academicJournals

Vol. 9(2), pp. 15-29, February 2017
DOI: 10.5897/JENE2016.0615
Article Number: 4CCABFB63387
ISSN 2006-9847

http://www.academicjournals.org/JENE

Journal of Ecology and the Natural Environment

Review

A review of Uganda and India's freshwater aquaculture: Key practices and experience from each country

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Received 28 November, 2016; Accepted 23 February, 2017

This paper reviews the current status of freshwater aquaculture in both India and Uganda. India has a long history of aquaculture, dating from the 4th century. Subsequently, the country has become a major contributor to global aquaculture and is believed to have more than 10% of the global fish diversity. Currently, India is the second largest aquaculture producer in the world with global contribution of 6.3% and the major contribution comes from freshwater aquaculture, whose share has gone up from 46% in the 1980s to over 85% in the recent years. Since 1980s, India has emerged as one of the largest investors and trading partners of Uganda. As such, there is much that Uganda can adopt from the India's freshwater aquaculture given their political, social and economic relations established overtime between the two countries. As the largest producer of Indian major carps, India has set the pace for change and innovation in culture practices since the 1960s. Uganda's aquaculture is also undergoing changes to meet the challenges of increasing demand, such comparisons through comprehensive literature review and case studies can form a strong foundation for future investment in aquaculture. In addition, generating information for each country's comparative advantage in aquaculture can assist in developing strategies for structural adjustment programmes. Some of those strategies, might promote integration of economic activities, human capacity building, information sharing and technology transfer.

Key words: Aquaculture, carps, fish, freshwater, India, Uganda.

INTRODUCTION

As the fastest-growing food producing sector in the world, aquaculture is increasingly acknowledged for its role in improving income and providing protein-rich food especially in developing countries (Hishamunda et al.,

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Table 1. Key drivers and barriers for freshwater aquaculture development in Uganda and India.

Uganda		India	
Drivers	**Barriers**	**Drivers**	**Barriers**
High demand for fish	Limited supply of quality seed	Advances in aquaculture biotechnology	Shortage of land and water
Declining supply from capture fisheries	Inadequate feed supply to sustain the real opportunities in aquaculture	Enhanced research and extension	High cost of fish feeds
Favourable sites for pond and cage aquaculture	Lack of sustainability after donor support	Adequate domestic feed ingredient resource base	Anomalies in aquaculture data
Increased support for aquaculture from donors	Limited technical support for farmers	Provision of incentives in form of subsides	Absence of long-term leasing policies
	Lack of aquaculture center to coordinate and collect aquaculture statistics	Enhanced human resource capacity	Poor post-harvest handling
	Poor governance of aquaculture	Richness in species biodiversity	
	Weak research and extension linkages	Functional producer agencies	
	Difficulty for farmers to access financial support from lending institutions	Sustained government support	
	Limited human resource capacity		

2014).Freshwater aquaculture has continued to form a major share of the aquaculture production of both Uganda and India. Uganda, like other developing countries, depends on agriculture including fisheries and aquaculture to provide the foundation of export growth and development. The Ugandan fisheries sector is important in terms of employment, poverty reduction and foreign exchange revenues. Although the trend in demand for Uganda's fish has been increasing, over-exploitation of fisheries resources limits export potential and expansion.

India established its diplomatic presence in Uganda in 1965, but the relationship between both countries dates back to the late 19th century when traders exchanged goods in dhows across the Indian Ocean. Eventually a number of Indians settled in East Africa, and many made Uganda their home. Politically, India's freedom struggle inspired early Ugandan activists to fight colonization and eventually achieved freedom in 1962. Socially, India is seen as a destination for quality and affordable education by Ugandans. Economically, India plays a leading role in the Ugandan economy, especially in manufacturing, trade, agro-processing, banking, sugar, real estate, hotels, tourism and information technology. India has increasingly become the major source of foreign direct investment (FDI) to Uganda. According to the Uganda Investment Authority (2015), India registered the largest number of FDI projects totalling 65 and these accounted for 26% of all the FDI projects in the financial year of 2014-15. Despite these interventions, investment opportunities in aquaculture by the Indian private sector are limited in Uganda although the country is endowed with vast freshwater resources constituting 18.2% of the country's surface area.

Situation analysis: Enabling environment and factors constraining the sector

The key factors that enable or impede aquaculture development in both countries were established after reviewing both the literature and a series of case studies (Table 1). Experience in India can offer lessons for enhanced aquaculture development, which, suitably adapted, might promote aquaculture in Uganda. The increasing demand and decreasing fish supply from capture fisheries provides an opportunity for aquaculture development in Uganda. With regard to the development strategy and investment plan (DSIP), fish is prioritised as a key investment opportunity over the medium term. The government is also planning to develop aquaculture parks in five gazetted areas including lakes and rivers in the central and western regions (Dalsgaard et al., 2012). Although there are attempts to enhance the enabling environment for the sector, the governance capacity is weak in terms of security of tenure at cage sites, accountability and environmental management. In addition, the sector has also been greatly affected by inadequate budgetary provision within the directorate of

fisheries resources and limited support for extension service providers, as well as limited production of fish seed and feed. In many cases, aquaculture research activities are hindered by the low budgetary support that eventually affects the quality of research, innovation and new aquaculture knowledge generated.

