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UTILIZATION OF WASTE WETLAND ECOSYSTEM THROUGH INTEGRATION OF FISH-CROP DIVERSIFICATION FOR ENHANCING PRODUCTIVITY AND ECONOMIC SUSTAINABILITY OF RURAL FARM COMMUNITIES IN INDIAN SUB-TROPICS

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ABSTRACT

Wetland has a pivotal role for maintaining its ecosystem and refreshing as Nature's kidney, recharging groundwater and over all, production of food materials for serving rural mankinds in a sustainable manner. Indian-subcontinent, particularly north-eastern part comprises 25-30% wetlands that intersected with main river system and it's so many tributaries, predominant in Indian subtropics, mostly in Indo-Bangladesh regions. These are immense valuable, resourceful for fish-crop diversification, which are nutrient-rich underutilized valuable aquatic food crops [besides deep-water rice, others are water chestnut (Trapa bispinosa Roxb.), makhana (Euryale ferox Salisb.), water-lily (Nymphaea spp.), Colocasia etc.), practiced either as sole system or integration of fish-crop diversity, as these have out-yielding ability and remunerative, mostly preferred by rural and urban people and ultimately, sustained economic stability to millions of people in the regions. This paper deals with number of case studies, were undertaken during last 15-16 years for proper utilization of waste wetland ecosystem in different agro-ecozones on a wide sector of downtrodden resource-poor to marginal farming communities. This TOT-cum-improvised low-cost updating agro-techniques were implemented at farmers' field on the integration of aquatic crops + fish variables for using natural resources as well as for enhancing productivity and economic viability (even >2.5 folds) at its sustainable manner. From the study it may be concluded that this improved practice is imperative to utilize this vast unused or waste wetland ecosystem, particularly north-eastern part of the country with impetuously for food, livelihood, engagement of household labours and ultimately, economic stability of rural people, who are inextricably linked with the system and sustainability as well.

Keywords: Wetland ecosystem, aquatic food crops, fish variables, production system, economic stability and rural sustainability.

INTRODUCTION

Vast wetland ecosystems, especially north-eastern part of the country are immense valuable for production of so many aquatic crops (food, food-cum-ornamental crop, non-food commercial crops etc.), mostly treated as underutilized crops, fish variables and aquatic crops-cum-fish variables and so many other beneficial aquatic flora & fauna, which are naturally sustainable, maintaining its ecological balance. These are furnishing generous output and economic stability for rural people in consequence.

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Glossary

Wetlands

Wetlands (inland as well as coastal) are the environments subject to permanent or periodic inundation or prolonged soil saturation sufficient for the establishment of hydrophytes and/or the development of hydric soils or substrates. Categorically, wetlands are the transitional phase in between dry terrestrial and permanently aquatic ecosystem, where, the soil is frequently waterlogged, and the water table is at or near the surface and the land is oftenly covered by shallow to certain depth of water, exists either permanently or semi-permanently or temporarily. Some common wetland types includes marsh, fen, wet meadow, swamp, bog, muskeg, wet tundra, tidal flat, river bottom, lowland, mangrove forest, tropical rainforest and floodplain swamp (Tiner, 1993).

'Tal' lands

The land, which is subject to prolong flooding during the rainy season, is known as *'Tal'* lands with various depths and durability. These are the lands of *'low-lying flood plains including back water swamps'* and cover a reasonable area in north-eastern part of the country. Depth and duration of submergence depends on the geomorphic situation and soil characteristics. These lands are mainly comprised of flat alluvial plains intersecting with the main river system (*The Ganges, Brahmaputra, Padma, Mahanad, Mahanadi, Rupnarayan* etc.) and its so many tributaries and canals etc. - possible to make a saucer shaped wetland ecosystem bounded by land terrestrial, covered to about 0.307 million ha, which numbering of >0.2 million of different shape and sizes.

Importance of wetlands: internationally

It is pronounced that in the way of development, Ramsar Convention (1971) held in Iran, the first Global Conservation Convention brought this subject to the International arena, highlighted and accepted treaty on 'Conservation and Wise Use of Wetlands' (Navid, 1988). Soil and water are the integral part of global natural resources, determined greatly wetlands and its diversity, habitats of thousands aquatic flora and fauna.

