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Spatial Pattern of Urban and Peri-Urban Aquaculture in Kolkata Metropolitan Area, India

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Abstract: *Sustainability and food security have become matters of serious concern worldwide since the last decade. Urban aquaculture is regarded as an important way of attaining greater urban food security as well as environmental sustainability. The cultivation of fish and aquatic vegetables as part of urban and peri-urban aquaculture is widespread throughout many cities globally. The people of West Bengal, India have usually been observed to consume a considerable quantity of fishes in their regular diets. Here, the rapid growth of aquaculture production has made the sector an important livelihood option. Semi-intensively managed ponds are frequently observed in and around the Kolkata Metropolitan Area of West Bengal but the actual scenario of production from these farms are not well documented. Consequently, it is difficult to assess the scale and extent of such activities in this area. Assessment of aquaculture practices in the Kolkata Metropolitan Area is thus required for a better understanding of this activity and sustainable extraction of this resource. In this paper, the major aquaculture areas of Kolkata Metropolitan Area had been demarcated and the variabilities as well as roadblocks of development of these activities had been explored through integration of literature, secondary information, and participatory feedbacks from the farmers. Results highlighted both promises as well as notable concerns in this context. Based on the findings, few realistically achievable management guidelines had been developed towards improving the aquaculture systems of this area.*

Keywords: *Aquaculture, Food security, Livelihood generation, Waste water, Wetland*

1. INTRODUCTION

Provision of food for a hefty number of people is a key issue of sustainability for any megacity in the contemporary world (Satterthwaite et al., 2010). Urban Agriculture is regarded as a suitable way out towards attaining greater urban food security as well as environmental sustainability (Smit and Nasr, 1992). Regular practice of UA is done in many cities of both developing as well as developed countries. The definition of UA can be explained as the sustainable growth of vegetables, raising of animals for food and other uses within and around the cities and towns. Production and delivery of inputs required for UA as well as processing and marketing of final products comes under the definition of Urban agriculture. (Eigenbrod and Gruda, 2015). Diversified development of agricultural production systems in cities and surroundings had been the result of ever growing demand for (Smit and Nasr, 1992). Factors such as proximity to markets, easy availability of urban organic wastes and waste water generally boost up agricultural activity in city peripheries. Green vegetables, milk, fish, meat and eggs have comparatively high market value, hence Urban agriculture gives importance to these products more than the other products (Symoens and Micha, 1995).

Urban aquaculture is also practised where waterbodies are available in urban environments (Edwards, 1998). It is a noteworthy subsystem of urban agriculture. Mostly in developing countries and some developed countries aquaculture plays an important role for employment generation and income to the farmers (Bunting and Little, 2003). Urban aquatic production is often essentially associated with the livelihoods of a considerable number of poor people (Jagger and Pender, 2001). Abundant surface water resources like small water bodies, inland water in coastal areas, estuaries are used to practice aquaculture profitably in around the urban and peri urban areas. Expansion of urban and peri-urban aquaculture propelled all over the world to meet the demands for fresh water fish in the city markets (de Haen *et al*., 2003). Despite the growing recognition of the roles of urban and peri-urban

aquaculture (UPA), actual materialization of the importance and potential of growing fish and edible aquatic plants in and around cities remains largely unattained across developing countries in general and India in particular. Accordingly, this paper tries to demarcate the major aquaculture areas of Kolkata Metropolitan Area (KMA), the third largest metropolis of India, and to explore the variabilities as well as problems of aquaculture activities in these urban and peri-urban settings.

2. SITUATION OF URBAN AND PERI-URBAN AQUACULTURE IN DEVELOPING COUNTRIES

The scope for cultivation of fish and aquatic vegetables are in lesser extent in African, European, Latin America as compared to the cities in south and south east Asia (Bunting, 2004a; Kinkela et al., 2017). Urban aquaculture offers various new opportunities such as food security and new employments in developing countries, lesser exploitation of natural resources and mitigation of poverty issues, thus it also plays a vital role in the livelihoods of many urban dwellers employed as farmers and traders. UPA can help mitigate urban poverty and enhance food security among urban and peri-urban dwellers (Satterthwaite et al., 2010).

