Investigations on the Potentialities of Crop-Livestock-Fish Integrated Farming System for the Marginal Farmers in Terai Region of West Bengal.

Thesis submitted for the

Degree of Doctor of Philosophy [Ph.D.] in Science.

By

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From
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TO WHOM IT MAY CONCERN

This is to certify that Smt. Soma Banerjee, M.V.Sc., has prepared the Ph.D. Thesis entitled "Investigations on the Potentialities of Crop-Livestock-Fish Integrated Farming System for the Marginal Farmers in Terai Region of West Bengal" for the award of Ph.D. degree of the University of North Bengal, under my guidance. This thesis is based on the original investigations done by her and that neither this thesis, nor any part of it has been submitted for any other Degree or any other academic award anywhere before.

Smt. Banerjee has carried out the work at the Department of Zoology, University of North Bengal and fulfilled the requirements of the Degree of Doctor of Philosophy in Science (Zoology) of the University of North Bengal.

Dated: 19th July, 2013

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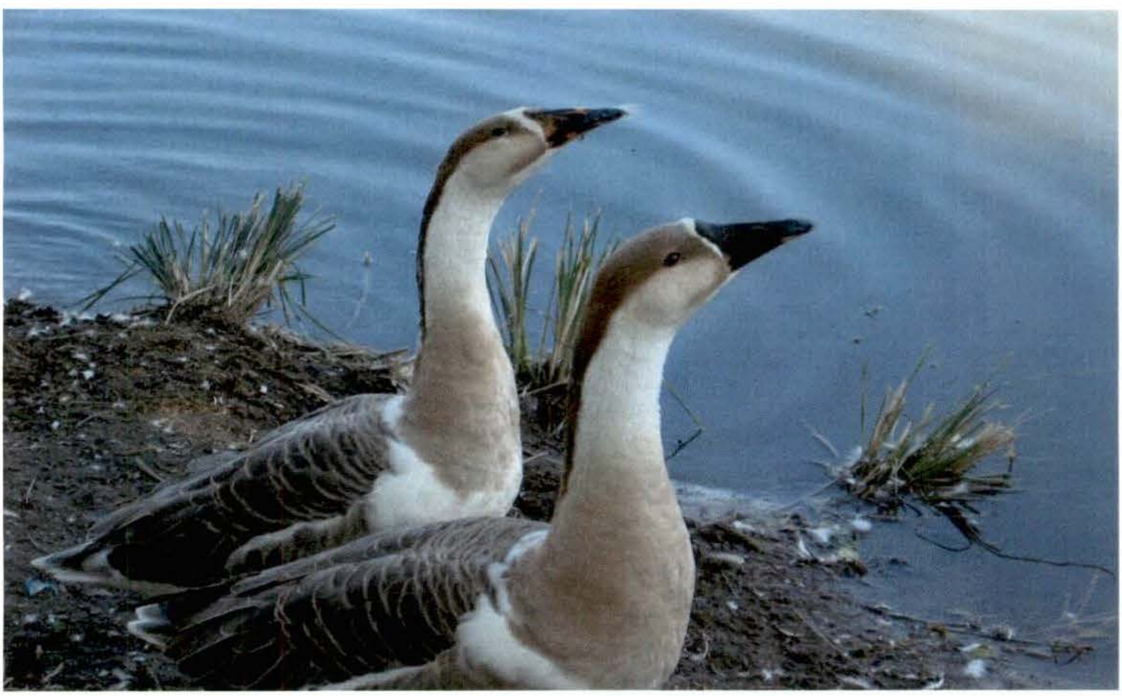

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Dated: 19.7.13

Place: University of North Bengal

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CONTENTS

LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
APHA	American Public Health Association
IFS	Integrated Farming System
NIFS	Non Integrated Farming
IMC	Indian Major Carp
GC	Grasscarp
DO	Dissolved Oxygen
CO	Free Carbondioxide
m	metre
ha	Hectare
wks	Weeks
@	At the rate
g	Gram
kg	Kilogram
l	Liter
no.	Number
yr	Year
pH	Hydrogen ion concentration
DMRT	Duncan's Multiple Range Test
SE	Standard Error
M	Mean
p	Probability
°C	Degree Celcius
C	Control
%	Per cent
mth	month
d	day

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INTRODUCTION

1.1 General Introduction

Integrated Farming System (IFS) seems to be the possible solution to meet the increased demand for food, stability of income and sustainable management of the limited natural resources and thereby improving the nutrition of the marginal farmers. Integration of different agriculturally-related enterprises with crops provides ways to recycle products of one component as input through another linked component and reduce the cost of production and thus raise the total income of the farm. The land area, specially cropped area, cannot be increased. Hence, multiple land use through integration of crop, livestock and aquaculture can give the best and optimum production from unit land area (Ravisankar and Pramanik, 2007).

We are aware of the fact that the Green Revolution in mid- sixties by new technological developments, transformed the Indian agriculture dramatically, resulting many-fold increase in production and productivity and making the country self-sufficient in food production. But, this growth in food production showed a reverse side too, that is, environmental degradation and ecological imbalances (Shalendra and Tewari, 2003). It was realized, that intensive agriculture with indiscriminate use of agricultural inputs in the irrigated areas and cultivation of highly fragile lands in the rain fed areas have caused serious problem in sustainability of the Indian agriculture (Bhatia, 2001). It has also been realized by the present researchers that our planet Earth and its environment are disturbed due to over use of natural resources namely water, soil and air resulting into a depleted natural resources . It is now apprehended that this heavy cost of development is going to degrade natural resources. It is therefore, suggested that we must strike a balance between conservation of natural resources and the need for sustainable development.

About 70% of India's population lives in villages and 90% of its rural population depends on agriculture and allied activities for their livelihood (Radheyshyam, 2001). Again, about 75% of Indian farmers are marginal and small. Small land holdings are not well suited for mechanized farming. This coupled with poor economic condition and lack of resources cause slow growth rate in agriculture sector. The agriculture for marginal farmer is mostly subsistence type of farming (Singh and Gill, 2010). The aim of sustainability in farming can be achieved only when we are able to judiciously utilize natural resources by adopting the process of recycling, thereby protecting the environment and preserving and protecting the natural resources for future demand. Integrated Farming System (IFS) can support the three pillars of sustainable development, that is, social, environmental and economic development. IFS can be the integrated resource management which will include not only the crop-livestock - fish component, but also the use of other resources such as capital, labour, space and water. Benefits of integrated farming are synergistic rather than additive. Hence, IFS is "whole systems approach" not only to agriculture alone but also to aquaculture.