Freshwater aquaculture in India has benefited from sustained support for technology, innovation, and knowledge dissemination under the national and regional partnerships. Capacity building programs extended by the extension services, research institutions, universities, and networks, such as the Network of Aquaculture Centres in Asia-Pacific (NACA) have demonstrated a vital role for the development of India's aquaculture. For example, some of the key technological advances that have been registered, include, early breeding of Indian major carps by use of broodstock diet of "CIFABROOD", prevention of fish diseases by Cifax fish medicine, cryogenic preservation of carp milt and gene banking and developing a genetically improved variety of *Labeo rohita* (Jayanti rohu) (Reddy, 1999; CIFA, 2010). Despite these remarkable achievements, many traditional fish farming practices in India are inadequately documented. Shortage of water is also becoming a major limiting factor especially during seasons of erratic rainfall, hence, rendering many fish tanks and ponds unsuitable for providing optimal growing conditions for fish.

In both countries, quality feed remains as one of the most prominent barriers to expanded aquaculture production, especially in small and medium-scale production. In order to compete with capture fisheries, affordable quality feed need to be produced and maintained. There is also a serious gap in both countries regarding the reliability of aquaculture production data. Estimates between FAO data and what government agencies present, differ substantially. Moreover, the industry has to rely on data that are two or three years old. This makes business planning and market assessments ineffective in both countries.

STATUS OF AQUACULTURE

Uganda

Aquaculture in Uganda has a relatively recent history compared to India. It is reported that aquaculture started in 1953 with the establishment of the Kajjansi experimental station (Balarin, 1985; Rutaisire, 2007). The main purpose was to improve the nutrition of rural families through increased animal protein content in the diet, with the goal of reducing malnutrition. Fish farming reached a peak in the late 1960s, when approximately 11,000 ponds were reported to be in operation. In addition to increased technology adoption by farmers during this period, government researchers at Kajjansi were investigating carp culture, tilapia hybridization, and predator control (Balarin, 1985). Due to prolonged political instability in the 1980s, majority of the fishponds were abandoned and this greatly affected the aquaculture development with annual production being recorded as 30 to 40 metric tonnes. According to MAAIF (2011), there are about 2,000 emerging commercial farmers who own nearly 5,000 ponds with an average pond size of 1,500 m² per pond. Cage culture is another activity that has emerged with over 750 cages owned by groups or individuals. Consequently, current aquaculture production is estimated at 111,023 metric tonnes/year (FAO Fishstat, 2016). This increase has been mainly driven by the entry of commercial aquaculture producers, management of stocked communal water bodies and adoption of high density fish culture technologies (Owani et al., 2012).

India

The first reports of aquaculture in India date from around 321 B.C according to FAO's National Aquaculture Sector Overview for India (FAO, 2005). Kautilya's Arthashastra (321-300 B.C.) and King Someswara's Manasottara (1127 A.D.) each refer to fish culture. From the State of West Bengal, fish culture spread to other states of Tamil Nadu (formerly Madras) as early as 1911, and afterwards to other states like Punjab, Uttar Pradesh, Baroda, Mysore and Hyderabad. Freshwater aquaculture in India started with the stocking of carp in backyard ponds in West Bengal and Odisha and subsequently expanded to other states of India. The technological breakthrough in induced breeding of carps through hypophysation in 1957 transformed freshwater aquaculture and today carp culture forms the backbone of freshwater aquaculture practice in India (FAO, 2005). With assured supply of quality seed, the techniques of seed rearing and grow-out culture of carps has undergone rapid development and refinement through research and development. Freshwater aquaculture, mainly dominated by carps, contributes a major share of Indian aquaculture production (FAO, 2005). The continued impressive growth of freshwater aquaculture not only has led to substantial socio-economic benefits including food security through primary production, income generation in rural areas, and generating significant export earnings, but also utilized vast underutilized land and water resources. Table 2 illustrates the production statistics of the two countries over a period of 10 years.

Resource base for both countries

Uganda lies across the equator and is well-endowed with inland waters consisting of lakes, rivers and swamps.

Table 2. Aquaculture production statistics for Uganda and India (tonnes).

Year	Uganda	India
2005	10, 815	2,973,126
2006	32,390	3,182,817
2007	51,109	3,114,762
2008	52,250	3,855,763
2009	76,654	3,798,842
2010	95,000	3,790,021
2011	85,713	3,677,584
2012	95,906	4,213,980
2013	98,063	4,555,209
2014	111,023	4,884,021

Source: FAO: Fisheries and Aquaculture Information and Statistics Branch (2016) online query.

These constitute about 43,941 km^2 (18.2%) of the country's total area of 241,083 km^2 and are, by far, the major source of the country's fish resources (NEPAD, 2005; MWE, 2007). The streams and rivers, therefore, offer opportunities for pond culture, while the larger rivers and lakes offer prospects for intensive cage culture (MAAIF, 2011). The lowest altitude is 620 m (within the Albert Nile) and the highest altitude (Mt. Rwenzori Peak) is 5110 m above sea level (MWE, 2007; NEMA, 2010). The majority of the fish comes from Uganda's five major lakes (Victoria, Kyoga, Albert, George and Edward) (MAAIF, 2011). The climate is equatorial, with moderate humid and hot climatic conditions throughout the year characterized by two rainy seasons in a year, which merge into one long rainy season as you move northwards from the equator. The first rainy season is from March to June, while the second season is from August to November. The mean annual rainfall ranges from 700 mm in the drier areas to about 3000 mm in the humid areas (NEMA, 2010).

