Integrated Aquaculture within Agriculture Irrigation for Food Security and Adaptation to Climate Change

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Abstract: In the existing complexities of climate change, biodiversity, subsistence farming and several other issues associated with agriculture production, gaining self sufficiency in food security is challenging. Experiences from many countries suggest that aquaculture integration within agricultural irrigation, where aquaculture is a non-consumptive user of water, has contributed to increase overall productivity. Irrigation purposively provides water for agriculture in other than rain fed conditions. Strategically, however, irrigation should lead to efficient water management for increased agricultural production especially in present context of biodiversity loss, poverty, water, food and nutritional insecurity in the era of climate change. To overcome the problems of food security and many other relevant issues, the integration of aquaculture within agriculture irrigation is highly recommended.

Key words: Aquaculture within irrigation, food security, biodiversity, climate change

Introduction

Conceptualizing targets of food and nutritional security in the nexus of climate change, sustainable biodiversity, technical, economical and social constraints have been the center of many studies (Tilman, Peter and Johannes 2006; Howden; Soussana et al 2007; Dethier and Effenberger 2011). Food and nutritional security has been worsened in many countries. In the 1970s Nepal was a grain exporter; at present, however, grains are imported to meet the demand. Population growth has exceeded the agricultural growth rate. In 2011, the population had increased to 26.6 million, up from 11.2 million in 1970, and it is projected that by 2021 there will be nearly 34.1 million people in Nepal. To feed all, current agricultural production needs to be at least doubled while adapting to climate change without harming biodiversity, environment and water resources. Agriculture is the main aspiration to built strong base for economic growth, because the sector provides more than 70% of total labor dependency and 34.1% of GDP in national economy (Gurung, Pokharel and Wright 2011).

Irrigation purposively provides water for crop production, other than from rain. Thus, the irrigation is one of the most potential sectors for increasing agricultural production (Biswas 1989). It has been revealed that small reservoirs, small-scale multiple-use water systems, tube wells, and small and large-scale irrigation are likely to reduce poverty, where physical and financial infrastructure is yet to be developed (Kemp-Benedict, Cook et al 2011). About 33% of the cultivable agriculture lands of Nepal have irrigation facilities (NARC 2010). Further intensification and diversification for year round irrigation for increasing agriculture production is the main aim of irrigation sector (DOI 2010).

Global agriculture contributes substantially to the risk of climate change (Gibbs, Ruesch et al 2010), exacerbating food security especially to the poor (MOE 2010). In global Green House Gas (GHG) emission, Nepal's share is negligible (0.025%), but have been rated as the fourth most vulnerable countries in the world to face climate change detrimental impacts (Gurung, Pokharel and Wright 2011). It has been suggested that ecological intensification may reduce substantial GHG and support sustainable biodiversity (Tilman, Peter and Johannes 2006; Aggarwal, Joshi et al 2004). Supporting this idea, Yuan, Cao and Wang (2008) have shown lower mean per square meter per hour methane output of 8.52 mg in rice-fish-duck integration compared to 12.56 mg from rice farming alone, and 9.95 mg from rice-duck system.

It is clear that fish can recycle and supply available nutrients to maximize the use of scarce land and water resources for increasing agricultural production. Fish is one of the cheapest sources of animal protein, which can be produced economically utilizing 'ecological niches' in irrigation canals, ditches and in rice fields prior to water supply for crops. Despite such opportunities, per capita fish production is only 1.8 kg in year 2010, which is far below the requirement and ever increasing market demand. In Kathmandu Valley about 99% of the fresh fish sold is imported mostly from India and other countries. In 2009, conservative estimates showed that about 2,980 metric ton (mt) of fresh fish was imported (Winrock 2011). Considering the different forms of dried, canned, marine, and other high value fish products, Nepal might spent approximately 1.5 billion Nepalese rupees (US$ 20.5 million) in year 2009.