Wetland scenario

Wetland comprises 6.4 per cent (855.8 million ha) of the world total area (Maltby and Turner, 1983) of which 23.5 million ha covered in India, dominated mostly in north-eastern and coastal part (25-30%) of the country (Anonymous, 1986). Actually, the same environmental condition also exists in south-east Asian countries like China, Japan, Philippines, Thailand, Malaysia, Sri Lanka, Bangladesh etc. Survival of human civilization is inextricably linked with the wetlands since about 4500 B.C., which sustained economic stability of hundred million of people. And this swampy environment of the carboniferous period produced and preserved many of the fossil fuels on which we greatly depend now, for this James has rightly termed as *'nature's kidney'* of the world (James, 1995).

Scope and utilization of wetlands

Wetlands are highly exploited. Sufficient commercially exploitable species and aquaculture makes the wetlands more valuable. Aquatic species, conservation of mangrove forests as well as wild life conservation, fossil, fuels are derived from wetlands. The development and management of wetlands should form an important part of the integrated watershed management plans. This

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swampy, fertile, productive wetlands are continuously used by the rural farmers for production of fish variables, aquatic food crops (deep water rice, water chestnut, makhana, water lilly, Royal water-lily, *Colocasia* spp. etc.) and non-food crops (*Cyperus* spp., *Typha* spp., *Clinogyne dichotoma*, *Aeschynomene aspera*, *Brachiaria mutica*, *Coix* spp. etc.), ornamental and beneficial medicinal plants including fish genotypes which are immense valuable, nutritious, important and more popular in these regions.

Resource utilization

Meeting the challenges of sustaining food security and economic outturn for the poor and marginal farmers, it is thus possible with the resource utilization of the area. Development of improved farming systems in rainfed semi-aquatic to permanent aquatic wet areas that will diversity the farm through integration of aquatic food crops along with pisci-culture along with other components in multi-nature system approach. Such approach can ensure higher and stable farm productivity, income and year-round employment opportunity without degrading the environment. This will generate year round more income 2-3 folds than that of existing at present over the area. Encouragement of scientific culture on the integration of food crops - fish farming in wetland ecosystem is, therefore, most desirable due to the following sharing of advantages, which could possible to utilize at its maximum levels,

1. The synergistic effect of fish on aquatic food crops,
2. Control of aquatic weeds and associated insects by fish,
3. Increased efficiency of resource utilization, reduced investment risk through crop diversification and additional sources of food and income,
4. More frequent visits to the field particularly for fish genotypes by the farmers, resulting in better crop management,
5. Low risk for poor water chestnut and makhana growers with modest capital investment,
6. Year round employment opportunity for the farm family and
7. Consequently, improvement of farm family income and nutrition level.

Integrated approach : fish-crop diversity

Indigenous energy rich air-breathing live fishes like (including snake-headed) - Shoil, *Channa striatus*; Taki, *C. punctatus*; Gajar, *C. marulius*; Magur, *Clarias batrachus*; Singi, *Heteropnuestes fossilis* and Koi, *Anabus testudineus* are most important. Besides, *Chanda ranga, Chanda nama, Punctius ticto, Punctius sophore, Punctius sarana, Colisa pectoralis, Colisa fasciata* including Indian major sweet water carps like Rohu (*Labeo rohita*), Katla (*Catla catla*) and Mrigal (*Cirrhina mrigala*) are also important. These were used successfully under integrated system as it can able to fetch more money in the market due to its high price and prefer most of the common people, particularly in village and urban areas. The introduction of fish along with deep water rice in waste wetland ecosystems are common for the utilization of food and total productivity (Dutta *et. al*, 1984, Jhingran, 1991 and Puste and Bandyopadhyay, 2000) as well as for improving soil fertility by grazing on aquatic biomass and contributing through their feaces to nitrogen accumulation at soil surface (Brahmanand and Mohanty, 1999 and Bandyopadhyay and Puste, 2001).