India is a south Asian country situated between the Himalayas in the north and the Indian Ocean in the south and covers a total area of 3,287,728 km^2 (Sugunan, 1997). India's inland fisheries resources are diverse, comprising of rivers, floodplains, estuaries, mangroves, estuarine impoundments, lagoons, upland lakes, reservoirs and ponds. It contributes substantially to the world's biological resources from the long stretches of Eastern Ghats in the East, the greater Himalaya range on the Northern Plains and the Western Ghats on the west. The country is endowed with vast and varied fish germplasm resources with freshwater fish genetic resources constituting 756 species which have been recorded in the National Bureau of Fish Genetic Resources database (Lakra et al., 2010). The high level of biodiversity of the Indian fauna and flora is regarded as a particular strength, providing opportunities for diversification of production. The climate ranges from tropical heat in the south to temperate in the north. According to Sugunan (1997), India has 19,134 small reservoirs with a total water surface area of 1, 485,557 ha. Similarly, 180 medium and 56 large reservoirs of the country have an area of 527,541 and 1,140,268 ha respectively. The country has 19,370 reservoirs covering 3,153,366 ha.

Fish consumption trends

There has been a rapid increase in the demand for fish due to increased population, income, urbanisation and changing food habits in Uganda and India. However, wide regional variations do exist in fish consumption across regions, states and income classes in both countries which, may be attributed to religious beliefs, ethnic and geographical differences. In Uganda, farming of fish is a taboo in cattle farming communities because of a belief that fish have a negative effect on milk production. In India, cereals are the main source of calorie-intake for a vast majority of the population who cannot afford or do not consume fish. India's per capita fish consumption is estimated at 9.8 kg whereas the recommended intake is 13 kg (Ministry of statistics and programme implementation, 2011; NFDB, 2016). Uganda's per capita fish consumption stand at 11.5 kg which is slightly higher than that of India. Jagger and Pender (2001) reported that approximately 75% of Ugandans consider fish a traditional part of their diet. However, the consumption rates are affected by unreliable transportation network, underdeveloped markets and poor preservation technologies.

Marketing and credit

Uganda's aquaculture industry is divided into three main sectors; smallholder fish farms, medium-scale commercial fish farms and large-scale commercial fish farms (Dalsgaard et al., 2012). Smallholder fish farms focus on local markets whereas large-scale commercial farms concentrate on regional markets from neighboring countries. Recent market-oriented studies suggest that there is considerable potential for the development of markets for aquaculture products, largely due to the rapidly declining catches from the wild. Efficient markets for the sale of wild fish exist, but very little for farmed fish (Jagger and Pender, 2011; Dalsgaard et al., 2012). Although, there has not been enough production from aquaculture systems to sustain a steady market, the growing market share of multiple retail stores in the distribution of foodstuffs has significantly changed patterns of production, supply and distribution of

aquaculture products. Access to finance has also become a major issue, as higher levels of investment are required to respond to market demands including quality control. Despite the agricultural credit facility set up by the Government of Uganda in partnership with some commercial banks, the existing interest rate of 24% charged by many commercial banks limits many farmers from accessing credit to engage in aquaculture production (Jagger and Pender, 2011).

India's aquaculture has been developed under two models, the commercial aquaculture that have been engaged in large scale aquaculture enterprises (in terms of seed and feed production) and the smallholder aquaculture supported by either central or state government (World Bank, 2006). The former has largely been driven by private sector initiatives and enterprises while the latter by external support, national policies and programs. The enterprise model has generated growth and employment, often in poor regions. The public support has attempted to extend aquaculture development to rural areas through policy support, adaptive technologies, knowledge dissemination, and services (FAO, 2001). In the late 1980s, institutional agencies shifted their emphasis from marine and inland capture to aquaculture. Currently, credit facilities in form of loans and subsidies for the development of small-scale aquaculture are extended by the central and state governments through their development projects, fisheries cooperative societies and special programmes such as integrated rural development, small farmers development agency and fish farmers development agency. Besides, various financial institutes, agriculture development banks and commercial banks also provide credit and loan facilities. However, the absence of long-term leases makes it difficult for lending agencies to advance credit for capital investments.

Contribution to global aquaculture production

Both countries greatly depend on freshwater aquaculture of finfish however the potential for mariculture production of finfish remains largely untapped in India (FAO, 2014). Being a landlocked country, Uganda entirely depends on freshwater finfish aquaculture. According to FAO (2014), Uganda contributes only 0.14% while India ranks second in the world in total aquaculture production with a global contribution of 6.3% and freshwater aquaculture contributes to over 85% of the country's aquaculture production. Therefore, freshwater aquaculture is likely to provide directly to the supply of affordable protein food, particularly for the poor communities in both countries. This subsector is also expected, through continued promotion and sustainable development, to be the lead player in achieving long-term food and nutrition security and in meeting the increased demand for food in both countries.

PRODUCTION SYSTEMS

Pond culture

Pond culture represents the mainstay of aquaculture in both Uganda and India. In Uganda, pond culture is commonly practised in nearly every district of the country (Isyagi et al., 2009a). Among the factors that influence farmers' decisions on pond size are recommendations by extension staff, production costs and land size (Isyagi, 2007). With the drive to commercialize aquaculture production in Uganda, efforts to increase the pond surface have resulted in a current average of 500 m² per fishpond.

In India, the most successful system of fish culture is the polyculture or composite fish culture of three Indian major carp species - catla, rohu and mrigal along with three Chinese carps; silver carp, grass carp and common carp (Kumar, 1992). Rectangular earthen ponds (usually 0.1-0.2 ha and 1.5-2.0 m deep) are commonly used for the rearing of Indian major carps. However, with regard to fish breeding, special types of perennial, seasonal ponds or impoundments are simulated during the monsoon season owing to the accumulation of rain water from the catchment areas. These are either categorised as "wet bundhs" (perennial types) or "dry bundhs" (seasonal types) and these 'bundhs" vary in shape and size and also from state to state. Indian major carps can also be induced to spawn in breeding hapas which are normally kept stretched by ropes at each of their four top and bottom corners tied to bamboo poles in ponds.