Intensive paddy rice (*Oryza sativa*) farming including aquaculture is water-intensive systems. Rice culture and aquaculture technologies can only be sustainable if they are water-efficient. The irrigation sector can provide services to both rice culture and aquaculture practices. The goal of irrigation and aquaculture is utilization of water resources for sustainable ecology based agriculture production. If irrigation water could be managed wisely for field crops and aquaculture, then issues of water shortage, low fish, cereals, vegetable production food and nutritional security could be resolved with better options in the nexus of biodiversity conservation, climate change, and water scarcity. In line with these, this paper aims to elucidate Integrated Aquaculture within Agricultural Irrigation (IAAI) as a major adaptation measures to climate change vulnerability.

The Concept of Integrated Aquaculture within Agricultural Irrigation (IAAI)

The concept of aquaculture within irrigation system for multiple use of water was examined in 1972 in Laos (Pullin and Shehadeh 1980). The IAAI has been well illustrated by Cohen (1996) aiming to increase per unit land productivity at landscape and farming level.

Nepal is well endowed with freshwater resources with more than 6,000 rivers, numerous glaciers and lakes. Nepal also receives an intense monsoon; 85% of total rainfall occurs within 90-100 days from mid-June to mid-September. The remaining 15% of rainfall occurs over the rest of the year. This means tapping of large volume of water to be used in dry months or areas would be substantial in enhancing agricultural production. Traditionally, water from irrigation canals is meant for crops, vegetables and fruits as represented in Figure 1.

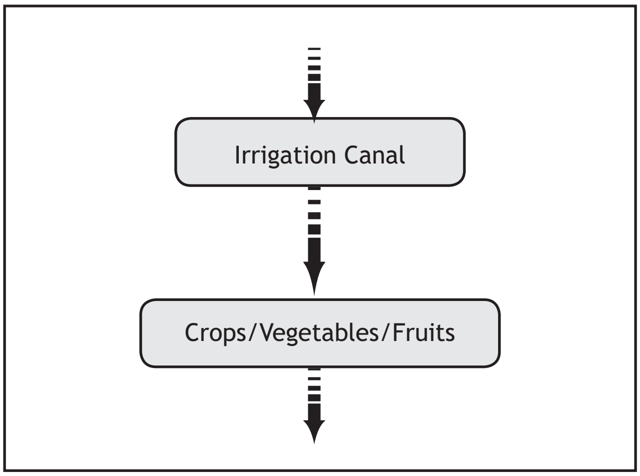

Figure 1. Schematic Traditional Water Supply from Irrigation.

It is important to note, fish only 'borrows' water for shortly to live-in. Therefore, use of irrigation water for aquaculture prior to entering into the crop fields; or fish integration especially with rice paddies would be water efficient agriculture system. Promotion of water efficient agriculture would be prerequisite to adapt the risk of climate change such as unpredictable extreme drought.

Similarly, as a measure of climate change adaptation harvesting of rainwater for agriculture sustainability has been advocated (UNEP 2009). These implying, if aquaculture could be integrated the practices of rain water harvest should be more economical, applicable and valuable for food and nutritional security. In such systems feasibilities of fish inclusion for farming should be examined.

To reduce the vulnerability of climate change integration of aquaculture with agriculture irrigation could be substantial to increase the efficiency of water and land use. The integration might protect biodiversity loss caused by expansion of subsistence agriculture encroaching forest and wetlands. Use of fertilizers and insecticides could also be reduced by integrating aquaculture within agriculture irrigation. The irrigation canals might supply the waters for aquaculture as designated in Figure 2. A, B and C. These approaches are in line with the goals of Department of Irrigation (DOI) aiming for year round irrigation and several other agencies fighting against hunger, food insecurity, biodiversity loss and climate change. At present the fisheries sector possesses at least 10 fish species which could be cultivated in integrated aquaculture agricultural irrigation-system (see Box 1).