Importance: aquatic food crops other than rice

Makhana or fox nut (*Euryale ferox* Salisb.) under the family - Nymphaceae and water chestnut (*Trapa bispinosa* Roxb.) under the family Trapaceae or Onagraceae are the annual floating-leaved herbs (with C_3 type of photosynthesis), mostly treated as underutilized aquatic crops, but has its importance, familiar and nutritious food crops growing in diverse areas from tropics to the Frigid Zone with a great importance to wide sector of rural people. It is a native to South-East Asia with the prevalence of tropics to sub-tropics

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accomplished by humid to sub-humid environmental countries like China, Japan, Malaysia, Thailand, Philippines, Java, Sumatra, Nepal, Bangladesh, Sri Lanka and India. Fresh immature kernels of water chestnut fruits are used as a popular article of food in raw or cooked form, which are abundant source of starch, protein, minerals, amino acids, vitamins including medicinal and therapeutic value. Similarly, mature makhana kernels posses high nutritive value comprised rich in carbohydrate (76.9%), protein (9.7%), minerals (1.3%) and fat (0.1%), are used as milk pudding, varieties of sweetmeat dishes, vegetable curry and as costly popped form, which is being exported to foreign countries.

METHODOLOGY

From the literature survey, it is inferred that very limited or no information is still available in the study zones as well as our country, regarding the evaluation of the system of such aquatic food crops (water chestnut, makhana and other important aquatic crops) along with fish genotypes under integrated aqua-terrestrial ecosystem. To realize the facts with great significance this paper deals with number of case studies during the last 15-16 years on the integration of such important aquatic food crops along with fish variables at farmers' level were undertaken through the implementation of number of Government of India sponsored research projects [I.C.A.R., NWDPRA, TDET (DoLR), etc.] in wet bodies (pond systems) during pre to post-monsoon season for productivity and economic stability in the New, Old Alluvial as well as Coastal zones of Indian sub-tropics. It was implemented for proper utilization of waste wetland ecosystem (deep, semi-deep, temporary in nature under different agro-ecozones) on a wide sector of downtrodden resource-poor to marginal farming communities. This TOT-cum-improvised demonstration programmes were formulated and implemented on the development of integrated management programmes (i) System approach (need-based cleaning, excavation & renovation), (ii) methodological approach (field techniques, planting variables), (iii) Field management (agronomic management on fish-crop integrated system, inter & post-harvest care, processing and its marketability), (iv) INM utilizing organic as well inorganic sources of nutrients, including (v) Low-cost fish-feed, utilizing properly unused/waste wetland ecosystem in the regions. The unique approach of watershed plans (*bherri* system), which were formulated integrately for upright production system of aquatic crops + fishes, exhibited more economic return due to wide use of natural resources.

In otherwords, the success of the adoption of modern techniques of agricultural cum aquaculture production will be reflected through increased productivity. Keeping the above mentioned points, the present study had been conducted under New, Old Alluvial as well as Coastal Zones of these sub-tropics with the following objectives –

I. To disseminate the result oriented outcomes of the production system of aquatic crops cum fish culture in a very systematic manner including agro-techniques to the common fish-farm communities in the zones through communication processes, on the variables like –
    a) Crop enterprises,
    b) On fish variables and
    c) On integration of fish-cum-aquatic food crops.

The pilot studies were emphasized to use the extensive system approach in wetland ecosystems as 'On station trial' to choose best one through some excavation or earth manipulation to make it watershed or *Bherri* system (Fig.1 & 2), because of their divergence as well as their production potential. The precise

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objective is to find out the suitable agro-techniques to the zone-specific, which were implemented in a large-scale at farmers field as 'On farm demonstration' in areas of :

i. Suitable planting variables of aquatic crops adjusted with fish genotypes in integrated system,
ii. Integrated nutrient management system (low-cost plant as well as improved fish-feed) sustainable for optimum production and
iii. Management (fish-crop management, inter & post-harvest care & processing, marketing etc.).