Advanced production technology of fresh water and marine fishes in tanks to large scale aquaculture practices all are inculcated as activities under UPA (Siyanbola and Adebayo, 2012). However, it is found that in many Asian developing countries the waste water from the city is directly utilised as the source of nutrients to enhance the productivity. Agyapong (1999) noted that semi-intensive aquaculture production near Kumasi in Ghana involved the farming of tilapia and catfish (Kinkela *et al*., 2017) in ponds ranging from 12 to 54,000 m^2 and the production had been estimated nearly 150 tonnes per year. There has also been increasing concern regarding the negative impacts of climate change on food security. In lieu with this point of view, UPA represents a new dimension in fish production in the lowland floodplains and coastal areas of Bangladesh (Barua *et al*., 2012).

Integrated aquaculture is yet another practice that has gained wider acceptance among farmers on grounds of higher productivity, larger income and ecological sustainability (Kinkela *et al*., 2017; Lemaire *et al*., 2014). It involves a sequential linkage between two or more farming activities in such a way that outputs from one subsystem become inputs of another associated subsystem (Edwards, 1993; Rukera *et al.*, 2012). In several humid tropical countries, particularly in South-eastern Asia and South America, this diversification includes aquaculture as a subsystem of farms along with crops and livestock or both together to develop integrated agriculture-aquaculture systems (Phong *et al.*, 2011). Integrated fish farming can be of two types (Pillai and Katiha, 2004). It can be a system with no by-product utilization from one to another subsystem, but with optimum utilization of farming space and time, like paddy cum fish culture. Conversely, it may be a system, where by-products or wastes from one subsystem are being utilized for sustenance of the other like fish cum pig/ duck /cattle farming. Mainly in Asian countries cultivation of fish with livestock are generally associated with the main crop of that region, typically this system is built around a paddy field (Symoens and Micha, 1995; Ahmad, 2001). On the contrary, emphasis is given to vegetable crops (such as amaranth, sweet potato leaves, eggplant) on one side and to raising small livestock (such as pigs, chickens, ducks, and goats) along with the primary fish crops on the other in Africa (Kinkela *et al*., 2017).

Aquaculture in and around cities creates jobs and can improve the environment, reduce waste and provide quality food. Intensively managed aquaculture in urban and peri-urban areas is being developed by entrepreneurs in several countries (Siyanbola and Adebayo, 2012). Intensive production requires less land use as compared to the semi-intensive production (Bunting and Lewins, 2006). Establishing an intensive production system involves high capital since it is mainly based on the type of feed and energy used, but these types of intensive production considered as high valued products caters to niche market and export only to overcome the high operating and capital cost. Urban aquaculture has an important role in recycling organic wastes from industrial and urban activities (Asomani-Boateng and Haight, 1999; Bunting, 2004b). For example, by-products from chicken processing plants are used to feed catfish that are grown in urban aquaculture systems in Thailand (Little *et al*., 1994). The greater availability of domestic waste and by-products from food processing and marketing industries mean that producers are also able to exploit such resources thereby reducing their expenditure on fertilisers and feeds (Jayathilakan *et al*., 2012). Provision of subsidies to peri-urban farmers in the form of waste resources offer them a

significant advantage over other producers with limited access to such inputs. Treated wastewater has been used to produce tilapia in Lima, Peru. Studies have demonstrated that fish cultured in this way are acceptable to consumers and that the proposed approach is economically viable (Moscoso, 2005). Integration of aquaculture with wastewater treatment using stabilisation ponds and lagoons is widely advocated and several operational systems have been developed. Mara *et al*. (1993) described a rational design approach for lagoon-based wastewater treatment that optimised both wastewater treatment and fish production. Some researchers had demonstrated that there are several advantages of sewage fed aquaculture that there is no requirement of additional supplementary feeding since the sewage water from the city used contains various nutrients suitable for fish feeding, which results in low input cost in comparison to the production (Das, 1995). It also helps in reducing the pollution level of rivers and on aquatic ecosystems but also produces animal cheap protein (Bunting, 2004a). Nowadays, different technologies are used to prevent contamination of waste water used for fish production and growing vegetables as compared to earlier waste water usage around cities (FAO, 1997).

According to some researchers, the proximity of aquatic farming systems to urban areas presents a number of problems (Mara and Cairncross, 1989; Strauss, 1991; Edwards, 2001). These may be especially severe if contamination of waste resources crosses permissible limits so that the quality of fish or plants being cultured becomes toxic (Smit and Nasr, 1992). Such problems could be avoided by using more of livestock waste, inorganic fertilizers and other supplementary products to enhance production.