Although IFS is economically and environmentally a sound system, motivation and awareness of the farmer is the key factor to get the benefit of integration. The farmers should be extensively educated regarding the benefits of this system. IFS is a developmental tool to fight against the food crisis through waste, land and space utilization efficiently. It can be said that information, integration and participation are the building blocks to achieve sustainable development in agriculture and allied science. Integrated crop-livestock-fish farming system is a proven environmentally sustainable and economically viable technology that encompasses rational utilization of available resources. Fig-1 shows the contribution of different components in IFS (Ravisankar and Pramanik, 2007).

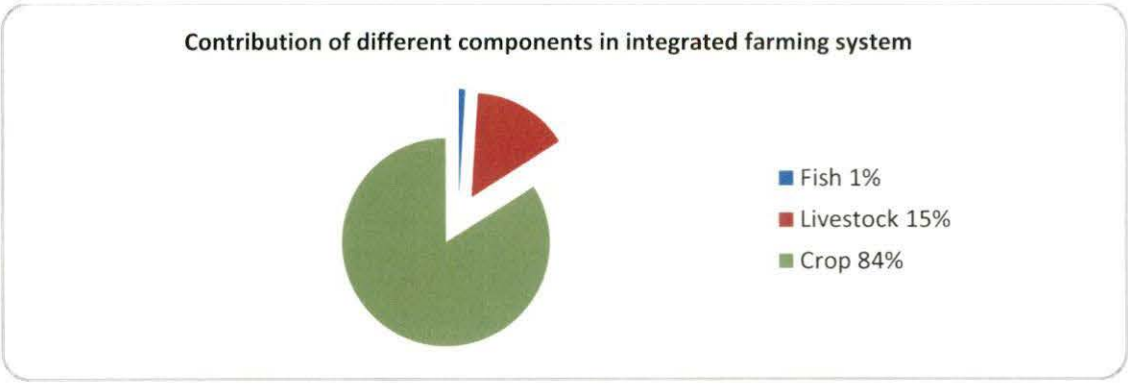


Fig-1: Contribution of different components in Integrated Farming System (Ravisankar and Pramanik, 2007).

According to Panda (2002), the main features of the crop-livestock-fish IFS are as follows:

a) Best utilization of the waste of livestock as an input of protein source for fish.

b) Economic utilization of the space in which the two subsystems occupy part or all space required for individual system.

c) There is an increased productivity, more income generation, gainful employment and cheap availability of animal protein with minimum expenditure.

Above all these, the two systems as shown in Fig-2 usually help each other in maintaining ecological balance and best utilization of natural resources in and around the pond area (Edwards, 1993).

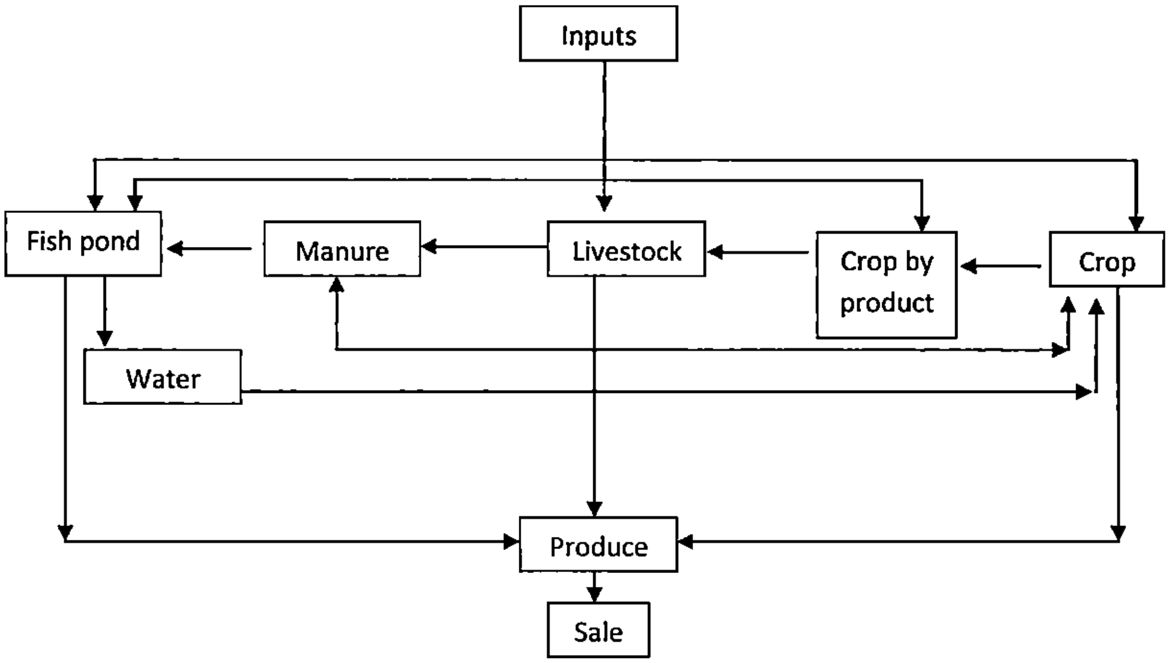


Fig-2: Major interactions between the various subsystems in a feedlot-fish integrated farm (Edwards, 1993).

Li and Mathias (1994), in China, had successfully integrated fish culture with waste treatment and other forms of aquatic food production. IFS can be used to bring marginal land, such as saline soil, wetlands into production where that would not be possible with agriculture or aquaculture alone (Mathias, 1994). The water in these marginal lands is too shallow for fish culture yet crops and livestock may be easily flooded. As an alternative to drainage, which is common elsewhere, the shallow ponds are excavated to allow proper fish culture, and the resultant soil is used to build up the dykes above flood level for use as agriculture and livestock land (Chan,1993). India's fish output can be increased fourfold from the current level , if only we fully exploit the farm technology and knowledge available with fishery scientists and facilitate the transfer of information to all section of farmers in a quick and efficient manner (Das,1984).

1.2 Key areas identified for research

In India, IFS is emerging as an important tool to increase farm productivity and sustainability of marginal farmers, which is about 75% of the total farming communities. These marginal farmers are very resource poor in respect to land, finance and knowledge. Throughout India, there are various agro-climatic conditions which influence the result of IFS. Hence, farming community can get the benefits from IFS only if a location specific IFS package is developed depending on the agro-climatic condition of that location. It has been realised that even well planned and monitored trials will produce results that are not directly applicable elsewhere. As the result obtained from different IFS is very much location specific, proper assessment and refinement of this technology through different adaptive research can help in developing the location specific IFS packages which inturn can increase the overall farm productivity of marginal farmer.