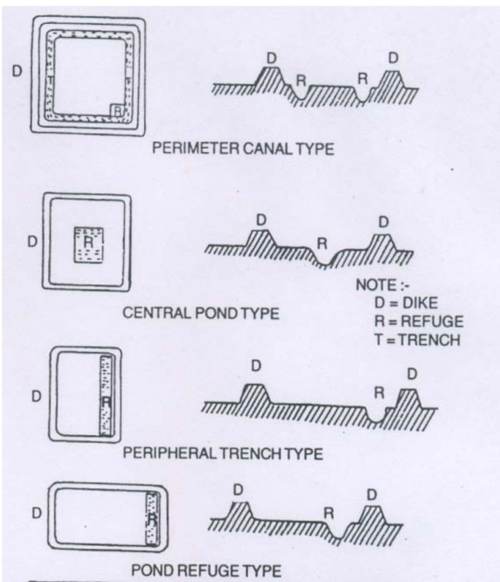

Fig.1 Different types of pond-refuges/*bherrii* system

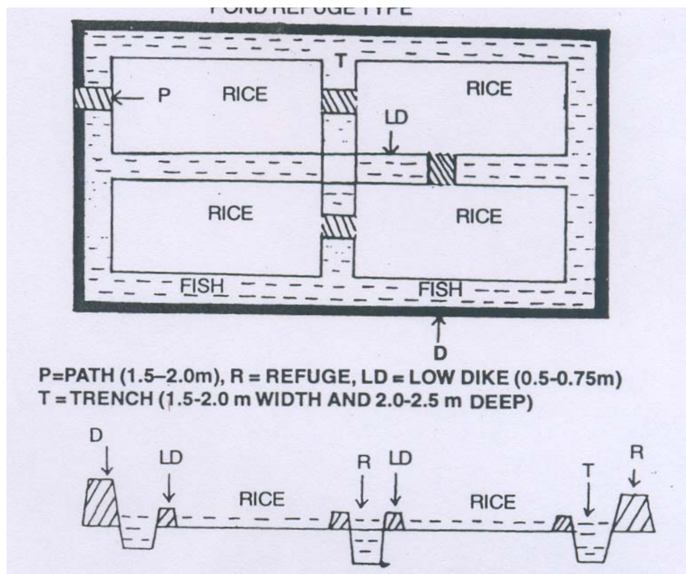

Fig.2 Field diagrams of combined fish-cum-rice/other crop culture

These are based on the interrelation between available socio-economical factors, natural resources, adaptability of agro-techniques in fish-farming community with involving NGO's (WATER, SARVODAYA, Taldi Netaji Sangha etc.) following step of actions in farmers' field as *'On Farm'* trials; a composite structured schedule was formulated for collecting information regarding the background characteristics of the respondents and standardization of their socio-economic status of the zones. The field project trials-cum-demonstrations were launched a massive and constructive extension programme under extension commanding area in the zones. According to the programming, particularly -

STEP I

A. Major aquatic food crops [1. Sole crop of water chestnut (*Trapa bispinosa* Roxb.), 2. Sole crop of makhana (*Euryale ferox* Salisb.)]; B. Rice cum fish culture; on C. Aquatic food crops (water chestnut and makhana) cum fish variables and D. Aquatic food and non-food crops (mat-sedges) cum fish variables in a 3-tier system with a view to conserve and wise use of wetlands as well as economical viability of the resource-poor farm families of these zones. These were undertaken mainly during pre to post-monsoon season with number of variables (wetland types and characteristics, water management, planting variables, nutrient

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management, plant protection measures etc.) focusing on production potential, production economics, quality of foods, soil, environment and water characteristics etc.

In the system approach, particularly in sole system, both crops (water chestnut & makhana) were transplanted maintaining 1.5 m x 1.5 m row to row and plant to plant apart, and all individual fish fingerlings were stacked in the respective pond @ 6,000 fingerlings when these were cultured as sole system and were maintained at 2.0 m x 2.0 m row to row and plant to plant apart, when it combined with fish of different types. In mixed system, fishes were allowed 75% of the main plot (4,500 fingerlings ha^{-1}). Makhana was transplanted during first week of April (in 50 cm of water depth), while, water chestnut during first week of July (in 70 cm of water depth due to accumulation of rainwater). All fishes were stacked during the second week of July after initial establishment of both the crops for synchronous effect of fishes on it. Seedlings of both the crops were transplanted 2-3 plants/stool. For fertilization, crops received N, P_2O_5 and K_2O @ 20 : 30 : 20 kg ha^{-1}, applied as basal. Foliar application of zinc based micronutrient (Chelamin @ 150 g ha^{-1} 300 l^{-1} of water) + NPK (0.5% conc. of each nutrient at a time *i.e.* 0.5 + 0.5 + 0.5 = 1.5% conc.) at 20 days interval of 30 DAT and continued up to mid of November.