3. STUDY AREA

Aquaculture production has made radical growth in recent years made it an important sector for fishermen in West Bengal. Shrimps and prawns are the mass scale production products from aquaculture here (Paul, 2016). Since fish provides rich resource of protein for people of West Bengal, hence fisheries play major roles in nutrition, employment and foreign exchange earnings of the state (Paul and Chakraborty, 2016). Feeding the large number of people of Kolkata is also a key issue as this megacity is ever increasing in both extent and population. KMA is a continuous and extended form of urban agglomeration which comprises municipalities, corporations, suburbs and intermediate rural areas that are socio-economically tied to the urban core (Figure 1). Kolkata list third in the population category in India after Delhi and Mumbai, with 14,112,536 persons (GoI, 2011). The official statistics published by the Department of Fisheries, Government of West Bengal projected that the demand for fish is ever increasing in this region (Table 1). Thus KMA provides a prospective market for the growth of urban fisheries.

Table 1: *Projected daily demand of fish in Kolkata city and KMA*

Year	***Kolkata Municipal Corporation (lakh tonne)***	***KMA (lakh tonne)***
2014-15	*224*	*700*
2015-16	*227*	*710*
2016-17	*230*	*720*
2017-18	*234*	*730*
2018-19	*237*	*740*
2019-20	*240*	*750*

Source: *GoWB, 2016*

It is to be noted that the productions from UPA in KMA as well as West Bengal are not differentiated in state level statistics. Consequently, it is difficult to assess the scale and extent of such activities in urban and peri urban areas. Semi-intensively managed ponds are frequently observed in towns and cities in and around Kolkata city. Assessment of aquaculture practices in KMA is thus becomes imperative for better understanding of this activity in an urban setting and for sustainable extraction of this resource.