For the present study, Terai and Teesta alluvial agro-climatic condition of West Bengal were selected. Terai region of northern region of West Bengal is situated between $25^0 57'$ and 27^0 N Latitude and $88^0 25'$ and $89^0 54'$ E longitude with an altitude of 360 ft above Mean Sea Level (MSL). This northern region of West Bengal is situated along Darjeeling and Bhutan hills in the north, Bihar border on the West and Assam border on the North East. It includes Siliguri sub-division of Darjeeling district, entire Jalpaiguri and Coochbehar districts and Islampur subdivision of North Dinajpur district. Total geographical area of the zone is 12,025 km^2 which is 13.5% of the area of West Bengal. The share of the population of the area is 9.7% of the State of West Bengal. Rural population comprises more than 90% of the population of this zone. The soil of this zone is sandy loam to loam type having 1-3 feet deep dark brown top soil with rich humus content and medium or strong acidic in nature having high fixing capacity for phosphorus, poor micronutrients content. The climate of this zone is subtropical with warm humid except a short spell of winter from December to February. Average annual rainfall of the zone varies from 2100 – 3000 mm. while, the range of minimum and maximum temperature of the area is $7^0 - 8^0$ C and $24 - 33\ ^0$ C, respectively. The relative humidity ranges from 48 % to 87%. The maximum rainfall (about 80% of the total) is received from South-West monsoon during the rainy months of June to September. Generally, subtropical humid climate prevails in this zone comprising of prolonged rainy season. The rainy season starts from first week of May and continues up to last week of September having intermittent and occasional heavy rainfall. Ponds in this area are mostly seasonal and shrinking in nature. The water in the ponds generally stay from April to September or October depending on the rainfall.

In Terai Region more than 80% of farmers are marginal farmers with landholding less than one hectare (ha) along with small seasonal water bodies (0.01ha). Most of the marginal farmers in rural areas depend on agriculture and livestock as their main source of income. In this rain fed Terai region, rain water is the key factor for agriculture and fish farming. Sometimes, owing to low rainfall, serious problem arise which exposed farmers to high risk. Hence, any alternative source of income is very important for marginal farmers to mitigate their hardships. IFS, being a low cost farming, interact with more than one component and reduce the risk of farming for example, delayed rain or drought in a particular season may greatly hamper the cultivation and fish farming, but rearing of livestock may give some revenue to augment the financial condition of a marginal farmer in Terai region of West Bengal. Thus, IFS is considered as a low risk farming system approach, which is very much suitable for marginal farmers. Traditionally, many societies use animal wastes for fertiliser and fuel. It has been felt that manures contain large amount of partially digested feed hence, animals which consume good quality of food will generally produce good quality of manures. Direct ingestion of the unconsumed elements by the fish may be the most important source of feeding. Hence, in the present study, the cows are allowed to be fed on concentrates and the resultant manure, thus obtained, is utilized for fish production. But, there are also reports that an excessive use of organic manure may create anoxic condition in pond (Boyd, 1982) resulting a low productivity, thus in another study ducks were introduced in the integrated pond to maintain the oxygen level. Again, the ducks droppings may further fertilize the pond for more cumulative production. The pond bottom soil contains high nutritive value due to the decomposed organic wastes. Desilting pond every year to strengthen the dykes of the pond creates a scope to utilize the pond bottom soil for agriculture for an additional income ,thus this holistic approach of faming , further increase the farm productivity.

In this present study, two IFS packages involving three components, namely livestock (cattle and ducks), pond (fishes) and the pond dykes (turmeric) were assessed against the non-integrated farming system (NIFS) to recognise the best packages of farming for marginal farmers of Terai region of West Bengal. Thus, it can be realised that the problem of low farm productivity of marginal farmers of the Terai region of West Bengal seeking solution from IFS.

Based on the above hypothesis, the research work entitled "**Investigation on the Potentialities of Crop-Livestock-Fish Integrated Farming System for the Marginal Farmers in Terai Region of West Bengal**" was executed during the years

2008-2011 for the location specific adaptive research, at Jalpaiguri District of West Bengal.

1.3 Objectives of the present investigation

- ✓ To observe the effect of different Integrated Farming System (IFS) and Non Integrated Farming System (NIFS) on pond water quality.
- ✓ To study the effect of IFS and NIFS on pond soil quality.
- ✓ To follow the qualitative and quantitative zooplankton production under different IFS and NIFS.
- ✓ To find out the growth parameters and production of different fishes under different IFS.
- ✓ To understand the overall economics of different components namely livestock, vegetables and fishes used in different farming systems.

Review of Literature

2.1 Introduction to Integrated Farming Systems

Integrated fish farming is a sequential linkage between two or more farming activities (ICAR, 2006). It has been evident that integrating fish-livestock farming was well developed in China, Hungary, Germany and certain other countries (Hickling, 1960; Ling, 1971; Tapiader, 1977; Woynarovich 1979, ICAR, 2006). In China, the traditional farming was integration of fish-livestock- agricultural crops, including vegetable farming. The integration of livestock-fish-crop has received considerable attention during past three decades with emphasis on the incorporation of animal manures as fertilizer and nutrient for promotion of natural feed in fish ponds (Wohlfarth and Schroeder, 1979; Delmendo, 1980). Bhowmik (1986) mentioned, that the effective and purposeful dissemination of IFS is possible with proper coordination between the following four systems-

1. Technology generation systems (Research)
2. Technology communication systems
3. Technology utilization systems
4. Technology support systems

Mohanty *et al.*, (2010) reported in a case study that the integrated farming system model consisting of field crops (Rice, groundnut, maize, pigeonpea and ragi), horticultural crops (Yam, banana, tapioca and vegetables), vermicomposting and poultry (Banaraja breed) of a tribal farmer enhanced the productivity as well as the profitability 7 times higher as compared to the conventional farming system.

Among the different culture systems, "Integrated fish farming" refers to a combination of practices, incorporating the recycling of the wastes and recourses from one farming system to the other, with a view to optimize the production efficiencies and achieve maximal biomass harvest from a unit area, with due environmental considerations (Kumar and Ayyapan, 1991). Traditional integrated fish farming in China, with its multi-millennia history (Hu and Zhou, 1989 ;Yang *et al.*, 1992), is amongst the best developed and long-standing of farming practices but, it has only received systematic research attention in last two decades of the 20th century (Li, 1987; Ruddle and Zhong, 1988; NACA, 1989; Yan and Yao, 1989; Li and Mathias, 1994). In the integrated fish farming system, wastes, leftovers and by-product from other farm activities are used to raise fish and so produce highly valued fish protein. Other wastes such as pond silt are used as fertilizer for plant crops (Wang, 1994).