On an average each fingerling weighed 6 g at the time of release. Besides NPK including spray materials, fishes were supplied feed of powdered mustard oilcake + rice husk in 1:1 ratio @ 6 times of body weight of fishes at weekly interval in sole fish system and 75% of feed in combined treatments of crop + fish systems. Sometimes, as per the nutritional requirements of fishes, animal protein (e.g. fish-meal, silk-worm cocoons as when available) was added with fish-feed (rice bran and mustard/groundnut oilcake). For all the cases extra 15% fingerlings were also allowed for the mortality percentage of different fishes due to various intercultural operations were done in the ponds. A borderline area of 0.75 - 1.00 m of individual plot was tried to provide as free water surface for easy movement of fishes as well as for the supply of fish-feed in time. Protection measures for fishes and crops were taken as and when required and as minimum as possible. Water chestnut consumed as immature fresh fruit; pickings were started from September, continued up to first fortnight of December, while makhana seed kernels and fish of different genotypes were harvested at the end of December and April to May (at least 2 times) depend upon the depth of submergence at that time.

Number of variables was used in the study. However, for easy comparison among the fishes of different categories and crops due to their heterogeneous characters, all the variables were converted to makhana yield equivalent (MYE) in terms of production (t ha^{-1}), was determined with the following formula:

$$\text{Makhana yield equivalent (t ha}^{-1}\text{)} = \frac{\text{Market price of the crop/fish to be compared (INR)}}{\text{Price of the makhana t}^{-1}\text{ (INR)}}$$

For calculation of MYE, GMR (gross monetary return), NP (net profit) and B-C ratio (benefit-cost), market price of all the produces were considered as follows (Table 1),

Table 1. Market price of WC (water chestnut), Mak (makhana) and different type of fishes

Items	Price (INR t^{-1})	Price (US \$ t^{-1})
Fishes		

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Magur	1,50,000	3,260.9
Singi	1,40,000	3,043.5
Rohu	60,000	1,304.3
Katla	55,000	1,195.6
Aquatic food crops		
WC	6,000	130.4
Mak	30,000	652.2

STEP II

On community basis on fish groups (FG_1: live-fishes, Magur - *Clarias batrachus,* Singi, *Heteropneustes fossilis,* Shoil, *Channa striatus* and Gajar *C. marulius* and FG_2: sweet water fishes, Rohu - *Labeo rohita,* Katla, *Catla catla,* Mrigal, *Cirrhinus mrigala* and Silver carp, *Hypophthalmicthys molitrix*) was restricted, using improved and judicious eco-friendly fish-feed materials (F_1: powered mustard oilcake + rice husk in 1:1 ratio, F_2: neem oilcake, F_3: poultry droppings + cowdung (1:1) @ 6 times body weight of fish at weekly interval, which compared with F_4: without fish-feed, sometimes applied very little amount as and when available to the farmers as local practice) in cluster basis in villages (4 clusters) to develop centers for further dissemination of new technologies on fish production as well as quality of produce (Puste and Basu, 2004).

FINDINGS WITH INTERPRETATIONS

Technological adaptation and outcome of the system

The inland fresh-water fish culture in the rice field played a significant role in the economic utilization of waste wetlands in food production as duel purpose. It will however, contribute substantially to increase the production of fish as well as grain production per hectare from inland water. Besides food production, bottom soil of the pond also improved considerably in consequence due to integration of both culture. Keeping in view a details field experiment was carried out to visualize the impact of fish-feed and type of different carps on the yield performance of improvement of soil status as a whole (Puste and Bandyopadhyay, 2000 and Bandyopadhyay and Puste, 2001).