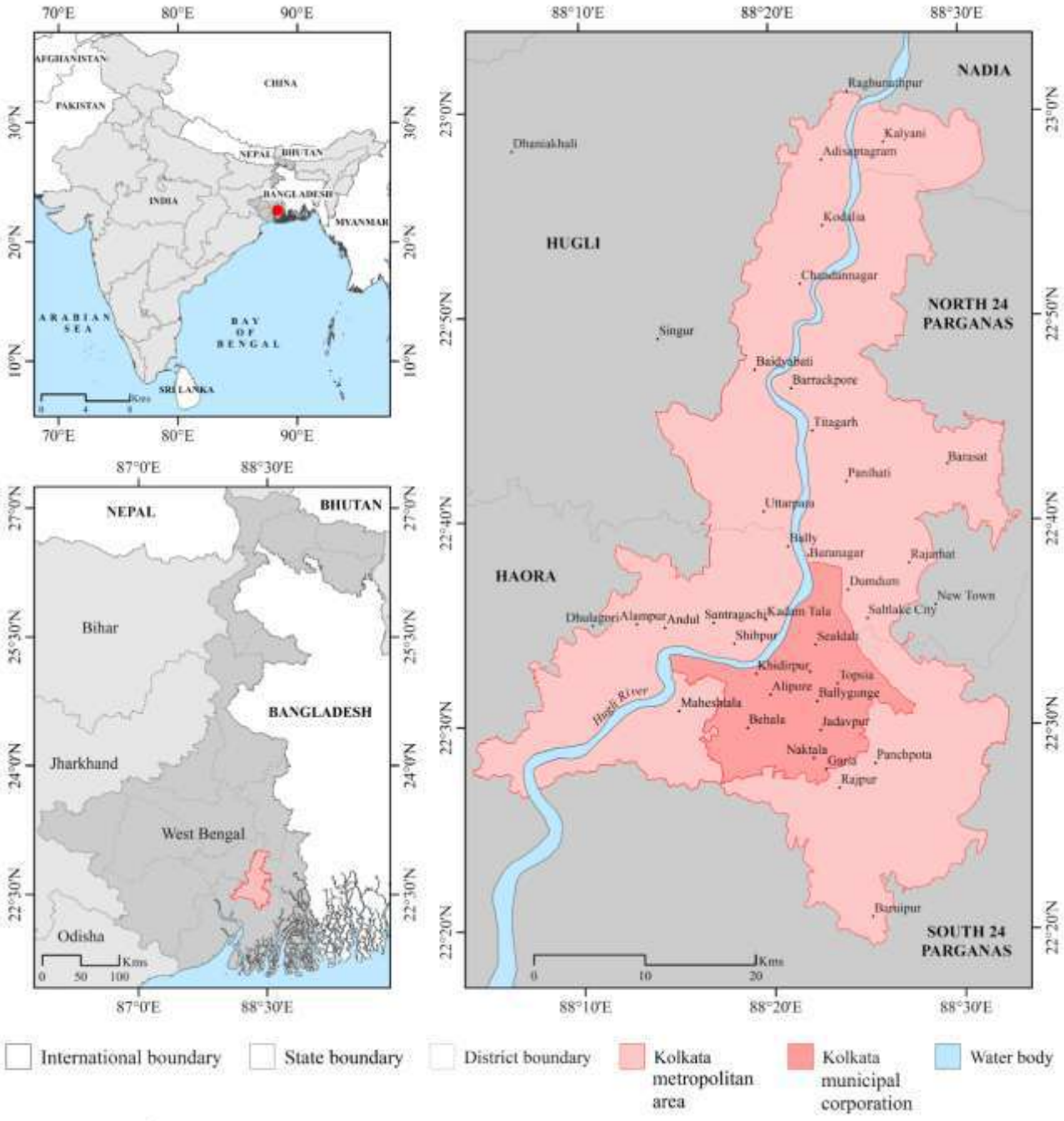

Figure 1: *Location of the study area*

4. METHODOLOGY

1. Data source

The present study had been primarily designed on secondary information. Relevant data were collected from the *Handbook of Fisheries Statistics* published by the Department of Fisheries, Government of West Bengal (GoWB, 2016) and also from various books and published research papers. The delineation of the major aquaculture areas was based on exhaustive reviews of literature and analyses of open source satellite images.

2. Image classification

The digital data of landsat 8 for land use / land cover (LULC) mapping for the year 2017 9 April) could be classified by using the combination of supervised signature extraction and maximum likelihood method. Before processing

and classification of satellite imagery, an extensive field survey was performed throughout the study area. Survey conducted to extract accurate locational data for each identified LULC class, creation of training sites and matching of spectral signatures. Satellite data was enhanced before the classification using ERDAS Imagine 2014 software to improve the quality of images and to achieve better accuracy in classification. Subsequently, vector layer is digitized over a raster scene. These vector layers consist of various polygons overlaying different LULC types. The training sites helped at this stage in developing spectral signatures for the outlined areas.

3. Perception survey of UPA practitioners

A detailed questionnaire was used for the collection of information from the UPA farmers during the field surveys. Data sourced from the family members of the fishermen by informal interviewing and discussions regarding aquaculture and its practices. Separate focus group discussions (FGDs) were also conducted to identify the problems and prospects related to UPA. Earlier researches/research papers did not highlight the importance of open discussions with the farmers/fishermen brings out various issues they face which now could be identified easily. (IFAD, 2014). This is particularly important in the context of UPA since this involves complex interactions between different stakeholders. Many farmers and non-farmers participated in the FGDs to supplement information which were not adequately captured by the structured questionnaire schedule.

5. RESULTS AND DISCUSSION

1. Status of UPA in KMA

KMA is endowed with many kinds of fishery resources like lakes, ponds, wetlands and rivers (GoWB, 2016*)*. The major water body of this area is the Bhagirathi river which runs from north to south of KMA. Small canals like Bhadreswar canal, Ichhapur canal and Narayanpur canal are present here. Moreover, the famous East Kolkata Wetlands occupies the south-eastern part of the study area. From satellite images, it became evident that water resources were chiefly concentrated in only few parts of KMA. Consequently, these areas represent the potential zones for urban aquaculture activities. Most of these water bodies in and around Kolkata belong to either private individuals or the government (GoWB, 2016).

