# ENHANCING WATER PRODUCTIVITY THROUGH MULTIPLE USES OF WATER IN INDO-GANGETIC BASIN

## MULTIPLE USES OF WATER

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### Abstract

Growing water scarcity and competing water demands are expected to reduce diversion of water for agriculture in the future. Efforts are needed to utilize the available limited water resources efficiently and effectively. Multiple uses of water is inevitable to produce more with less water. Water resources projects not only provides water for irrigation but also provide water for a range of other productive uses such as home gardens, livestock, fishing and aquatic products, and micro-enterprises such as brick-making. In the Gangetic flood plain of Indian state of West Bengal, wetlands are used as multiple system and have significant impacts on livelihoods of the local people through the most important benefit arising from fisheries, followed by wetland cultivation and jute retting. Integration of secondary reservoir or small tank in the tubewell based irrigation system has been demonstrated at Patna, India as an effective mechanism to better regulate water and also enhance water productivity by raising fish in the reservoir to generate additional income and improve livelihood. The technology of multiple use of canal water was also demonstrated at Bhubaneswar, India using service reservoir and gravity drip irrigation and sprinkler irrigation, and integrating fish culture in the ponds and raising horticulture on the pond embankments. Similarly, MUS projects in Nepal have showed that the use of micro-irrigation in conjunction with MUS is a potent combination. Rice-fish farming trials conducted at Patna has been found to be useful in productive utilization of seasonally waterlogged lands in canal commands. Makhana (*Euryale ferox*) cum fish culture in water bodies of North Bihar, secondary reservoir for rainwater harvesting and productive utilization etc. are some other examples of multiple use of water in the IGB. This paper presents the results of different studies conducted on multiple use of water in the eastern Indo-Gangetic plains.

Key words : Indo-Gangetic Basin, water productivity, multiple use systems, rice-fish culture, Makhana (*Euryale ferox*)

## 1. INTRODUCTION

Water is the most precious natural resource and is indispensable for all economic and social development, and ending poverty and hunger. However, with ever-increasing population, industrial growth, water pollution, and climate change, the water availability per capita is shrinking day by day. Irrigated agriculture accounts for about 70% of total water withdrawals worldwide, but in Asia the irrigated agriculture accounts for 90% of total abstraction (Seckler et al. 1998). Growing water scarcity and competing water demands often involves reallocation of resources away from irrigation in favor of municipal, industrial and environmental uses (Molden et al. 2001). Hence, efforts are to be made to utilize the available limited water resources efficiently and effectively to ease water scarcity and provide food and nutritional security, while ensuring multiple other factors, including environment. The Multiple uses of water i.e. using the available water sources for more than one uses/ production system is inevitable to produce more with less water. Multiple use systems, operated for domestic use, crop production, aquaculture, agroforestry and livestock, can improve water productivity and reduce poverty. However, intensification of multiple use of water in the catchment may affect downstream flow both in terms of quality and quanity. There is a need for proper understanding and economic evaluation of non-irrigation uses (Meinzen-Dick and van der Hoek, 2001) and to greater recognition of the linkages between water management activities and aquatic ecosystems (Bakker and Matsuno, 2001).

It is well recognized that people uses water for multiple purposes. This multiple use happens at different levels: the household level, the water system level, and the catchment or basin scales. For example, in many rural and urban areas, domestic water supply networks are used for small-scale productive activities. Similarly, irrigation schemes not only supplies water for irrigating field crops, but are also used for livestock or backyard irrigation as well. The aquatic systems such as wetlands including rice-based systems provide many critical productive and ecosystem services like recharging groundwater, flushing contaminants, and supporting wildlife. Thus, multiple use systems can provide the more vulnerable users with low cost services for domestic water, water for agriculture, home gardens, livestock, habitats for fish and other aquatic resources and rural micro-enterprises such as brick-making. In order to derive maximum benefit from the depleted or diverted water and maximize output to increase water productivity, the productive or beneficial interventions of multiple nature of both non-consumptive and less water consumptive such as fisheries, aquatic crops, aquatic resources, livestock etc. may be integrated into the existing irrigation and water use systems/water infrastructures. However, an improved understanding of competition and complementarity of all water demands is essential for effective multiple use management (Li et al. 2005). The productive utilization of available water resources is instrumental in increasing local community resilience and risk management that may result from climatic uncertainty.