Application of fish-feed (powdered mustard oilcake + rice bran in 1:1 ration @ 6 times body weight of fish applied at weekly interval) increased the grain and straw yield of rice [Sabita (NC 492), a tall *Indica*] by 19.0 and 13.0%, respectively. The addition of fish-feed also helped to increase the fish yield by 7.0% and different types of carps influenced the grain and straw yield of rice and fish yield significantly (Table 2). Higher grain (2.433 t ha^{-1}) and straw yield of rice (4.301 t ha^{-1}) was achieved by the plots, where Katla (*Catla catla* Ham.) was allowed. Among the carps, Katla produced highest amount of fish yield (1.344 t ha^{-1}) and the performance of Rohu (*Labeo rohita* Ham.) and Mrigal (*Crrihinus mrigala* Ham.) was statistically at par. Introduction of Katla, Rohu and Mrigal in rice field might increase the CO_2 concentration by respiration in crop canopy level and accumulated higher percentage of nitrogen and other elements in soil through their faeces and thereby, increased the grain and straw yield to the tune of 24-58 and 15-53%, respectively. On the

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other hand, an additional higher yield of fish was also observed (1.082 to 1.344 t ha^{-1}) under rice cum fish culture ecosystem, which provided several natural planktons needful for rapid growth of fish. Application of fish-feed not only increase the fish yield by providing better feeding material but also helped to increase the productivity of rice due to its manurial value.

Table 2. Effect of fish feed and carp on grain, straw yield of rice and fish yield

Treatments	Pooled yield (t ha^{-1}) of two years		
	Rice grain	Rice straw	Fish
Fish feed			
Without fish-feed	1.869	3.303	0.886
With fish-feed	2.225	3.734	1.513
S.Em ±	0.006	0.098	0.048
*C D (*p*=0.01)*	N.S.	N.S.	0.396
*C D (*p*=0.05)*	0.208	0.440	0.215
Types of carps			
No fish	1.541	2.802	-
Rohu	2.299	3.738	1.172
Katla	2.433	4.301	1.344
Mrigal	1.915	2.233	1.082
S.Em ±	0.078	0.103	0.036
C D (*p*=0.01)	0.317	0.419	0.155
C D (*p*=0.05)	0.231	0.307	0.111

Improvement of soil status

In general, available nitrogen, phosphate and potash status of pond soil were improved after two years of experiment. Application of fish-feed increased the soil nitrogen, phosphate and potash status by 111.0, 9.7 and 57.7 kg ha^{-1} respectively, which was far better than control. All the carps performed better to improve the N, P and K status of soil in comparison with the application of no fish. Among the carps, Katla was superior to the others. Fish-feed by its manurial potentiality and carps with the addition of their faeces helped to improve nitrogen, phosphate and potassium status of soil, which was reflected on the outcome from each component of the integrated rice-fish culture (Bandyopadhyay and Puste, 2001).

Integration of fish-cum-aquatic food crops

An intensive case study was carried out in RBD (randomized block design) replicated four, where, individual aquatic food crops and fish genotypes [T_1 - LF (Singi - *Clarias batrachus*) & T_2 - LF (Magur -

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Heteropneustes fossilis); T_3 - SW fish (Rohu - *Labeo rohita*) & T_4 - SW fish (Katla - *Catla catla*) and T_5 - Water chestnut (*Trapa bispinosa* Roxb.) & T_6 - Makhana (*Euryale ferox* Salisb.)] were considered as six sole treatments along with four mixed treatments combined of crops with fish variables (T_7 - Water chestnut + LF (both in 1:1 ratio); T_8 - Water chestnut + SW fish (both in 1:1 ratio); T_9 - Makhana + LF (both in 1:1 ratio); T_{10} - Makhana + SW fish (both in 1:1 ratio) altogether ten treatments. In the sub-plot treatments, four combinations of both fish groups were allowed for their competitive effect of two variables (Puste *et al*., 2004).