Potential List of Fishes for Integrated Agriculture-Aquaculture Practices in Nepal's Terai and Mid-Hills

- Silver carp (Hypophthalmichthys molitrix)
- Bighead carp (Aristichthys nobilis)
- Rohu (Labeo rohita)
- Naini (Cirrhinus mrigala)
- Bhakur (Catla catla)
- Grass carp (Ctenopharyngodon idella)
- Common carp (Cyprinus carpio)
- Tilapia (Oreochromis niloticus)
- Catfish (Clarias gariepinus)
- Rainbow trout (Oncorhynchus mykiss)

Practices and Potentialities

In general, China, Australia, Israel, Sri Lanka, Laos, Cambodia, Bangladesh and India are the countries where irrigational water is prioritized to use for aquaculture in integration with crops (Halwart and van Dam 2006). In Israel, Tilapia fish farms have been established between the main water source and crop fields (Cohen 1996). In India, fish pens and cages have been used to rear fish in irrigation canals (Ray, Panigrahi et al 2010).

In Nepal rice is cultivated as the number one staple foods in about 765,000 ha of cultivable lands (IRRI 2011). On average about 34% of total monthly expenditure in Nepalese families goes to purchasing rice, reflecting the importance of rice based diets (Agostinucci and Margaret 2008). However, Nepal's national rice productivity is about 2.91 mt/ha in 2011, or about 2-3 times below China and Vietnam (IRRI 2011). Such low productivity is due to lack of modern technologies and poor inputs (quality seed, fertilizers, etc.). The use of chemical fertilizers is only 30 kg/ha, one of lowest in the world due to unavailability and inaccessibility in Nepal. In integrated rice-fish farming, the rice is known to be enhanced about 9% with additional production of 529 kg of fish/ha than in rice monoculture (Gurung and Wagle 2005).

Emphasis on IAAI is needed from irrigation for water; agronomy for less pesticide use; and fisheries for readily available fingerlings. The potentialities of IAAI are enormously high in the southern plain (Terai) and mid-hills. Since aquaculture technologies for cold water regions have been developed (Gurung, Pradhan et al 2008), the IAAI should also be promising to high hill areas. It has been estimated that if only 10% of total irrigated rice field could be brought under the rice-fish integration, the present cultivable national fish production of about 22 thousand metric tons could be doubled (Gurung and Wagle 2005). In the Terai there are many shallow and deep tube wells for irrigation with meager annual operation of far less than 400 hours. If integrated rice-fish farming is practiced, the pumping hours will be increased and the tube well system will also be financially viable.

As an example of aquaculture integration with agriculture irrigation at landscape level, we might take Begnas Irrigation Project which has supplied water to fish farm and to crop fields (Figure 3) operatives over the last two decades without any negative effect on irrigation water for crop production downwards. Similarly, fisheries in Phewa Lake generates an income of about 10 million Nepalese rupees annually in recent years (equivalent to 0.13 million US dollars) to hundreds of fishers by cage fish culture and capture fisheries (Gurung, Wagle et al 2005). The same water from the lake irrigates crop fields. Other successful examples are Fattepur Fisheries Center of Saptari District and Banganga Irrigation of Kapilvastu District, both in the Terai. In these locations, economical analysis on IAAI at landscape level is likely to show substantial benefits to farmers as a result of multiple uses of water resources than farmers of areas without integration.

Strength, Weakness, Opportunity and Threat (SWOT) Analysis

SWOT (Strengths, Weakness, Opportunity and Threat) analysis on IAAI adapted from Gooley (2003) has revealed following advantages and disadvantages:

Strengths

- IAAI encourages the multiple use of water in the context of climate change.
- Infrastructures for irrigation and fisheries could be utilized more efficiently.
- Technological knowledge of IAAI and listed fish available.
- Huge market for fisheries products.
- IAAI is one of the strategies of agriculture commercialization and mitigation of climate change impact.
- IAAI approach may also be helpful in managing flood.
- Rice-fish integration could be a tool to control pest through fish into rice field.
- IAAI might control expansion of farming area, thus a way out to sustainable biodiversity.