Integrated water resources management (IWRM) encompasses all aspects of water resources development, management and use for dealing with competing water sectors at the basin or catchment scale. The Multiple Use Services (MUS) is an approach for providing multiple uses services at systems level and downwards. Thus, adopting an integrated, multiple-use approach to water resources development and management is an opportunity to achieve Millennium Development Goals (MDG) of eradicating extreme poverty and hunger and ensuring environmental sustainability. Homestead-scale MUS is the most effective way of using water to contribute to all Millennium Development Goals (van Koppen et al 2009). This paper addresses innovative approaches for managing available water resources though upscaling science based and field tested models for sustainable multiple use water supply system for increasing water productivity and sustainable agricultural development to feed the growing population in IGB. The paper also discusses the results of different studies conducted on multiple use of water in the eastern Indo-Gangetic plains.

## 2. INDO-GANGETIC BASIN

Indo-Gangetic basin, which refers to the Indus and Ganges basin, spans Bangladesh, India, Nepal and Pakistan. It lies mostly in the Indus-Ganga-Brahmaputra plain, which extends 3,200 km between the mouth of the Ganges River, to the east, and that of the Indus, to the west. The basin among the world's largest and most productive basins, forms the floor beneath the "roof of the world", the Himalayas. The rivers encompassed are the Ganga, Indus, Beas, Yamuna, Gomti, Ravi, Chambal, Sutlej, and Chenab. The IGB provides the economic base for agriculture, forestry, fisheries, livestock, including urban and industrial water requirements for about a billion people. Given the diversity of agro-climatic, social and economic conditions in the four riparian countries, the basin is a study of contrasts and opportunities in all respects. The basin is spread over an area of 225.2 million ha and the net cropped area is 114 million ha. As per 2001 census the population of IGB is 747 million. Rural population in Bangladesh, India, Nepal and Pakistan is 79.9, 74.5, 86.0 and 68.0% respectively of the total population. About 35% of the population in the IGB is below poverty line. High population growth in these countries remains a cause of concern of water and food security, poverty alleviation and resource conservation. In IGB about 91.4% of the annual water use is for agriculture purpose followed by 7.8% for domestic use. Growing water scarcity and competing water demands are expected to reduce diversion of water for agriculture in the future. The water productivity of crops and livestock is low in IGB partly because of negligence on crop-livestock and water nexus and their impact on livelihood. In order to improve overall water productivity of irrigation and water resources systems, the productive interventions such as growing vegetables, fruits, livestock, fisheries and other living aquatic systems need to be integrated into the existing irrigation and water resources systems such that more food may be produced out of available water resources.

## 3. MULTIPLE USE SYSTEMS

The term multiple-use of water is increasingly used in the water sector and the concept of multiple-use services (MUS) has emerged as an alternative approach to providing water services aiming to meet people's multiple water needs in an integrated manner. Multiple uses of water can be defined as the practice of using water from the same natural or manmade system or infrastructure for multiple uses and functions. In essence, a multiple use approach involves (1) assessing the range of water needs in collaboration with end users, (2) examining the water sources available - from rainwater to wastewater to piped systems, and (3) matching water supplies to needs based on the quantity, quality and reliability required for various purposes. Three crucial aspects of a multiple-use approach that are neglected in traditional approaches to water supply are: participation of local communities, identification of all water needs, and consideration of the different water sources available. Multiple-use services (MUS) is the conceptual approach of providing water services provision for multiple uses, incorporates also the roles and functions of water related systems for local communities. As defined by many researchers (e.g., Van Koppen et al. , 2006) Multiple-use Water Services (MUS) is a participatory, integrated and poverty-reduction focused approach in poor rural and peri-urban areas, which takes people's multiple water needs as a starting point for providing integrated services, moving beyond the conventional sectoral barriers of the domestic and productive sectors. The term "water services" signifies that water provision involves considerably more than merely the creation of hardware. MUS aims to supply water appropriately for all the different demands within an integrated framework. The service approach to multiple use also implies that not all the water to meet people's needs necessarily should come from just one piece of hardware. The provision of multiple sources for multiple uses can be considered as part of a MUS service approach. While traditional systems tend to focus on improving agricultural productivity through single-use (e.g.

irrigation), MUS applies a wider livelihood perspective to water services. It relates closely to the concepts of integrated water resources management (IWRM), and provides practical approaches through which aspects of IWRM can be operationalised.

