations, inorganic fertilizers are not available or are too expensive, and efficient utilization of organic residues such as crop residues and manures is constrained by a temporal mismatch between availability and application. Diversification of farming activities potentially increases nutrient efficiencies. One promising additional activity is aquaculture and the development of integrated aquaculture - agriculture (IAA) systems.Although integrated aquaculture - agriculture farming systems have been developed and practiced in some parts of Asia, they have not been widely adopted. In many developing countries, especially in Africa, aquaculture itself is still poorly developed. Aquaculture is considered separately from agriculture and its benefits are measured in terms of fish production, ignoring its role in nutrient cycling through integrated farming systems. Yet, the majority of nutrients entering ponds, including fertilizers, feeds and nutrients contained in inflows from channels or run-off from watersheds, accumulate in the sediment. These nutrients are a potential nutrient source for terrestrial agriculture.This thesis explored the use of fish ponds as nutrient traps (besides fish production) to increase the nutrient use efficiency in mixed farming systems. Focus was put on (i) nutrient utilization efficiency of agricultural by-products such as crop residues and animal manure in aquaculture production, and(ii) in quantitative aspects of sediment and nutrient accumulation in aquaculture ponds, and pond sediments potential as a fertilizer in land-based agriculture.n chapter 2, aquaculture components were ideotyped for existing agricultural farming systems and benefits from resultant ideotyped integrated aquaculture - agriculture OAA) farming systems were evaluated and quantified. The results showed that integration of an aquaculture component in agricultural farming systems provided the opportunity to recycle eroded nutrients, in addition, aquaculture provided an opportunity to utilize nutrients from agricultural by-products otherwise lost through leaching during storage. As the majority of nutrients added to ponds accumulate in the sediment, nutrients are stored for later use. In different agro-ecological zones of the Kenyan highlands this

practice reduced soil fertility decline by 23 - 35%, increased agricultural production by 2 - 26% and raised the overall farm food production by 22 - 70%. The results indicated that there may be more benefits from pond sediment utilization than fish production alone and also demonstrated that integration of aquaculture is not a threat to agricultural production. The nutrient storage capacity of ponds and the linked increase in productivity largely compensates for the small loss in land surface for crop production.In chapter 3, the nutrient utilization efficiency of agricultural by-products in fish ponds was investigated and compared to that of supplemental foods. Using multivariate analyses, the trophic pathways in organically fertilized and feed driven semi-intensive culture environments were explored. By ANOVA models, water quality, sediment quality and tilapia growth and yields in the two environments were also compared. In both environments, a phytoplankton based food web dominated, and fish nutrition in both environments was mainly based on natural foods. Extrapolated fish yield data indicated that with equal nutrient input and stocking density, organically fertilized environments could achieve production rates similar to those in feed driven environments. The results challenge the general assumption that supplemental or complete foods are well utilized by tilapia in ponds and underscore the need for further research on fish nutrition in ponds. In chapter 4, the sediment and nutrient accumulation in semi-intensive fish culture ponds within one culture period was quantified, the effect of input type (chicken manure vs. formulated feed) and stocking density (1 or 2 fishes m"2) on sediment and nutrient accumulation evaluated, and the accumulated sediment's potential for use in land-based agriculture estimated. An accumulation of up to 173 tons of sediment ha' cycle" (5 months) was observed in the semi-intensive production ponds and contained between 100 - 300kg of nitrogen, 1.8 - 5 tons of organic matter, 0.2 - 1.1 kg of available phosphorus and 50 - 125 kg of exchangeable potassium. Both sediment and nutrient accumulation were not affected by input type or stocking density. The results indicated that often reported accumulation of phosphorus in pond sediment may be in non-available forms. However, accumulated sediment had a high potential as nitrogen and potassium fertilizer and as a soil conditioner. By recommended Egyptian fertilization rates, the accumulated nutrients during a tilapia production cycle could potentially meet the nitrogen fertilizer requirement for 0.35 - 1.2 hectare and the potassium fertilizer requirement for 0.7 ~ 1.5 hectare.A part of the nutrients that accumulate in aquaculture ponds are lost through seepage. Normally, the assumption is made that seepage water and pond water have the same composition. In chapter 5, the use of rhizons as a standard methodology to measure the concentration of nutrients in seepage water was developed. The results showed that assuming identical chemical composition in seepage water and pond water results in an underestimation of nutrient losses due to seepage. Direct sampling of seepage water using rhizons provided a standardized and easy to use method to quantify nutrient losses due to seepage from earthen pond soils.The findings of this thesis are discussed in chapter 6 and main conclusions are given. The study demonstrated, from a bio-physical point of view, the technical feasibility of aquaculture - agricultural integration and the effect on nutrient cycling through the whole farming system. For further understanding of the benefits of IAA systems, future studies should asses the socio-economic feasibilities of IAA systems. The study has also shown mat agricultural by-products do not necessarily result in lower fish production compared to the use of formulated feeds. The results stress the need to search for new concepts for pond nutrition, as the present use of formulated diets serves more as an expensive fertilizer than a direct feed.