Tanks

Tanks of various designs are commonly used in modern hatcheries for induced breeding of multiple species of fish in both countries. In many hatcheries, the system is normally composed of holding tanks, breeding tanks and the larvae rearing tanks. The sizes of these tanks depend on production cost, space utilization, water quality maintenance, and fish management. In Uganda, tanks were first introduced in the early 1990s with the aim of producing European eel, *Anguilla anguilla* on private farms (Isyagi, 2001). Currently, circular and rectangular tanks are commonly used by the catfish hatcheries for spawning and seed production.

In India, circular (Chinese type) cemented tanks are generally used to conduct artificial breeding of carps. This kind of tanks creates a favourable environment and facilitates fish spawning. In addition, there are no dead areas and the water flow through the tank is uniform, and can be used to rapidly concentrate and remove settleable solids (Timmons et al., 1998). Therefore, this kind of establishment facilitates artificial environment to trigger the broodstock for early and large scale production of

spawn to meet the seed demand of carp fish farming in India.

Cages

The declining fish catches in the Ugandan lakes and rivers have been a motivating factor for expanding the operations of cage aquaculture. Compared to fish pond culture, cage culture in Uganda, is a newly introduced intervention promoted as an alternative production system for increasing aquaculture production. It has been reported that cage culture started in 2006, and is being encouraged by the Government of Uganda as a development priority (Blow and Leonard, 2007). The most common cage technology is the low-volume high density (LVHD) cages of 8 m^3 with stocking rate of 200-400 fingerlings/m^3 depending on the flow rate and water depth. Cage farming of Nile tilapia, *Oreochromis niloticus* in Uganda is based on hatchery-produced fry and the use of pelleted feed. This type of production system is now being practised by many actors such as research institutions, local governments, private investors and donor agencies. The Source of the Nile (SoN) fish farm, is among the private sector companies involved in cage culture with production trends ranging from 40 to 300 tonnes of *O. niloticus* in 2010 and 2011 respectively (Dalsgaard et al., 2012). The farm is trying to expand its production capacity to around 2,500 tonnes per year. In addition, a pilot project was launched in 2012 under the Uganda - China friendship agriculture technology centre to promote cage farming on Lake Victoria (Dalsgaard et al., 2012). Currently, a minimum of 12 tonnes of *O. niloticus* are harvested every year from the established pilot cages.

In India, commercial fish farming in cages is low despite the potential of different reservoirs located throughout the country. Spawning and fry culture of Indian major carps and exotic carps are reared in cages fabricated out of high- density polyethylene (HDPE) woven fabric with 40 mesh/inch during April to May and July to August while common carp and giant freshwater prawn during rest of the year (Sharma, 2012). Cages with 1 to 3 mm mesh sizes are used for rearing of fry and the stocking rate ranges from 700 to 2500 fry/m^2. Prioritizing production of fish from reservoirs has been initiated as a strategy for increasing inland fish production. In the recent years, the National Fisheries Development Board (NFDB) has supported several initiatives for cage culture in reservoirs located in Jharkhand, Chhattisgarh and Assam.

Recirculating aquaculture systems (RAS)

In both countries, RAS is the most technologically challenging and currently the most expensive way to culture fish. In India, the application of RAS has been mainly for research towards understanding the effect of stocking density on growth and survival of different fish species (Sharma and Chakrabarti, 2003). The choice of fish species to be cultured under this type of system, largely depends on the feeding habits of the fish, availability of seed for stocking, acceptability of artificial feed and market value.

Integrated carp farming

In India, an integrated approach of composite fish culture together with compatible combination(s) with poultry, duck, pig rearing and cattle is now being adopted (Kumar, 1992). Under this system of farming, small livestock and farm yard animals such as pigs, poultry and ducks are integrated with composite fish culture by siting animal housing units on the pond embankments in such a way that the animal wastes are diverted into fish ponds for recycling. The fish not only utilise the spilled animal feed but also directly feed on fresh animal excreta which is partially digested and is rich in nutrients. Production levels of 3 to 5 tonnes/ha/year have been demonstrated by the integration of fish with poultry/duck/pig (Ayyappan, 2007).

MAJOR FRESH WATER SPECIES REARED

The main species being produced in Uganda are *O. niloticus* and *Clarias gariepinus* however other species are or have been important in particular parts of the country including *Cyprinus carpio* and *Tilapia zillii* (Rutaisire, 2007; Dalsgaard et al., 2012; FAO Fishstat, 2016). Successful spawning of *Labeo victorianus and Barbus atlantis* as initial steps to their culture has been conducted at Aquaculture Research and Development Centre (ARDC). Abi Zonal Agricultural Research and Development Institute (Abi ZARDI) is also investigating the adaptability of *Alestes baremoze* under captivity.

The culture of carps forms the backbone of freshwater aquaculture practice in India (Katiha et al., 2005; FAO, 2014). As an initiative for diversification of species, the Indian government, permitted exotic *O. niloticus* to be integrated into existing aquaculture systems from 2012. Freshwater aquaculture mainly includes the culture of carps, culture of catfishes (air breathing and non-air breathing), culture of freshwater prawns and culture of tilapia. Catfish culture has recently expanded in the country, comprising mainly of *Clarias batrachus*, *Pangasius pangasius*, *Clarias gariepinus* and *Pangasius hypophthalmus* (Suresh, 2007). Freshwater prawn farming has received increased attention only in the last two decades due to increased consumer demand. Efforts have been made to develop the hatchery technology for

Table 3. Freshwater species that are currently cultured in Uganda and India.