Van Koppen et al. (2006) made distinction between *de facto* and planned multiple-use services. The *de facto* MUS, is the most common type of MUS, refers to systems which were developed with a single use in mind, but which are *de facto* used for multiple purposes by users themselves. Planned multiple-use services are services that have been planned from the outset for multiple purposes. Van Koppen et al. (2006) further used the terms domestic-plus and productive-plus (or irrigation-plus) services to indicate how services have been expanded to move from a single-use system to meeting multiple ones. A domestic-plus system is a system developed to meet domestic needs, but expanded to cover some small-scale productive uses as well. This may have been done *de facto* by user themselves, or in a planned manner by developing specific management measures or infrastructural add-ons to facilitate small-scale productive uses. An irrigation-plus system is an irrigation scheme which has started to cater for other uses, such as domestic uses, fisheries or backyard gardening. Renault (2008) provides examples of how these uses are explicitly addressed in the management of large irrigation systems.

The MUS offer significant advantages in that they have greater potential to generate more income and benefits, decrease vulnerability with more diversified livelihood strategies, more effectively reduce poverty by simultaneously addressing multiple dimensions of poverty, and increased sustainability of services. An investigation of a multiple-use water supply system (MUS) in Bangladesh reavealed that MUS meet needs for water better than the conventional systems with the benefits of increased productivity and incomes, reduced irrigation costs and easier access to iron-free domestic water but the systems are not affordable for the communities over a ten-year timeframe (Fontein et al. 2010).

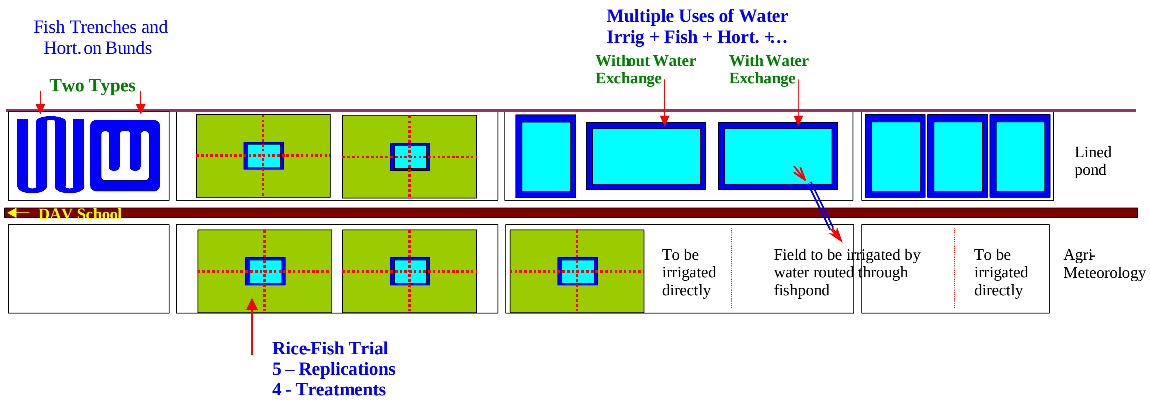
### 3.1 Multiple use systems in IGB

Multiple uses of water are gaining importance in the IGB, a lot of interest has been generated and work on multiple water use has been undertaken at experimental farms, watersheds and farmers field. Evidences of multiple uses of water could be found in irrigated, rainfed, waterlogged, coastal and hilly areas/watersheds. It is increasingly recognized that promoting multiple water uses of water entails largely untapped opportunities to enhance water productivity. Different forms of multiple use systems, i.e., multiple use of harvested rainwater, canal water after outlet and in the network itself, groundwater where pumped water from tubewell used for other productive purposes before it is delivered to field for irrigating field crops etc have been investigated at different locations in IGB. For example, in a tubewell based irrigation systems at ICAR Research Complex for Eastern Region (ICAR-RCER), Patna, India multiple use of water was implemented by routing pumped irrigation water through secondary reservoir, where water was stored up to a desired capacity for aquaculture and then released in desired stream size for irrigation purpose. The technology of multiple use of canal water was demonstrated at Bhubaneswar, India (Srivastava et al. 2004), where a 2510 $m^3$ service reservoir was constructed such that the water can be applied through gravity to a command of 1.9 ha under drip and 2.8 ha under sprinkler irrigation. Multiple water use was demonstrated with the integration of fish in the ponds and raising horticultural crops on the embankments. It was reported that service reservoir could be used for multiple use and the annual cost of the pond could be recovered by growing papaya in the bund and fish in the pond. With the integration of ducks and intensive vegetable cultivation on outward slopes of the embankment, the total cost of the system inclusive of drip and sprinkler can be recovered from multiple uses of reservoir itself. Use of canal networks for cage fish culture in Tamilnadu, India indicated a net return of INR 10000/- from rearing of fingerlings in a canal of 1 km length with 100 cages. The International Development Enterprise (IDE) implemented MUS concept of developing water supply systems for both domestic and productive uses, especially at and near homesteads in Nepal. These MUS systems used piped network to supply water to village collection tanks and distributed the water to taps for domestic use and irrigation of land near the homestead. In the middle hill areas, multiple-use water services with micro irrigation application were implemented to improve the water productivity and found as a potent combination. In the Gangetic flood plain of Indian state of West Bengal, wetlands are used as multiple system and have significant impacts on livelihoods of the local people. The study showed that the people living in the surrounding area of wetland derive the major economic benefits from wetland cultivation, direct irrigation, jute retting, and fisheries. The most important benefit is from fisheries, followed by wetland cultivation and jute retting. The irrigation benefits were found low due to larger distance of the land from the wetland, and the easy access to shallow groundwater in the region (Mukherjee, 2008). The following section presents the results of different forms of multiple use system tried at ICAR RCER, Patna.