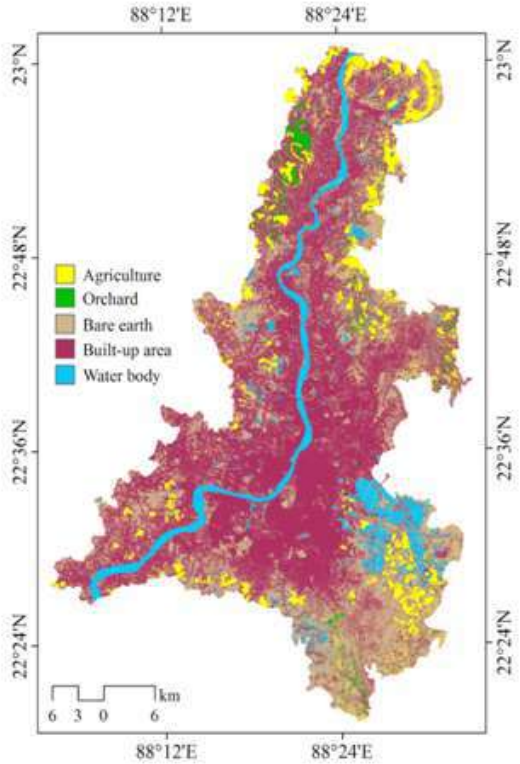

Figure 2: *Location of water bodies in KMA*

A common feature in all parts of the KMA is that farmers who practise aquaculture do not depend solely on aquaculture for their sustenance. Generally one or many farming practices are conducted together by most farmers. It was observed during fieldworks that many households had at least one pond in the form of a pit resulting from the excavation of soil used to raise the level of the homestead floor above the high water mark during floods. Such ponds become a potential source for small-scale aquaculture activities in these areas. Farmers generally practice carp polyculture and tilapia dominated mixed species culture in these small ponds adjacent to their homesteads primarily for subsistence. In many areas, large and medium sized ponds are managed by groups of farmers commercially by forming a cooperative. According to the farmers' opinion, aquaculture was more profit bearing than conventional agricultural practices so that they were gradually diversifying their livelihoods by adopting fish culture along with conventional rice or vegetable farming. This characteristic is common in throughout KMA.

In the southern and southern eastern parts of the study area, farmers of places like Sarmatsapur, Baragachhia, Srikrishnapur, Kalipur, Jayenpur-Hogalkuria, Jiadargot and Sajneberia were found to combine aquaculture with banana orchards. In these parts, most of the areas are under aquaculture intercropped with orchards and vegetable cultivation along the embankments. The ponds were usually found to be dominated by fish species such as tilapia *(Oreochromis mossambicus),* sarpunti *(Puntius gonionotus),* catfish and varieties of carps. However, the major hindrances of this culture system were inferior water quality and vulnerability to seasonal flooding that allowed fishes to escape and leave farmers with severe economic losses. In general, farmers see this culture system as second only to rice in terms of importance to their food, nutrition and income security.

Paddy and fish culture (either rice and fish together or fish and then rice) on seasonal farmlands are characteristics of UPA particularly in the eastern parts of KMA namely in Keutia and Basudebpur sites. In reality, these sites are part of a huge floodplain wetland named *Boritir Beel* which remains inundated for a substantial period annually. Essentially during the seasonally flooded fields there are two varieties of paddy and aquaculture system are found to be practised. One was the simultaneous rice cultivation in deep water fields with supplied fish during the flooded season, and then followed by rice cultivation (boro variety) on the same shallow flooded fields in dry season, and the other was mainly the rice cultivation and then followed by supplied fish culture in the same enclosure. A unique trend observed in the UPA practices of KMA area was the widespread presence of sewage fed aquaculture system. The waste water of Kolkata Municipal Corporation (KMC) is naturally treated in the East Kolkata Wetlands through its usage for aquaculture purposes. This wetland covers a total area of nearly 3,800 ha and is the main aquaculture sites located within the KMC boundaries. Development of this type of one of a kind technique of using domestic waste water for aquaculture by farmers dates to the 1930s (Nandeesha, 2002). Stabilization ponds are used as water sources in vegetable fields. The said technique of converting the waste water into consumable product is found to be the largest in operation system all over the world (Nandeesha, 2002). The growing fish demand in the metropolitan areas can also be met by this technique. Actually, fish produced from this area were reported to meet almost 15 percent of KMC's demands (Gupta and Gangopadhyay, 2013). A variety of agricultural crops like rice, corn and vegetables (such as tomato, aubergine, cabbage, leafy greens etc.) were also found to be produced here. Initially 4,700 ha of this wetland was dedicated to aquaculture but, over the years, human encroachment and urban sprawl had engulfed considerable portions (Gupta and Gangopadhyay, 2013).

5.2. Variations in species cultured and aquaculture systems in KMA

Three types of aquaculture systems were generally found in the UPA activities of KMA, viz., i. Polyculture; ii. Monoculture; and, iii. Cage and Pen Culture. Firstly, Polyculture of Indian carps or Indian and exotic carps together (composite culture) was more common than monoculture. Among the carp species, Indian major carps *(Labeo rohita, Catla catla, Cirhinus mrigala, Labeo calbasu*) and Chinese carps (*Hypophthalmichthys molitrix, Ctenopharyngodon idella, Cyprinus carpio*) along with some minor carps as Thai sarpunti *(Puntius gonionotus*) were the major species. The species mix of 3-6 carps including three Indian major carps and three exotic carps was found to be very popular. Recently, tilapia had been reported to gain popularity as a cash crop among most farmers. Selection of cultured species depended on ecological conditions of sevaral water bodies and local market demands at different sites.