In India, fish culture has undergone gradual change during the past few decades, and there has recently been some movement to integrated livestock and crop farming. Though the integrated fish farming system is already well developed in China, Taiwan, Malaysia, Hungary and certain other European countries (Hickling, 1960; Delmendo, 1980; Sharma and Olah, 1986), very little attention has been given to this system in India. But, the sustained research efforts of Indian scientists to develop production systems that would optimize farmers return through the judicious use of farm wastes have resulted in development of an integrated farming systems in which livestock such as ducks, pig and poultry are raised along with fish (Yadava and Bhatnagar, 1992; Yadava and Vaishali, 1993; Singh, 1996). Steps are being taken to develop a better understanding of this type of farming system and to adopt this system to meet the needs of India's small and marginal farmers in order to improve their social and economic circumstances. Though these groups have small land holdings but they have surplus labour and once fish culture has been integrated with other farming systems, fish management typically becomes the major farm activity because fish ponds are often more productive and so more profitable than the other farm activities (Dhawan and Sehdev, 1994).

There have been two major directions to aquaculture development in Asia in the last decades; conventional intensification and system integration (Edwards *et al.*, 1997; Michielsens *et al.*, 2002). Closer and more strategic integration within the broader farming or livelihood system, where the pond becomes a focus for diversification and enhanced nutrient and water use efficiencies (Integrated Aquaculture–Agriculture Systems), has become an important phenomenon in Asia (Nhan *et al.*,2007). However, recent studies suggest that many poorer people are benefiting from increased aquaculture production in a variety of ways (Faruque *et al.*, 2006; Little *et al.*, 2007). Small ponds, either owned or leased, are common assets among poorer households partly for fish culture but also for a variety of other purposes including irrigation of vegetables (Little, 2000; Little *et al.*, 2007). Pond fertilisation and feeding increases production of natural fish food organisms in ponds (Singh, 1984; Milstein, 1993). Nevertheless, only 5–30% of the nutrients added in this way are converted into harvestable products (Edwards, 1993), the remainder is lost to the pond water or accumulates in the sediment. The latter can be used, along with pond water to simultaneously fertilise and irrigate the surrounding vegetable crops which potentially benefit households through subsistence food and income generation (Little and Muir, 1987). Unfortunately, there are few quantitative studies that document this practise (Karim *et al.*, 2011).

Adoption of new technologies is frequently undermined by their labour intensity (Little *et al.*, 1996; Doss and Morris, 2001) but, Karim *et al.*, (2011) observed that all the activities related to integrated farming system can be managed by the households. Cost for resource management (labour and other inputs) was much higher for fish than vegetable as relatively less time and labour were invested by the households for growing vegetables on pond-dykes and contracted hired labour was normal for fish harvest. Hallman *et al.*, (2003) found that vegetable production was relatively easier to adopt than fish culture and less likely to increase vulnerability whereas, in contrast, loss of fish to flood or theft could increase household vulnerability. The study of Karim *et al.*, (2011), provides strong evidence that both fish and vegetable production can be commercialised and remain complementary, even as aquaculture is intensified through use of more nutrient inputs. It can be realized that the integrated farming system (IFS) is by itself self-employment oriented, these improved technologies would definitely provide lots of employment opportunities to the farmer and to improve the livelihood of the farmers.

On farm studies all over the world typically have shown huge differences in yields and economic performance between farms despite very similar resource endowments (Gatenby and Humphries, 2000), which was also observed by Karim *et al.*, (2011) as yield and economic performance of farms varied considerably and perceived that differences in education, knowledge, and past experiences among farmers are largely responsible for this disparity. According to Ugwumba *et al.*, (2010) the farmer's education, years of experience and type of IFS are positively correlated with the expected income which implies that farmers who are educated, have more years of experience and can combine many viable enterprises tend to be more efficient in production and consequently will realize more income. This agrees with respective findings of Adeoti (2004) and Chan (2006) that years of experience and type of IFS reduce farmer's inefficiency and thus increase productivity and income.

As per Bagchi and Jha (2011), pisciculture may be part of the solution to the increasing need for food diversity and arresting the decline in per capita protein nutrition of the Indian populace in the years to come. Polyculture is the only possible way of simultaneously producing more than one fish species from the same rearing space (Papoutsoglou *et al.*, 1992 and Papoutsoglou *et al.*, 2001). The principle of polyculture is based on the fact that cultured fish species feed on different levels of food chain and environment (Milstein *et al.*, 2002). The productivity of the aquatic system is thus increased by more efficiently utilizing ecological resources within the environment. Stocking two or more complimentary fish species can increase the maximum standing crop of a pond by allowing a wide range of available food items and the pond volume to be utilized (Lutz, 2003).According to Jha *et al.*, (2006) polyculture had a direct effect on the number of marketable fish.

2.2 Importance of Integrated Crop - Livestock - Fish Farming System

Fish is a major source of protein for the increasing world population especially in the developing countries like Africa, Asia and South America (FAO, 2006a; Gabriel *et al.*, 2007) and the major solution to the dietary protein shortage in such countries is increased fish production (Nnaji *et al.*, 2009). Fish is produced from capture and culture (aquaculture) fisheries operations and according to FAO (2006b, 2008 and 2010), captured fisheries production decreased from year 2000 to 2008 (from 95.6 to 89.7 million tons) while aquaculture production rose from 35.5 million tons in the year 2000 to 52.5 million tons in the year 2008. However, aquaculture production was found to be hampered by obsolete fish farming technology, dearth of good quality fish seed, high cost of aquaculture operation etc. The need for a low-cost system of fish production to meet the food needs of rural and urban poor and also minimize the utilization of resources for greater output become pertinent. So, integrated fish farming which combines fish farming and other types of human activity (mainly agriculture activities) became important to ensure that waste products from one activity become an input into the fish farming activity and this leads to reduction of production cost (Nnaji *et al.*,2011).

Again, it is also needed to mention that, after rapid Green Revolution and food security during last three decades it was realized that we have completely ignored the soil health, sustainable food production and mining of the micronutrients, as a result the high productive areas are now encountering sustainability problems. There was stagnation in the crop productivity and in some areas crops started showing declining trends in yield. It was also again observed that crop production under intensive cultivation over the years had resulted in large scale removal of nutrients from the soil. It has been suggested that application of organic manure in agriculture not only regularly supply the macro, micro and secondary nutrients but also improves soil physical properties and soil biological health (Singh, 2001). Shalendra and Tewari (2003) also admitted to the fact that the Green Revolution in mid – sixties transformed the Indian agriculture dramatically resulting many-fold increase in production and productivity and making the country self-sufficient in food production, but this growth in food production showed reverse side too as environmental degradation and ecological imbalances occurred. They suggested that this threat had led to the need of promoting sustainable agriculture, which can be achieved by adopting a number of measures as water management, promoting organic farming and so on.