## 4. RESULTS AND DISCUSSION

In order to develop and demonstrate productive utilization of waterlogged areas, a research project was initiated at ICAR-RCER, Patna with various multiple use options. Three multiple water use based farming systems (Fig. 1), namely secondary reservoir fed by canal seepage, fish trenches-cum-raised bed and rice-fish culture using nylon pen under seasonally waterlogged lands adjoining Patna main canal were undertaken (Sikka et al. 2010). The different features, integration of different uses and future scope for productive utilization of waterlogged areas in enhancing water productivity and livelihoods are discussed below.

*Figure 1 Layout of various multiple use interventions in the Experimental*




### 4.1 Secondary reservoir for integrated agriculture and fishery

Medium deep waterlogged lands (0.5 – 1.0 m) can be modified in the form of a reservoir or pond that can be used for multiple uses. The excavated soil is spread around the periphery to form a bund with crest level at least 50 cm above the highest water level to ensure that water do not overflow the bunds. High value horticultural/vegetable production on bunds utilizing seepage water with little supplemental water can produce good profit from the land, which was otherwise poorly utilized. In conjunction, good fish production can be achieved with water quality management through water routing for irrigation purpose. Two options like routing of water with provision of water exchange and control reservoir without water exchange were tried.  The routed water containing good amount of nutrients provide opportunity for applying water to the fields in correct amount and at appropriate time, which enhances yield and quality of agricultural produce. Ducks, poultry, piggery, etc. are other components that can be added to have complementary benefits.

### 4.2 Rice-fish culture in seasonally waterlogged areas

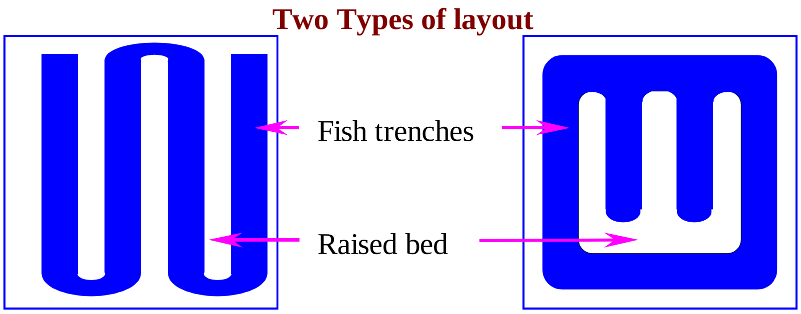
*Photo 1. Rice-fish System*

Rice-fish culture is useful in productive utilization of seasonally waterlogged lands in canal command with depth of water staganation upto 0.5 meter. Trial was undertaken to grow fish in the rice fields with central pond type fish refuge covering 10% of rice field area (Photo 1). Different options like fresh fingerlings and stunted yearlings were tried.

### 4.3 Fish trench-cum-raised bed

Lands having water stagnation of more than 1.0 m are not much beneficial for rice-fish culture. Trenches in such areas can be excavated in such a way that excavated soil is filled in alternate strips to make bunds. Coconut growing farmers in the backwater areas of Kerala extensively follow such farming practice. In Mekong Delta in southern Vietnam, farmers employ trenches within their fruit orchards, usually surrounded by a lateral trench and a connection to the adjacent rice field. To evaluate this concept, two types of layout of the fish trenches, viz., 1) meandering type trenches simulating river condition; and 2) continuous trenches surrounding island of raised bed simulating pond type conditions was undertaken (Figure 2).