Results from the study, fish-crop diversity was much important and substantial enough for more productivity per unit area per unit time. For easy comparison among variables, yield of fishes and crops were converted to MYE (Makhana yield equivalent) due to heterogeneous characteristics. Sole yield of all fishes (0.59, 0.54, 1.18 and 1.32 t ha^{-1}) and water chestnut and makhana (8.39 & 2.36 t ha^{-1}) dominated individually in respect to their associated yield. However in MYE study, among the combinations, superior results obtained with L-fishes (1.90 & 1.35 t ha^{-1}) + makhana (1.72) in respects to their cumulative yield (4.97 t ha^{-1}) followed by L-fishes (2.05 + 1.49 t ha^{-1}) + water chestnut (1.28 t ha^{-1}) due to their compatibility with the system. Regarding economic outcome, GMR, NP and B-C ratio (US$ 3,244 & 2,557 ha^{-1} and 3.71) were also very promising with the system, which economically viable particularly for rural farm families. Among the combined system, lowest values obtained with SW-fishes + makhana, due to their non-compatibility characteristics (Table 3 & 4).

Table 3. Yield and makhana yield equivalent (t ha^{-1}) of water chestnut, makhana and fishes

Treatments	Individual yield (t ha^{-1})						Makhana yield equivalent (t ha^{-1})						
	M	S	R	C	WC	Mak	M	S	R	C	WC	Mak	Total
T_1 - Sole M	0.59	--	--	--	--	--	2.95	--	--	--	--	--	2.95
T_2 - Sole S	--	0.54	--	--	--	--	--	2.52	--	--	--	--	2.52
T_3 - Sole R	--	--	1.18	--	--	--	--	--	2.36	--	--	--	2.36
T_4 - Sole C	--	--	--	1.32	--	--	--	--	--	2.42	--	--	2.90
T_5 - Sole WC	--	--	--	--	8.39	--	--	--	--	--	1.68	--	1.68
T_6 - Sole Mak	--	--	--	--	--	2.36	--	--	--	--	--	2.36	2.36
T_7 - WC + LF	0.41	0.32	--	--	6.38	--	2.05	1.49	--	--	1.28	--	4.82
T_8 - WC + RC	--	--	0.86	0.98	5.82	--	--	--	1.72	1.80	1.16	--	4.68
T_9 - Mak + LF	0.38	0.29	--	--	--	1.72	1.90	1.35	--	--	--	1.72	4.97
T_{10} - Mak + RK	--	--	0.76	0.78	--	1.48	--	--	1.52	1.43	--	1.48	4.43
CD (*P=0.05*)	0.08	0.07	0.19	0.21	0.89	0.25	--	--	--	--	--	--	--

Table 4. Gross monetary return and benefit-cost ratio of the system

Treatment	Net profit (INR '000 ha^{-1})	Benefit-cost ratio
T_1 – Sole M	66.97 (1456)	3.11
T_2 – Sole S	55.39	2.74

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	(1204)	
T_3 – Sole R	51.24	2.62
	(1114)	
T_4 – Sole C	52.98	2.70
	(1152)	
T_5 – Sole WC	31.86	1.72
	(693)	
T_6 – Sole Mak	52.54	2.88
	(1142)	
T_7 – WC + LF	112.19	3.46
	(2439)	
T_8 – WC + RC	107.69	3.29
	(2341)	
T_9 – Mak + LF	117.60	3.71
	(2557)	
T_{10} – Mak + RC	100.86	3.15
	(2193)	

Parenthesis indicates USD, GMR, Gross monetary return; K, Katla; LF, Live fishes; L, Litre; M, Magur; Mak, Makhana; MYE, Makhana Yield Equivalent; M, Mrigal; NP, Net profit; RK, Rohu + Katla; S, Singi; SW, Sweet water fishes and WC, Water chestnut

Step II: System adapted on community basis for rural sustainability

Individual fish yield

In the field study, these were implemented on community basis in each zone covering 3-4 villages in each cluster. In the demonstration cum improved trials, all the fish variables were cultured individually but for convenience for presentation individual fishes were grouped into two; *e.g.* FG_1, composed of Magur, Singi, Shoil and Gajer; and FG_2, which composed of Rohu, Katla, Mrigal and Silver carp. These were reared with normal but improved nutritional status (powdered mustard/groundnut oilcake + rice bran in 1:1 ration @ 6 times body weight of fish at weekly interval) along with proper management practices. Fingerlings, fish-feed and other necessary inputs were supplied to the farmers timely from the institutional project's sources. Individual fish yield in cluster I & II in both the groups comparatively least performed than that of cluster III & IV, may be due water quality and depth of submergence of the respective ponds. It is more contrasting and comparable enough with the local practice. The magnitude of yield increased in all the individuals were to the tune of 46.0 to 78.0 per cent, more prominent in Magur, Singi, Mrigal and Silver carp (Table 5). A significant price differences were noted in between local market or *hat* and zonal trade centres of the zones. In most of the cases, fish farmers are sale out their output directly to the middlemen in the trade centres, with reasonable profit margins. Fewer cases they sale out their fishes locally with small harvests.