Fresh water species	Uganda[a]	India[b]
Tilapia		
Nile tilapia, *Oreochromis niloticus*	✓	✓
Redbelly tilapia, *Tilapia zillii*	✓	×
Carps		
Exotic carps		
Common carp, *Cyprinus carpio*	✓	✓
Grass carp, *Ctenopharyngodon idella*	×	✓
Silver carp, *Hypophthalmichthys molitrix*	×	✓
Indian carps		
Catla ,*Catla catla*	×	✓
Rohu, *Labeo rohita*	×	✓
Mrigal, *Cirrhinus cirrhosus*	×	✓
Catfishes		
African Catfish, *Clarias gariepinus*	✓	✓
Magur, *Clarias batrachus*	×	✓
Stinging catfish, *Heteropneustes fossilis*	×	✓
Pangas catfish, *Pangasius pangasius*	×	✓
Sutchi catfish*, Pangasius hypophthalmus*	×	✓
Freshwater prawns		
Giant river prawn, *Macrobrachium rosenbergii*	×	✓
Monsoon river prawn, *Macrobrachium malcolmsonii*	×	✓
Gangetic prawn*, Macrobrachium gangeticum*	×	✓
Indian freshwater pearl mussels		
Pond mussel, *Lamellidens marginalis*	×	✓
Paddy field mussel*, Lamellidens corrianus*	×	✓
Riverine mussel, *Parreysia corrugata*	×	✓
Fish species under research towards breeding		
Alestes baremoze	✓	×
Labeo victorianus	✓	×
Barbus atlantis	✓	×
Lates niloticus	✓	×
Lates calcarifer	×	✓
Chanos chanos	×	✓
Piaractus brachypomus	×	✓
Anabus testudineus	×	✓

Source: [a]Rutaisire, 2007; [b]FAO, 2005.

seed production of these prawns. The giant river prawn, *Macrobrachium rosenbergii* is cultured either under monoculture or polyculture with major carps. Table 3 summarizes the different freshwater species currently reared in both Uganda and India.

PRODUCTION TRENDS OF MAJOR FRESHWATER FISHES

According to FAO Fishstat (2016), the total production of *O. niloticus* was 52,303 tonnes in Uganda compared to 43,586 tonnes of C*. gariepinus* in the year 2012. As a result, *O. niloticus* is now the most popular species for aquaculture in Uganda (Table 4). The underlying factor for this increase is attributed to enhanced cage culture programmes in the country and yet *O. niloticus* is the main species commonly used in this kind of system. It is also easier to produce fish seed of *O.niloticus* as compared to other fish species. The rearing of *C. carpio* has gradually receded to almost insignificant levels. *T. zillii* has also been neglected by farmers because of its

Table 4. Freshwater aquaculture production (tonnes) by species groups.

Year	Uganda				India			
	African catfish	Nile tilapia	Common carp	Redbelly tilapia	Catla	Mrigal	Rohu	Common carp
2002	2,728	1,797	230	160	424,381	401,545	440,842	359,325
2003	3,000	2,000	300	200	421,203	398,537	437,540	442,874
2004	3,827	1,660	50	-	1,010,838	221,064	923,156	-
2005	6,528	4,221	41	18	1,135,746	217,127	931,556	-
2006	20, 941	11,365	47	23	1,188,293	109,033	1,048,357	-
2007	34,096	16,763	73	128	1,920,516	145,287	386,076	-
2008	35,000	17,000	70	130	2,160,708	281,525	504,745	-
2009	54,956	21,445.2	75.5	128	2,191,797	304,767	495,707	-
2010	63,000	31,500	120	170	2,705,184	87,686	279,004	186,454
2011	57,300	28,101	127	80	2,148,427	131,793	645,300	-
2012	43,586	52,303	17	-	2,458,788	165,782	627,662	-

Source: FAO - Fisheries and Aquaculture Information and Statistics Service (2016).

slow growth rate (Rutaisire, 2007).

The three Indian major carps, namely catla (*Catla catla*), rohu (*Labeo rohita*) and mrigal (*Cirrhinus cirrhosus*) contribute the bulk of production of the India's total fresh water fish production (FAO, 2005). *C. catla* is the fastest growing Indian major carp species and widely distributed throughout the country (Kumar, 1992). According to FAO Fishstat (2016), production of *C. catla* was estimated to be 2.4 million tonnes in 2012 (Table 4).

FEED PRODUCTION

Feed represents one of the highest operating costs in aquaculture systems (Rana and Hasan, 2013). The choice and feed management practices have a significant impact on the economic performance of a production system. The recent interventions in the production of fish feed in form of floating or sinking pellets have been a key factor to increased aquaculture production for both Uganda and India. In Uganda where *O. niloticus* is cultured as the major crop in polyculture or in semi-intensive monoculture, feed accounts for 60 to 70% of production costs and the reported feed conversion ratio (FCR) of using farm-made feeds is estimated to be 5.0 compared to 1.5 - 1.8 of dry-pelleted manufactured feeds (Isyagi et al., 2009b). Similarly, the FCR of using farm-made feeds in India is estimated as 3.0 compared to 1.7 to 1.8 of dry-pelleted manufactured feeds (Jayasankar, 2012). A number of ingredients such as, vegetables, grass, cereals, oilseed cakes, industrial and kitchen wastes, insects and fishmeal are used as fish feeds in both countries. The cost of feed ingredients varies with the agricultural calendar and also according to the region. At the peak of the harvest season, commodity prices tend to be lower and then increase with demand and decreasing supply. Transportation of feeds and feed ingredients takes various forms including carrying the sacks on people's head, bicycles and trucks.