*Figure 2. Two types of layout of trenches*




Meandering type
Simulating river conditions

Island type
Simulating pond conditions

### 4.4 Returns from different multiple water use systems

Secondary reservoir with horticulture on dykes gave highest gross income as well as net income followed by fish in secondary reservoir alone. Net income from fish in the secondary reservoir with horticulture on dykes was INR. 132590 per ha per year (Table 1). Fruit crops contributed 56% to the net income followed by fish (27%) and vegetables (17 %). Net income gained from fish alone in secondary reservoir was INR 93550 per ha per year and the entire amount came from fish production (Table 2). Similarly, fish in sunken trenches with horticulture on raised beds also gave comparably good income. Net income from this system was INR 80951 per ha per year of which 54% was contributed by fruit crops. Vegetables contributed 22% and the remaining 24 % was contributed by fish. Net income from Rice-wheat system with fish refuge in the center was in the tune of INR 29694 per ha per year, out of which 11 percent was contributed by fish and 89% was contributed by rice and wheat. These systems were compared with traditional rice-wheat system where net income was INR 27965 per ha per year. Increase in net income was highest (374.13 percent) in case of fish in dugout pond and horticulture on dykes. Increase in net income over rice-wheat system was 6.18% in rice-wheat system with fish refuse at the center, 189.47 percent in fish in sunken trenches with horticulture on raised beds, and 234.53 percent in fish in dugout secondary reservoir. Water productivity (return in rupees/cubic meter of water used) of secondary reservoir with water exchange ranged between 3.74 to 15.2 where as in control pond without water exchange it ranged between 10.3 to 14.4. In the trenches water productivity values ranged between 1.5 to 6.51.

*Table 1. Relative returns from different multiple water use systems*

| Water use system | Gross income (INR/ha/yr) | Cost of cultivation (INR/ha/yr) | Net income (INR/ha/yr) | % Increase over rice-wheat system | Benifit-cost ratio |
|---|---|---|---|---|---|
| Rice and wheat | 54965 | 27000 | 27965 | 0.00 | 2.04 |
| Rice and wheat with fish refuge in the centre | 56342 | 26648 | 29694 | 6.18 | 2.11 |
| Fish in sunken trenches, horticulture on raised beds | 142010 | 61059 | 80951 | 189.47 | 2.33 |
| Fish in secondary reservoir and horticulture on dykes | 234289 | 101699 | 132590 | 374.13 | 2.30 |
| Fish alone in dug out secondary reservoir | 168750 | 75200 | 93550 | 234.53 | 2.24 |

(1 INR = 0.022 US$)

*Table 2. Contribution of various components (%) to net income in different water use systems*

| Water use System | Rice and wheat | Fish | Fruit | Vegetables |
|---|---|---|---|---|
| Rice and wheat | 100.00 | 0.00 | 0.00 | 0.00 |
| Rice and wheat with fish refuge in the center | 88.88 | 11.12 | 0.00 | 0.00 |
| Fish in sunken trenches, horticulture on raised beds | 0.00 | 24.01 | 53.87 | 22.11 |
| Fish in dug out pond and horticulture on dykes | 0.00 | 26.66 | 55.92 | 17.42 |
| Fish in dug out secondary reservoir | 0.00 | 100.00 | 0.00 | 0.00 |

Feed back of farmers' revealed that fish in trenches- cum- horticulture in waterlogged area is the most preferred option (37%) followed by fish pond cum secondary reservoir (19%) and rice- cum- fish cultivation (19%). Only 15 % farmers were reluctant to adopt any fish production technology. This is manly due to lack of irrigation facility and local security of the fish ponds. In general, majority of the farmer's were of the view that small farmer's can easily adopt the technologies and there is more income from less investment.

### 4.5 Multiple uses of rainwater harvesting reservoir in medium uplands in plateau region

In the experimental farm of Horticulture and Agroforestry Research Programme, Ranchi, India a rainwater harvesting pond was constructed with a water capacity of 1200 $m^3$. The command area of the pond consists of 100 x 70 m (0.7 ha) area, in which litchi based multi-tier horticultural system has been adopted. Fish production in the pond, vegetable / fruits / pulse production on the bunds measuring 3.0 m width around the ponds, supplementary irrigation to cereal production on a limited area of 50 x 25 m (0.125 ha) with surplus runoff storage during monsoon season, and irrigation through gravity fed drip irrigation to multi-tier horticulture are the uses of the harvested rainwater in the system. An analysis of climatic data indicated that after initial irrigation for plant establishment to 60 plants of litchi, 180 plants of guava up to end of June, enough water will be available for vegetable cultivation on about 1000 $m^2$ for two season (November-March and March-May). About 46.9% of water from 1.8 m deep pond will go as surface evaporation losses. Alternatively, the vegetables for the two seasons can be grown on 1500 $m^2$ without irrigation to any plant of fruit trees.