Table 5. Individual fish yield and their price study

Variables	Av. yield (t ha^{-1})	Av. price of fishes (INR t^{-1})

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	Cl. I	Cl. II	Cl. III	Cl. IV	Av. yield	Av. local yield	Local market	Zonal trade
FG_1								
Magur	0.57	0.59	0.68	0.64	0.62	0.38	1,30,000 (2,826.1)	1,50,000 (3,260.9)
Singi	0.52	0.56	0.62	0.58	0.57	0.32	1,20,000 (2,608.7)	1,40,000 (3,043.5)
Shoil	1.32	1.38	1.46	1.52	1.42	0.96	1,10,000 (2,391.3)	1,30,000 (2,826.1)
Gajer	1.38	1.44	1.50	1.52	1.46	0.92	1,10,000 (2,391.3)	1,30,000 (2,826.1)
FG_2								
Rohu	1.14	1.19	1.27	1.24	1.21	0.83	50,000 (1,086.9)	60,000 (1,304.3)
Katla	1.28	1.35	1.43	1.38	1.36	0.86	40,000 (1,086.9)	55,000 (1,195.6)
Mrigal	1.09	1.15	1.26	1.22	1.18	0.68	40,000 (1,086.9)	50,000 (1,086.9)
S. carp	1.18	1.26	1.39	1.33	1.29	0.74	40,000 (1,086.9)	45,000 (978.3)

Av., average; Cl., cluster; Parenthesis indicates US$ (1US $ = INR 46.00), INR-Indian Rupees

Group fish yield

Application of eco-friendly and judicious fish-feed (powdered mustard/groundnut oilcake + rice bran in 1:1 ration @ 6 times body weight of fish applied at weekly interval), applicable on fish variables in grouped basis were remarkably influenced the fish yield, practiced in farmers' fish ponds on community basis of different villages of the zones. Almost all the feed items were more or less equally effective for such increment of fish yield and it significantly differed from control pond, where fishes were nourished without any fish-feed (Table 6). The increment was to the tune of 82.2 to 116.4% in FG_1 and 98.5 to 131.0%, respectively in FG_2. However, among the 3 fish-feed materials highest results obtained with F_1 (powered mustard oilcake + rice husk in 1:1 ratio @ 6 times body weight of fish at weekly interval), although it quite statistical at par with other treatments in the field studies. The practice of proper fish-feed was quite effective to rearing and to increase fish yield irrespective of fish variables in the different 4 clusters of the zones (Puste and Basu, 2004).

Table 6. Fish yield in groups as influenced by fish-feeds

Variables	Cl. I		Cl. II		Cl. III		Cl. IV		Av. of clusters	
	FG_1	FG_2	FG_1	FG_2	FG_1	FG_2	FG_1	FG_2	FG_1	FG_2
Fish feed										
F_1	1.02	1.28	1.19	1.34	1.21	1.33	1.18	1.32	1.15	1.32
F_2	1.00	1.22	1.12	1.18	1.18	1.26	1.15	1.21	1.11	1.22
F_3	1.04	1.18	1.13	1.22	1.12	1.24	1.09	1.22	1.09	1.21
F_4	0.56	0.59	0.55	0.58	0.64	0.67	0.61	0.64	0.59	0.62

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CONCLUSION

The vast wetland ecosystem may effectively be utilized through the cultivation of so many aquatic crops, fish variables which not only valued to human beings but also imperative for the upliftment of resource poor rural economy as well, who are inextricably linked with the system. Besides, wetlands are continuously enriched by adding large quantities of biomass, enriched in sequence, which has possible to utilize this enriched biomass effectively for production of arable crops as well as improvement soil nutrient status in consequence in the zones.

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