The general animal feed industry in Uganda started in the late 1960s. The total current feed production is estimated at 80,000 metric tonnes/year, of which 85% of the feed is for the poultry market (Rutaisire, 2007; Cocker, 2014). The feed manufacturers in the country are categorised as formal and informal producers with the former involved in manufacturing of pelleted fish feed, whereas the latter are either small-scale mixers or backyard mixers with basic skills of operating feed mills (Cocker, 2014). The manufacture of aqua-feeds in form of sinking pellets started in 2006 when the fisheries investment for sustainable harvest project supported the Ugachick Poultry Breeders Ltd, with technical and financial support (USAID, 2009; Isyagi et al., 2009a). Previously, the country was depending on small amounts of specialised feeds imported by the private sector. According to USAID (2009), only 260.57 tonnes of aqua-feeds were documented to have been produced in 2008 from the three companies (Ugachick Poultry breeders, SoN and Nuvita). However, the production has increased over the recent years and currently, ugachick poultry breeders is the leading manufacturer of commercial aqua-feeds in the country and the main distributor within the East African region. The only available reported production data indicate that in 2011, Ugachick had produced 4,000 tonnes of floating pellets for grow-out fish and out of this, 60% were exported and 40% were for the local market (Daily Monitor, 2012). Despite these recent advances, the development of aquaculture in Uganda is constrained by the high cost of the commercial feeds and a lack of technical know-how to make appropriate farm-made feeds.

The use of industrially manufactured feeds in the Indian

Table 5. Governance of aquaculture inputs from the year 1950 to 2000.

Inputs	Country and period					
	1950s- 1970s		1980s – 1990s		2000s	
	Uganda[a]	India[b]	Uganda[a]	India[b]	Uganda[a]	India[b]
Seed	Central government	Government owned and natural collection	Wild	Government owned and natural collection	Private-sector hatchery	Private-sector hatchery
Feed	Farmer	Farmer	Farmer	Government owned, farmer and companies	Private sector	Government owned and private sector
Extension	Central government	Government owned	Central government	Government owned	Private sector and central government	Private sector, central and state governments
Research	Central government	Central and state governments	Central government	Central and state governments	Central government	Private sector, central and state governments

Source: [a]Isyagi et al. (2009a); [b]NFBD, 2016.

aquaculture began in the early 1990s when feeds were imported from Taiwan Province of China, Southeast Asia and the United States of America for shrimp production (Suresh, 2007). Currently, India has adequate domestic feed ingredient resource base for aquaculture production sectors. For example, India is one the major producers of rice bran and soybean meal, the chief ingredients in fish feeds. The available data indicates that the country is estimated to have 26 feed mills with a total capacity of 2.88 million tonnes of feed for both shrimp and fish annually (Anand and Umakanth, 2014). Current freshwater fish feed production is estimated at 0.7 million tonnes/year. As a major producer of carps, the country has made major advances in the improvement of feed and nutrition of freshwater fish species in relation to broodstock diets. ICAR- CIFA has developed a broodstock diet that advances gonadal growth and maturation.

AQUACULTURE POLICY AND LEGISLATION

The background information on Uganda's fisheries and aquaculture policy and legislation is summarized in FAO's National Aquaculture Legislation Overview (NALO) for Uganda (FAO, 2011) while that of India is summarized in the National Aquaculture Legislation Overview for India (FAO, 2004). In Uganda, the Directorate of Fisheries Resources (DFR) under the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) is the competent authority responsible for inspection, certification and approval of aquaculture establishments and related practices. The main legislation regulating the aquaculture sector is the Fish (Aquaculture) rules of 2003. It guides the sector in production and marketing of aquaculture products (FAO, 2011). The current policy under which aquaculture is embedded is the National Fisheries Policy. Despite the promising potential of aquaculture in the country, it is important that specific policies and strategies through which the major bottlenecks hindering the progress of aquaculture development in the country are addressed.

India, being a federal republic, subdivided into states and union territories, the state legislature has the power to make laws and regulations with respect to a number of issues including water, land rights and tenure, fisheries, as well as the preservation, protection and improvement of stock and the prevention of animal disease (FAO, 2004). However, at the central level, several key laws and regulations relevant to aquaculture include the Indian Fisheries Act (1897), Environment (Protection) Act (1986), Water (Prevention and Control of Pollution) Act (1974) and the Wildlife Protection Act (1972). In addition, the Ministry of Agriculture has designed guidelines for sustainable development and management of aquaculture. Coastal aquaculture authority also formulated guidelines for increasing production and productivity in traditional and improved traditional systems of shrimp farming with the objective of optimising yield levels in such systems on sustainable basis.

GOVERNANCE OF AQUACULTURE INPUTS

Initially, the Government of Uganda and the Government of India provided everything to the farmer at their own cost from technical backstopping to seed supply. However, there has been general shift of institutional support for aquaculture from traditionally-produced feed and seed provided by the public sector, to private sector provision (Table 5). The collapse of public sector seed production has led to establishment of private hatcheries in Uganda. Regional aquaculture stations built for seed

production and training are now non-functional. These were generally operated through donor funding and eventually closed after the projects had ended. It is generally believed that seed production in Uganda is mainly for private sector.

The central and the state governments have undertaken several policy initiatives and measures to boost the growth of aquaculture in India especially during the 2000s. Some of the policies undertaken to boost fish production include; assistance in the form of subsidies with regard to construction of new ponds, renovation of ponds and tanks, first year inputs (fish seed, fertilizer and manure), establishment of fish seed hatcheries and fish feed mills. In terms of extension, the farmers' training centres not only disseminate technology to farmers, but also provide a communication channel to the researchers about field problems and indigenous technical knowledge.