Saraswat *et al.*, (2010) revealed, that modern agricultural practices had been exhausting the nutrient supplying capacity of soil on one hand and the disposal of huge amounts of wastes due to modernization posing a major threat to environmental ecosystem on the other hand. To overcome this situation, disposal of wastes into soil and water through recycling is more fruitful rather than other option as they have high metabolic rate. Laban (1994) suggested, making natural resource management sustainable the constraints and potential at local level should be given high priority. Szoszkiewicz *et al.*, (2001) indicated the positive economic and environmental effects of IFS and implied that this kind of agriculture should be supported and extensively implemented. Fish, particularly small fish, are rich in micronutrients and vitamins, and thus human nutrition can be greatly improved through fish consumption (Larsen *et al.,* 2000; Roos *et al.,* 2003). Desai (2002) also suggested that IFS approach was required in agricultural development. Schematic diagram of the major interactions between the various sub-systems in a crop-livestock-fish integration farming system is explained in Fig-3 (Edwards 1993).

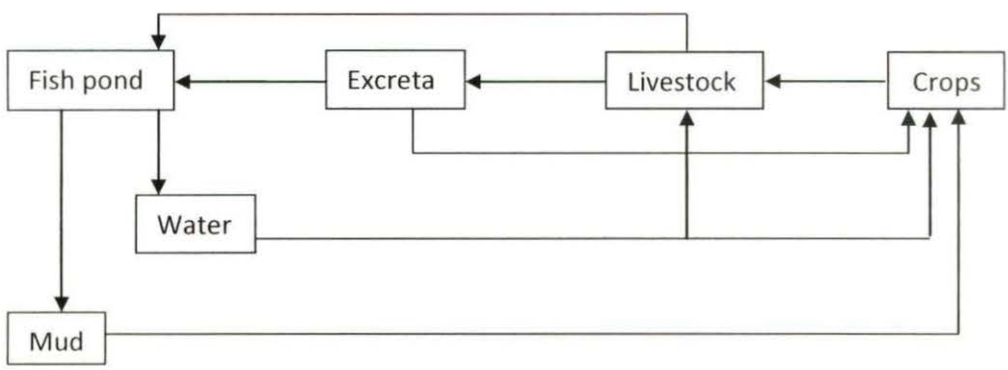


Fig-3: Schematic diagram of the major interactions between the various subsystems in a crop- livestock-fish integration farming system (Edwards, 1993).

During the first decade of the 21st century, two contrasting trends have been noticed—(i) India is being recognized as the global power in the key economic sectors with consistent high economic growth and (ii) its slow growth observed in the agriculture sector is causing concerns for the future food and nutritional security of the country. Indian agriculture contributes to 8% global agricultural gross domestic product to support 18% of world population on only 9% of world's arable land and 2.3% of geographical area. Nearly one-third of the country's population lives below poverty line, and about 80% of our land mass is highly vulnerable to drought, floods and cyclones. On the brighter side, India possesses substantial biodiversity — nearly 8 % of the world's documented animal and plant species are found in our country. Many of these are considered crucial for livelihood security of poor and vulnerable population. Therefore, conservation of natural resources, maintenance of biological wealth and acceleration of agricultural growth are considered of paramount importance in the present context as well as of the future (ICAR, 2011).

2.3 Integrated Farming System and its Sustainability

According to Gill (2009), with the dawn of the new millennium, Indian agriculture has manifested slow growth, causing a deep concern because the livelihood of more than 75% of country's population depends on the agriculture sector. This imbalance may create inequity in the country. Therefore, The National Commission on Farmers addressed the threat to livelihood security and had recommended IFS as one of the way to ensure profitability, balanced food, clean environment, employment, regular income generation throughout the year, high input-output ratio, sustainability and ultimately upliftment of the rural masses. The basic necessity of integrated farming is not only to make the farm an independent unit but also to fulfil the demands as input to other structural units (Sharma and Das, 1988; Rath, 1989a, 1989b). Sustainable agricultural integration is defined as producing more output from the same area of land while reducing the negative environmental impacts and at the same time increasing contributions to natural capital and the flow of environmental services (Pretty, 2008; Royal Society, 2009; Conway and Waage, 2010; Godfray *et al.*, 2010). It is now understood that agriculture can negatively affect the environment through overuse of natural resources as inputs and such effects are called negative externalities because they impose costs that are not reflected in market prices (Baumol and Oates, 1988; Dobbs and Pretty, 2004).Many countries documented that modern agricultural system has marked negative externalities with environmental and health problems (Pingali and Roger, 1995; Norse *et al.*, 2001; Tegtmeier and Duffy, 2004; Pretty *et al.*, 2005; Sherwood *et al.*, 2005)

Kumar *et al.,* (2011) observed seven farming system models with different combinations of crop, animal, fish and bird for sustainable productivity, profitability, employment generation and nutrient recycling for lowland situations and found that Crop+ fish + duck + goat emerged as the best Integrated Farming System (IFS) in terms of productivity, net returns (Rs159,485 yr^{-1}), employment generation (752 man- days yr^{-1}) and income sustainability index for net returns (80%). Ahmed and Garnett (2011) realised that rice and fish integration could be a viable option for diversification. Such farm diversification will enhance food security. Integrated rice-fish farming increases rice yields and makes the rice field ecosystem an efficient and environmentally sound production system for rice and fish. Rice monoculture cannot alone provide a sustainable food supply, while integrated rice fish farming is the best in terms of resource utilization, productivity and food supply. It is, therefore, suggested that integrated rice-fish farming is a sustainable alternative to rice monoculture.

The integration of aquaculture with livestock results in a more efficient use of resources than what is possible with aquaculture farming alone. Also the benefits of diversification include a reduction in the risk of total crop failure, additional sources of food and extra income for poor farmers (Gupta, 1987). Integrated fish farming can be used to bring marginal lands such as saline soils and wetlands into production where that would not be possible with agriculture or aquaculture alone (Mathias, 1994). Polyculture or mixed species culture takes the advantage of the diversity of feeding preference and is often important in allowing higher stocking densities for more yields. Mixed species culture may aid in the maintenance or improvement of water quality within the pond, allowing a higher stocking rate of fish. Chinese consider the grass carp to be a "living manuring machine" since its high fiber intake and poor digestibility result in large amounts of faecal waste being produced in the pond and further entering into the food web to feed other fishes (Little and Muir, 1987).