## 4.6 Multiple use of water bodies in Makhana based farming system

Makhana (*Euryale ferox* Salisb.), a monotypic genus belonging to the family Nymphaeceae, is an emergent floating macrophyte commercially grown as a cash crop in the littoral parts of the flood plain wetlands of North Bihar, India. Traditionally makhana is grown as a sole crop and water bodies are utilized for only seven months from February to August for growing makhana. Hence, efforts were made to maximize the productivity of water bodies through multiple uses of water by makhana- cum- fish integration and makhana and fish rotation with a goal to develop a model of integrated system of makhana cum fish culture in order to utilize the water body throughout the year. In this technology, a refuge covering 10 % area of net water bodies as a central vacant space created in makhana ponds. The stunted carp fingerlings of 10-18 g were integrated in the refuge area of the ponds in the month of April in makhana –cum-fish integrated system, and in September also after harvest of makhana. The fishes were harvested in the month of December-January before emergence of makhana seedling on water surface. The integration of fishes with makhana resulted in fish yield of 1.83 to 4.03 q/ha and makhana seed yield of 10.64 to 20.63 q/ha as depicted in Table 3. The net income from integrated makhana based farming system ranged from INR 44, 686/ to INR 51,216 per ha/year. The successful integration of fish with makhana farming thus offer multiple uses of water, leading to greater efficiency in resource utilization and generation of additional food and income to the makhana –cum- fish growers. Integrating fish culture with makhana as concurrent crop and after makhana cultivation as a crop rotation is an improved production system that assures more return from water body than from cultivation of makhana alone. Besides this, for alternate income generation activities such as seasonal vegetables and fruits on the bunds of makhana ponds, vermi compost unit, poly houses for vegetable and fruit nursery, apiculture, poultry farming etc. are also being tried at farmer's pond for increasing water productivity as well as per unit area productivity.

*Table 3. Net Income from makhana –cum- fish farming through multiple use of water bodies*

| Farmer | Pond Area (ha) | Makhana | | | Fish | | Net Income (INR) |
|---|---|---|---|---|---|---|---|
| | | Gurri Producton (q/ha) | Lava Production (q/ha) | Net Income (INR/ha) | Yield (q/ha) | Net Income (INR/ha) | |
| Farmer-1 | 0.236 | 15.25 | 5.04 | 29,153 | 4.03 | 16,208 | 45,361 |
| Farmer-2 | 2.909 | 20.63 | 6.81 | 32,313 | 1.86 | 13,436 | 45,749 |
| Farmer-3 | 2.181 | 18.34 | 6.05 | 42,182 | 2.08 | 9,034 | 51,216 |
| Farmer-4 | 1.090 | 10.64 | 3.51 | 24,367 | 1.83 | 20,319 | 44,686 |

## 5. SUMMARY

Multiple uses of water are found to be beneficial to enhance overall productivity of water resources. It provides variety of food materials, e.g. fish, fruits, vegetables, eggs, etc. apart from cereals and other crops. It also helps in ensuring the nutritional security to the rural population as they are deprived of such diversity in food under prevailing rice-wheat cropping system. Results from different studies revealed that aquaculture is common in all most all the systems and the most beneficial component of multiple use system as it is a non-consumptive use of water resulting in the most productive use of water. Successful integration of fish with makhana also offers multiple uses of water leading to greater efficiency in resource utilization and generation of additional food and income to the makhana- cum- fish growers. Additional income was generated by growing horticultural / vegetable crops on the bunds required to facilitate aquaculture and utilizing the stored water. Though there is immense potential of multiple water use system in all water domains, there are some constraints (e.g. social impediments, poaching and theft, local conflicts and water rights, pereniality of water, lack of capital investment and resources in developing the system, provision of aeration specially for resource poor and socially disadvantageous users) for its scaling up for wider adoption that need to be addressed through intensive research efforts, social mobilization and institutional support. As intensification of multiple use of water in the catchment may affect downstream flow, delineating water rights may be a complicated process in multiple water use systems and need efforts in evolving multifaceted approach to ensure participation of all the relevant stakeholdes in the negotiations over any water reallocation issues.

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