From 2000, the private sector (mainly those involved in feed production) in both countries started extension activities with larger commercial farms. In addition, farmer-to-farmer transfer of knowledge is also a common source of information about new technologies in both countries. However, the current aquaculture extension system in Uganda is often under-resourced leading to poor service provision and dissatisfaction amongst farmers (Isyagi et al., 2009a).

KEY INSTITUTIONS SUPPORTING AQUACULTURE

The key institutions supporting aquaculture sector in Uganda include public sector, local governments, private sector and non-governmental organisations (Table 6). The public sector, mainly MAAIF and its associated agencies have key roles of supporting aquaculture in areas of capacity building, fish seed production and research and extension provision (NEPAD, 2005). The private sector is active in fish breeding and fish grow-out production. There has been continuous mobilisation of fish farmers by Walimi fish farmers' cooperative society (WAFICOS) which is the main Uganda's fish farming association legally registered under the Uganda cooperative alliance. The society had registered 315 members from all regions of Uganda by 2010, it comprised of grow- out fish farmers, fish seed producers and breeders, trainers, fish feed manufacturers, processors, input suppliers and researchers (Walakira et al., 2010).

In respect to the increasing role of inland fisheries in overall fish production, the Indian government has been implementing two important programmes in the freshwater sector. These are the fish farmers' development agencies (FFDAs) and the national programme for fish seed development. A network of 429 FFDAs covering all potential districts in India are in operation for development of freshwater aquaculture (NFDB, 2016). The Indian Council of Agricultural Research has also been a principal agency for the aquaculture research and development in India (Table 6).

INTERVENTIONS BY KEY INTERNATIONAL FUNDING AGENCIES

In the last 16 years, international donors have supported substantial projects in Uganda to overcome the technical and scientific bottlenecks in Uganda's aquaculture. These projects have mainly focused on seed production, cage farming, infrastructure development, improved human capacity and feed production (Table 7).

The international external assistance for aquaculture development in India has reduced in recent years as compared to the period of 1988 to 1995 when the country received major loans from development banks for external aid to aquaculture (Kongkeo, 2011). The two main sources of credit for India's aquaculture have been the World Bank and the Asian Development Bank. The Norwegian Agency for Development Cooperation (NORAD), Norway and the Department for International development (DFID), United Kingdom have also funded institutional cooperation projects on genetic improvement of *L. rohita* and *C. catla* respectively. Other international organisations, including the UNDP and DANIDA have also provided aid to India for the development of fisheries sector (Kumar et al., 2003). Under the Bay of Bengal Programme (BOBP) that started in 1979, assistance was provided for the development of small-scale fisheries and enhancing the socio-economic conditions of the fishing communities. The states of Andhra Pradesh, Bihar, Orissa, Uttar Pradesh and West Bengal benefited from the shrimp and fish culture project that was financed by the World Bank in 1992 to 1999.

CONCLUSION AND RECOMMENDATIONS

Freshwater aquaculture has emerged as a fast-growing industry and a viable alternative to the declining capture fisheries in both countries. It contributes to supplies of animal protein, generation of employment, and also means of improving farm income. As the population increases in both Uganda and India, the demand for fish and the aquaculture sector is projected to grow. It is therefore vital for both countries to review and formulate policies for the sustainable development of aquaculture. For this to happen, a wide range of management practices need to be considered that address constraints related to marketing and research policies.

Review of existing legal frameworks

The existing administrative and legal frameworks need to

Table 6. Key institutions supporting aquaculture sector in Uganda and India.

Uganda	**Role**
Ministry of Agriculture Animal Industry and Fisheries (MAAIF) (Directorate of Fisheries Resources)	Support sustainable, market oriented fish production, management, development, control quality and safety of fisheries products; for improved food security and household income
National Agricultural Research Organisation (NARO)	This is the apex body for guidance and coordination of all agricultural research activities in the national agricultural research system in Uganda
Local governments	They are primarily responsible for providing technical services to the farmers
Non-governmental organisations	These support fish farming when identified as an activity that can improve the livelihoods of their clients
Tertiary institutions	Train fishery personnel and conduct research
India	**Role**
Ministry of Agriculture and Farmers Welfare (Division of Fisheries)	The agency is responsible for planning, monitoring and the funding of several centrally sponsored developmental schemes related to fisheries and aquaculture in all of the Indian states
Indian Council of Agricultural Research (ICAR)	This is the apex body for coordinating, guiding and managing research and education in agriculture including horticulture, fisheries and animal sciences in India
National Fisheries Development Board (NFDB)	Develop fisheries and aquaculture by adopting new and innovative production technologies, management and utilization of unutilized and underutilized water resources
Ministry of Science and Technology (Department of Biotechnology)	Supports various research institutions and universities for conducting the training programs for researchers involved in various sectors aquaculture and marine biotechnology
National Bank for Agriculture and Rural Development (NABARD)	Facilitate credit flow for promotion and development of aquaculture
National Agriculture Development Scheme NADP or Rashtriya Krishi Vikas Yojana (RKVY)	Provide the states and territories of India with the autonomy to draw up plans for increased public investment in agriculture
Agricultural Technology Management Agency (ATMA)	Addresses the key constraints faced by extension system in the country
State agricultural universities	Train fishery personnel and conduct research

be reviewed, in this way, the Ugandan government needs to analyse the existing legal frameworks, policies and institutions to address the specific characteristics and requirements of aquaculture. Specific policies and strategies related to the use of exotic species for aquaculture, aquatic animal health, aquaculture products and public health, aquaculture sector management and capacity building should be properly designed and promoted.