Thus, environmental pollution resulting from the accumulation of unutilized manures from agricultural production can largely be avoided by using them for aquaculture production (Edward, 1980; Wohlfarth and Hulata, 1987). It is also important that each integrated aquaculture and agriculture operations maximize the existing infrastructure, respect the natural environment and synergistically optimize the effort of management and labour resulting profits along with long-term viability (Springer, 1992).

2.4 Organic Manure in Integrated Fish Farming System

The use of different animal manures in fish farming as well as the methods used in a variety of integrated production systems have been reviewed by Edwards (1980) and Wohlfarth and Hulata (1987). Management parameters, culture techniques and fish yields attainable in manured ponds were known from the numerous experiments, but very little is known of the different processes by which the manure is converted into food for fish (Pekar and Olah, 1998). Direct consumption of manures, autotrophic production utilizing the mineral fraction of the manure, and heterotrophic production based on the organic matter content of the manure were defined as possible modes of conversion (Tang, 1970; Schroeder, 1978; Wohlfarth and Schroeder, 1979). Several studies have been conducted on the fish production efficiencies of different manures in various countries (Sinha and Sharma, 1961; Sharma and Olah, 1986; Little and Muir, 1987; Pekar and Olah, 1991; Vincke, 1991; Zoccarato *et al.*, 1995; Jha *et al.*, 2004; Francis *et al.*, 2004; ICAR, 2006; Kumar *et al.*, 2011, Banerjee and Barat, 2012).

IFS also called as Integrated Aqua- Agriculture (IAA) was based on fish culture in ponds and were closely integrated into the energy and nutrient pathways of conventional farming. The key to its importance lies in the fact that the ponds can accept many forms of agricultural waste, including livestock and human manures, and convert those manures into high grade fish protein. It was indicated that integrated fish farming pond provided a mechanism for protein recovery from manures, as well as other low-grade agricultural wastes (Mathias, 1994). The rate of conversion of manure-based protein into fish protein by the integrated fish pond can be as high as 29% (Hepher, 1988). It was observed that the production system of integrated fish pond derived energy from two sources, one from organic waste flowing through bacteria, the other from solar energy flowing through phytoplankton (Mathias, 1994). Thus, livestock manure is a very important source of nutrients for fish cultivated in ponds (Hopkins and Cruz, 1982). Integrated fish farming can be called as model of recycling wastes, comprehensive utilization of various farm products, saving energy, fully utilizes the natural resources and finally maintain the ecological balance (Rath, 1990). Fish farming using cow manure is one of the common practices and among all livestock excreta, cow excreta is the most abundant one in terms of availability. A healthy cow weighing about 400-450kg excretes over 4000-5000kg dung, 3,500-4,000 litre urine on an annual basis. Cow manure particles sink at 2-6 cm min^{-1} as against 4.3 cm min^{-1} of pig manure. This provides sufficient time for first to consume edible portion available in dung. Furthermore, biological oxygen demand of cow manure is lower than that of other livestock manures as it is already decomposed by micro-organism in ruminant. A unit of 5-6 cows can provide adequate manure for 1ha of pond. In addition to 9000 kg of milk, about 3000 to 4000 kg fish $ha^{-1}year^{-1}$, can also be harvested with such integration (ICAR, 2006). Nutritive values of different animal excreta are described in Table- 1.

Table-1: Nutritive value of different animal excreta.

Animal	Excreta	Moisture (%)	Organic matter (%)	Nitrogen (%)	Phosphorous (%)	Potash (%)
Cattle	Faeces	80 -85	14	0.3	0.2	0.1
	Urine	92-95	2.3	1.0	0.1	1.4
Pig	Faeces	85	15	0.6	0.5	0.4
	Urine	97	2.5	0.4	0.1	0.7
Chicken	Faeces	78	25.5	1.4	0.8	0.6
Duck	Faeces	81	26.2	0.9	0.4	0.6
Rabbit	Faeces	10	37	2.0	1.3	1.2
Goat	Faeces	10	-	2.7	1.7	2.9

Source: NACA Technical Manual 7 (1989). The figures are subject to variation depending on the management practices.

The dry matter content of duck manure produced by ducks raised in fish ponds was determined to be 43.4%, and this number has often been cited by Woynarovich (1976 and 1979). The dry matter content measured by Mukherjee *et al.*, (1991) was 16 and 49%, while daily manure production by the ducks were found to be15.5 g dry matter duck $^{-1}$. But, according to Barash *et al.,* (1982) the manure production levels at different ages lie between 68 and 74 g dry matter duck $^{-1}$ and 17 to 53% dry matter content for the manure. It was observed that 100 ducks ha $^{-1}$ of water body would be needed to excrete duck droppings (6,000 kg ha $^{-1}$ yr $^{-1}$) to meet the 'safe' level dose of the duck wastes for one year (Yadava and Bhatnagar, 1992; Yadava and Vaishali, 1993). Sasmal *et al.*, (2010) observed that the mean loading rate of duck manure in integrated pond was 6.2 kg ha $^{-1}$ d $^{-1}$ at a stocking density of 300 duck ha $^{-1}$.

Until recently, cow dung was the most commonly applied manure (Schroeder, 1977; Nayak and Mandal, 1990). In South Asia and Israel, cow dung is commonly used for pond fertilization. According to Pillay (1995) composition of cow dung usually ranges from 78 to 79 % water, 0.5 to 0.7 % N, 0.1 to 0.2 % P and 0.5 % K with an organic matter of 17 % and C:N:P ratio of 17:1:0.2.

Pond fertilization to increase fish yields has long been practiced throughout the world. The use of animal manures for fish culture is an extension of traditional land crop cultivation, which uses available on – farm resources within reach of many small scale farmers in Asia (Zhu *et al.*, 1990; Edwards, 1993). Pond fertilization practices using animal wastes are widely used to sustain pond productivity at low cost (Pekar and Olah, 1990) which is most elegantly demonstrated in China, where all farmers raise livestock to supply fertilizers for fish farming (FAO 1997). A wide variety of materials have been used as organic fertilizers (manures) in aquaculture; these include grass leaves, sewage waters, livestock manures, industrial wastes and night soils among others (Hickling, 1962). Although organic fertilizers can be utilized directly as food for invertebrate fish food organisms and fish, they are intended primarily to release inorganic nutrients for phytoplankton and zooplankton growth (McIntire and Bond, 1962; Hall *et al.*, 1970, Boyd, 1982). A school of scientists (Dutta and Goswami, 1988; Patro and Roy, 1988; Kestemont, 1995 and Zoccarato *et al.*, 1995) have recognized the efficiency of various organic manures in increasing productivity of fish ponds.