Weaknesses

- The commitment from National Planning Commission, Ministry of Irrigation, and Ministry of Agriculture and Cooperatives is yet to come for IAAI.
- IAAI is poorly organized and experiences among experts and farmers are fragmented.
- Fish are vulnerable to chemical use specially insecticides.
- Insufficient fingerling production and distribution facilities for IAAI.
- Initiatives from irrigation and agronomy sector for IAAI are lacking.
- Might add extra cost for regulation of water supply system for aquaculture.

Opportunities

- The primary beneficiaries are the rural communities.
- Primary producers may shift towards higher value commodities with higher rate of return on investment.
- Opportunity for commercial crop and fish production.
- Support biodiversity by reducing forest encroachment for subsistence farming.
- Low greenhouse gas emission.

Threats

- Fish could escape to natural water courses.
- Might impact burrowing animals such as rats, snake, bird, and some mammals.

What Next

The farming systems in Nepal are overwhelmingly of the subsistence type (more than 83%), where family labor is engaged to fulfill their basic needs, but almost none for marketing. The per capita landholding is 0.14 ha; nearly half of the holdings are less than 0.5 ha (Sharma 1999). Subsistence agriculture is less productive and economical causing chronic poverty, environmental encroachment and biodiversity loss (Karkee 2008).

Since subsistence agriculture is associated with low levels of economic activity, breaking the vicious cycle of subsistence agriculture is essential to reduce poverty (Abele and Frohberg 2003). If the agricultural sector has to meet future needs, traditional practices should be motivated towards more ecological intensification. It is expected that ecological intensification of farming approach might support smallholders for sustainable production (Cassman 2005).

Aquaculture is one of the fastest growing food industries in the world (De Silva and Davy 2010), gaining high importance for livelihood, jobs, and food and nutritional security. In Nepal, aquaculture needs to be emphasized as a one of the easiest means of fish production for food and nutritional security, by strengthening its network with the irrigation sector. In brief, fish production can be achieved if water is 'borrowed' to aquaculture briefly for integration to increase agricultural production. According to IWMI (2010) Nepal, along with many countries, is facing acute

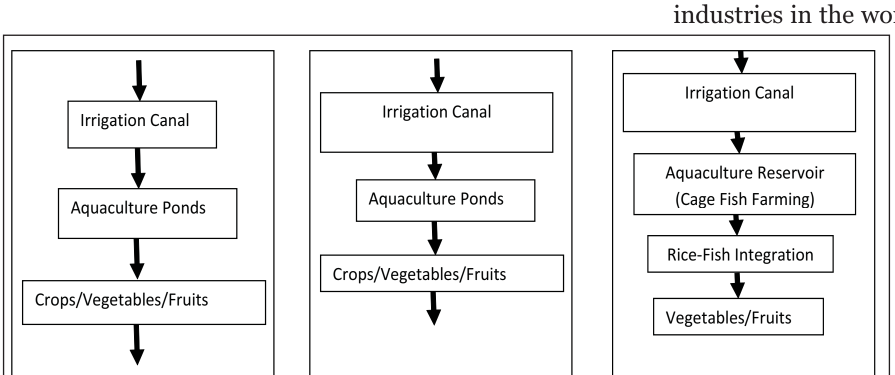

Figure 2. Schematic View of Agriculture Irrigation-Aquaculture Integration – Traditional (A), Improved (B) and (C) Views – for Increasing Production.

Figure 3. A Model of Agriculture Irrigation and Aquaculture Integration in Nepal. Water Supply in Fish Farm from Nearby Begnas Irrigation Project (Photo by the Author).

Figure 4. Begnas Irrigation Project (Photos by the Author).

water shortage despite of having vast resources. It is suggested that aquaculture integration within agriculture irrigation could be one of sustainable ways to efficient use of water resource for adapting the climate change vulnerability.

For equity based resource utilization, the traditional concept of irrigation should be changed to more challenging perspective for environmental sustainability. Thus, irrigation facilities could be used more economically, efficiently and comprehensively. It is advisable that IAAI system should be strongly recommended as a measure of food and nutritional security, sustainable biodiversity and water conservation in the era of climate change.

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