Quality production of affordable feed and seed

Policy instruments to boost feed production should be initiated in both Uganda and India. Such measures may

Table 7. Forms of aquaculture support from key international agencies in Uganda and India.

Period	Agency	Purpose
Uganda[a,b,c]		
1998-2006	Lake Victoria Environmental management (LVEMP), World Bank	Research on indigenous fish species
1999-2005	Department for International Development(DFID), United Kingdom	Improving small holder household livelihoods, income generation and food security through aquaculture
2003-2009	African development Bank	Enhancing aquaculture research and development with the aim of building up research capabilities and evolving aquaculture production systems
2004 -2006	World Food Programme	Improving nutrition and income through fish farming in the communities of West Nile region
2005-2008	United States Agency for International Development (USAID)	Facilitating development of a private sector-driven commercial aquaculture industry
2005 - 2017	NEPAD – CAADP Aquaculture Development Project	Increasing income and nutrition through production of farmed fish for domestic use and export
2009 - 2014	Chinese government	Improving the infrastructure capacity of Kajjansi Aquaculture Research and Development Centre, training and capacity building of farmers and researchers
2011-2017	World Bank (WB) Agriculture Technology and Agribusiness Advisory Services (ATAAS)	Increasing agricultural productivity and incomes of participating households by improving the performance of agricultural research and advisory service systems
2015-2017	Food and Agriculture Organization of the United Nations (FAO)	Promoting aquaculture production through quality seed and feed
India[d,e]		
1986- 2012	Asian Development Bank	Developing shrimp hatcheries and ponds
1992-1997	Norwegian Agency for Development Cooperation	Establishing a breeding program for rohu carp
1992 -1999	World bank	Supporting shrimp and fish aquaculture development in the sates of Andhra Pradesh, Bihar, Orissa, Uttar Pradesh and West Bengal

Source: [a]NEPAD (2005); [b]Isyagi et al. (2009a); [c]Dalsgaard et al. (2012); [d]Kumar et al. (2003); [e]Kongkeo (2011).

include explicit incentives for foreign investment, encouraging livestock companies to diversify into aquaculture and feed production, lowering tariffs on imported feed, promoting large integrated operations, and undertaking research to substitute fish meal with local ingredients. Specifically for Uganda, there is need to rehabilitate the regional fish fry production (hatcheries) and demonstration centers. These facilities have capacity to boost aquaculture development in Uganda with provision of quality fish seed to farmers. The Ugandan government should provide an enabling environment to promote investments in feed and seed sub-sectors. Similarly, the Indian government should diversify and put emphasis on seed production of other valuable species like catfish and murrels since these species command good price in several parts of the country.

Appropriate research and training

Improvements in genetics, nutrition, disease management, reproduction control, and environmental management through appropriate research, continue to widen choices for aquaculture, improve its efficiency and cost-effectiveness (Machena and Moehl, 2001). Research aimed at increasing and sustaining productivity

gains in the long- run to meet the demand of the growing population should be enhanced. Taking the above into consideration, Uganda needs to have a strategic aquaculture research agenda and a database of freshwater species that have been domesticated with their feeding and reproductive ecologies clearly documented.

Credit, marketing and infrastructure development

Considerable public investment in infrastructure and institutional strengthening is needed for sustainable development of aquaculture in Uganda. The flow of credit from institutional agencies needs to be increased for the poor fish farmers. The traditional credit system should provide not only lending services but also marketing services, such as product collection, preservation, processing and distribution, without lowering the unit price of harvest. Linking selected producer groups to feed inputs (buying bulk) and markets (selling volume) and improved market information systems should also be enhanced. Taking the above into consideration, there is an urgent need to reduce the interest rates levied by different financial institutions in Uganda.

Formation of a regional aquaculture network

Following an example of NACA in Asia, Uganda being one of the member countries of East Africa, can also form a network of aquaculture centre with other member countries of East Africa. This kind of network can solve diverse challenges, arising from a diversity of fish species, production systems and environment. Furthermore, cost-effectiveness of collaborative aquaculture research activities can be achieved.

Aquaculture data production

There are inconsistencies in the national aquaculture data for both counties. Data collection and its management need urgent attention. It is vital to establish a comprehensive data collection system at different levels. Similarly, access to, and effective dissemination of, reliable information is needed for informed decision-making and responsible actions.

Technology and knowledge transfer

Mechanisms for promotion of information, knowledge and technology transfer between Uganda and India should be encouraged. This can be managed and administered at institutional levels. The two agricultural research regulatory bodies representing both Uganda and India (NARO and ICAR respectively) can form a network intended for human capacity building, information sharing, research and technology transfer.

Developing production systems linking aquaculture with other agricultural production sectors

New forms of integrated aquaculture systems (integrated rice-fish, poultry-fish, livestock-fish and aquaponics) as well as other innovative systems that can effectively respond to environmental challenges need to be developed in Uganda. Integrating aquaculture with traditional cropping and livestock production systems has the potential to increase fish production. In addition, nutritional levels, food security and household incomes are also likely to increase.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

The authors would like to thank the Centre for Science and Technology of the Non -Aligned and Other Developing Countries (NAM S&T Centre, India) for the research training fellowship offered to the first author (Nasser Kasozi). Special thanks go to Dr. P. Jayasankar, Director of Central Institute of Freshwater Aquaculture (India); Dr. S. Kassim, Director of Abi Zonal Agricultural Research and Development Institute (Uganda) and Dr. A. Agona, Director General of the National Agricultural Research Organisation (Uganda) for allowing the first author to participate in a training fellowship for developing country scientists scheme for 2015 to 2016 in India.

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