It is now well recognized that the pond fertilization with animal manures is an effective method for increasing practically all nutrients and stimulate the production of bacteria, phytoplankton, zooplankton and benthos. The use of organic manure in fish farming is based on the assumption that the manure acts on two path ways: the readily decomposable organic matters of the manure provides dissolved and particulate substrates for bacteria and the bacterially laden particles supply foods to the filter feeding and detritus- consuming animals, while the mineralized fraction of the manure stimulates phytoplankton productivity similar to the action of inorganic fertilers (Hepher and Pruginin, 1981; Olah, 1986).

To maximize the fish production with available food organisms in ponds, polyculture with a verity of fish of different feeding niches has been most commonly practised (Ling, 1967; Prose, 1967; Olah, 1986; Wohlfarth and Hulata, 1987). The obvious advantages of using animal manures as a nutrients source for fish culture are that they are (1) Relatively inexpensive, (2) Readily available on farm and (3) Suitable for a variety of fish in polyculture. This procedure also mitigates the problem of solid waste disposal (Lin *et al.*, 1997). The importance of using animal manures in ponds lies in the fact that ponds can accept many forms of agricultural wastes, including live stock and human manures, and convert those manures into high grade fish protein. The protein contents of animal manures are as low as 10 to 20% (Fang *et al.*, 1986), which makes the recovery difficult. Only when the protein contents of manure reaches 20%, as it is often the case with the chicken manures, can be directly incorporated into feeds for other animals. However, the IFS pond provides a mechanism for protein recovery from manures, as well as other low grade agricultural wastes (Matthias, 1994). The rate of conversion of manure based protein into fish protein by the integrated fish pond can be as high as 29% (Hepher, 1988).

The amount of production in ponds depends heavily upon the quality of food available to the fishes. In the systems without supplemental feeding primary productivity forms the base of the food web that culminates in fish and crustacean bio mass. Natural level of primary productivity is seldom high enough to provide sufficient natural food for high rates of aqua cultural production. A large number of nutrients are required to stimulate phytoplankton growth. These nutrients include major elements (C, N, K, Si, Ca, P, Mg, S and Cl) and trace elements (Fe, Mn, Zn, B, Cu, Mo and Co). Some ponds have more nutrients in their bottom soils and waters than other ponds, and there is a large range in the natural productivity of ponds (Boyd, 1990). Background concentration of these nutrients in pond water are mostly derived from air, soil, source water and rains, and these elements are normally present in limited amounts, especially the major nutrients. To maintain adequate plankton production as natural food or support desirable fish yield requires fertilization by adding nutrients in either organic or inorganic form (Lin *et al.*, 1997).

According to Adewumi (2011) livestock wastes including animal manure and poultry by-products, which are a menace to the environment, are sources of wealth creation in fish farming. In Nigeria, about 932.5 metric tons of manure is produced annually from the well established livestock industries which keep expanding at the rate of 8% per year. Nigeria is the largest importer of frozen fish in the world with a fish demand of between 106,200 - 128,052 metric tons yr^{-1}. This situation calls for increased fish production which can be achieved through the effective utilization of livestock wastes. Properly treated animal manure can serve as organic fertilizer or feed component. Consequently, there is enhanced fish farming profitability, efficient resources utilization and conservation of environment due to waste management. Fig-4 describes the recycling of material in a well managed integrated fish farm (NACA, 1989).

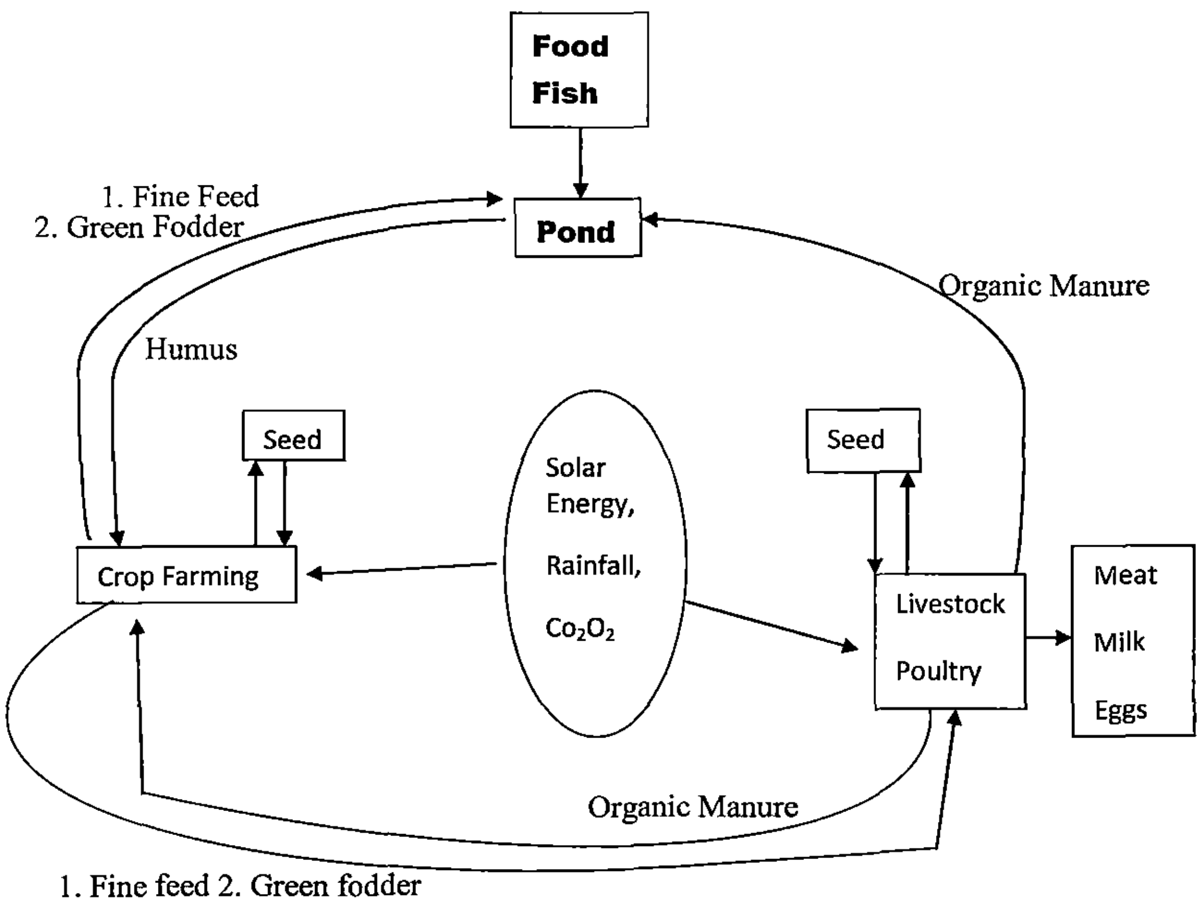


Fig- 4: Recycling of material in a well managed integrated fish farm.