Monoculture of catfish or hybrid magur (*Clarias batrachus) had* been found as a very popular practice in the southern peri-urban areas of KMA. Recently, farmers had become increasingly interested in this particular type of monoculture owing to the high demands in the market as livestock feed. In few sites, it had been transformed even into an industrial level because of the higher profit margins (Islam *et al*., 2004). Besides this, few farmers practicing monoculture of Shrimp is also found in eastern parts of KMA.

The third category was the Cage and Pen culture that was found to be comparatively rare in KMA. However, these practices were identified as important since fish produced in pens and cages played notable roles in lowering the overall prices of farmed fishes. Site-wise, Naihati area was identified as the prime one for this particular practice indicating towards the growing diversity of UPA.

5.3. Identified problems of UPA

The major limiting factors for farmers were recognized as the lack of knowledge on monitoring of soil and water parameters, feed composition and its nutritional value, and viability of different packages of practices. Moreover, involvement of too many intermediaries in the marketing system had resulted in dual problems, firstly, the consumers had to pay higher prices, and secondly, the original farmers did not get the deserved payments for their products since the major share of profits go to those intermediaries. In addition, modern as well as eco-friendly methods of pond preparation, fertilization, stocking, feeding, farmers' healthcare, property regimes, input supply, unavailability of quality fish seeds, output disposal, high interest rates for credit, political conflict over common property resources, theft of fish produces etc. were also identified as constraints limiting the actual potential of these practices in KMA.

Most of the ponds under aquaculture were under either public (community/ village/ government) or private ownership. Water of these ponds was mostly found to have open access to multiple uses such as drinking, agriculture and allied activities, and other daily domestic needs. Thus, the actual degree of freedom for applying the recommended levels of inputs were considerably reduced thereby resulting into lower yields.

In KMA, rivers and canals had always formed lifelines for the city. Convergences of unregulated industrial and urban expansion have augmented the encroachment of rivers which had taken their tolls on surface water quality. Almost all types of waste generated from human, industrial, and livestock origins along with the constantly increasing flow of pesticide and fertilizer residues daily move into these rivers and canals. Consequently, most parts of these water channels and surrounding perennial areas were found to be suffering from acute eutrophication (Edwards, 2008). It was evident from the analysis of satellite images that major parts of the UPA systems of KMA were located in wetlands on the peripheries of the city. Urbanization, with its ever increasing pressures on land and water, had gradually encroached on these wetlands resulting into severe livelihood losses of the poor farmers.

Similarly, the sewage fed aquaculture of the wetlands also had its own disadvantages. Many times the sewage contains high load of heavy metals and toxic chemicals (lead, chromium, zinc, arsenic) as well as poisonous gases with very low dissolved oxygen contents. Consequently, chances of plant-soil-water contamination and their eventual entering into human body through bio-magnification became more.

The hybrid fish farming also had its own negative concerns. Generally, this farming depended on animal offal and slaughterhouse wastes as fish feeds which often polluted the waterbody through deterioration in water quality and foul smell. This caused serious occupancy problems for the local inhabitants (Singh *et al*., 2015). Moreover, cultivation of these catfishes also had few ecological concerns since, being an invasive predatory species at the top of the aquatic trophic structure, they were reported to destroy the biodiversity rapidly in an aquatic environment (Odo and Inyang, 2001; Singh, 2014).

6. CONCLUSIONS

In recent years, UPA is recognized as a growing industry globally based on the fact that most of the consumers with potential purchasing capacity belong to the urban areas and, at the same time, large areas in and around the cities offer scopes for development of aquaculture industries (Bunting and Little, 2003). It is important for generation of income, livelihoods and food security. It can contribute in wastewater management as well as environmental

protection through recycling of municipal wastes by converting waste materials into consumable products. It is observed that aquaculture is an economically viable and ecologically sustainable venture if properly managed, particularly with respect to KMA. Hence, efficient utilization of the available resources, monitoring and regulation of effluent discharges, and treatment cum recycling of waste water should be considered as the immediate measures and necessary actions. Accordingly, urban planners and local government bodies of KMA should develop appropriate policies to incorporate this environmentally beneficial practise in their perspective plans of urban renewal.

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