Source: NACA Technical Manual 7 (1989).

2.5 Organic manure and pond water quality management

The various chemicals dissolved in the water, as well as the temperature and other physical attributes of water, all combine to form what is called water quality. Water quality in fish ponds is a major factor determining the production of fish (Diana *et al.*, 1997). Management of water quality in ponds help in enhancing the fish production though aquaculture therefore, by applying the simple water quality management practices in terms of ammonia and BOD by managing the input of waste in water the production can be enhanced (Chaudhary, 2012). Goal of water quality management is to regulate environmental conditions so that they are within desirable range for survival and growth of fish (Boyd, 1982).The stimulation of natural food production in the pond and its maximum utilization by the fish must be the primary consideration but this must be balanced by the maintenance of adequate water quality. The waste-fed eutrophic pond was found to be more productive than a natural pond, but was also less stable. Variation in water quality, especially dissolved oxygen levels may be harmful to fish growth, or even cause acute mortalities. This instability can be reduced by judicious management. It was evident that a balanced variety of fish species reduced the volatile and undesirable changes in water utilizing the different pond food organisms which typically triggered large changes in water quality (Little and Muir, 1987) .

Wide variety of organic manures such as grass, leaves, sewage water, livestock manure, industrial wastes, night soil and dried blood meal have been used (Hickling, 1962; Steinberg *et al.*, 2006) to improve fish production. Although organic fertilizer can be utilized as food for fish prey organisms and fish (Taiganides, 1978; Oribhabor and Ansa, 2006), they are intended primarily to release inorganic nutrients for phytoplankton and zooplankton growth. Phytoplankton and zooplankton often contain 40 to 60% protein on a dry matter basis and can support excellent fish growth (Edwards, 1980; Pillay, 1995; De Silva and Anderson, 1995; Wang, 2000). Studies on growth performance of cultured fish in relation to feeding provide information for successful application of organic manure, the management and exploitation of the resources (Chakrabarty *et al.*, 2008).

Sheri *et al.*, (1987), in his studies reported the best growth of major carps at water temperature range of 26 to 29 ^{0}C. Chandra *et al.*, (2005) observed in their studies, that variations in fish growth depended on electrical conductivity, pH, and total alkalinity and phosphorus contents of rearing water. Kang'ombe *et al.*, (2006) further observed, that poultry manure mainly donates nitrogen and phosphates to pond water which boosts pond productivity (natural food of fish) which in turn enhances the weight increment in fish.

Small scale fish farmers face the problem of poor growth and survival of fish along with the expensive formulated feeds. This problem occurred when some water quality parameters like, temperature, pH, alkalinity, concentration of phosphorus, calcium and ammonia were altered. Using organic manure in fish ponds altered the water quality, therefore lack of knowledge on effectiveness of the cheap method of manure application can solve this problem because fish production does not rely on availability of feeds in the ponds but also on water quality (Ludoviko and Kang'ombe, 2012). Several studies of small-holder aquaculture in Bangladesh, India, Thailand and Vietnam indicate that livestock wastes are the most commonly used inputs as organic fertilizers or supplemental feeding inputs (Edwards,2008a,b, 2009a,b,c,d, 2010a,b,c,d) Many water quality problems occasionally occur in intensive fish culture, but excessive production of plankton, low dissolved oxygen, and toxic metabolites are usually the most important problem (Boyd, 1982). The relationship between carbondioxide, alkalinity and pH is well known in limnology and in aquaculture (Wetzel, 1983; Boyd, 1990). Most of the alkalinity of freshwater is composed of carbon ions (CO_3^{-2} and HCO_3^{-}), which are interrelated; their proportion depends on pH (Diana *et al.*, 1997). One major characteristic of water quality that is important to the growth and survival of fish is dissolved oxygen (DO). Dissolved oxygen concentrations in ponds are affected mostly by phytoplankton biomass, with greater oxygen production and consumption occurring at higher phytoplankton biomass (Boyd, 1990).Use of organic fertilizer increases the biological oxygen demand (BOD) in ponds and can result in periods of low DO (Boyd, 1990).

It was observed that alkalinity potentially limited primary production and fish yield, since inorganic carbon was necessary for photosynthesis (Diana *et al.*, 1997). Boyd (1990) showed that alkalinity below 30mgl^{-1} as $CaCO_3$ limited primary production in well-fertilized ponds, while in unfertilized ponds alkalinities below 120mgl^{-1} could reduce primary production. It was indicated that organic inputs in pond might keep alkalinity at higher levels and even result in increases in alkalinity in comparison to use of inorganic inputs (Knud Hansen *et al.*, 1991; Teichert-Coddington *et al.*, 1992; Diana *et al.*, 1994). Use of organic inputs probably reverses the trend of carbon extraction during photosynthesis because of added CO_2 inputs and decomposition of manure in pond soils (Diana *et al.*, 1997).

Nitrogen is apparently limiting in some tropical freshwater systems (Zaret *et al.*, 1981; Setaro and Melack, 1984), including aquaculture ponds (Diana *et al.*, 1991; Khud-Hansen *et al.*, 1991; Teichert-coddington *et al.*, 1992). Forms of nitrogen in ponds include nitrogen gas, nitrate, nitrite, ammonium, ammonia and various forms of organic nitrogen (Boyd, 1990). Animal manures are generally low in N: P ratio (<3) and such low N: P ratio is not optimal for phytoplankton growth, which on average requires a N: P ratio of greater than seven (Redfield *et al.*, 1963; Wetzel, 1983). Ammonia reaches water through fertilizers, in fish from microbial decay of nitrogenous compounds (Boyd, 1982). Un-ionised ammonia is highly toxic to fish, but the ammonium ion is relatively non toxic (Boyd, 1990). Poor growth of fish in culture tanks has been attributed to the accumulation of ammonia (Andrew *et al.*, 1971; Smith and Piper, 1975). Ammonia is more toxic when dissolved oxygen concentration is low (Merkens and Downing, 1967). Lloyd and Herbert (1960) showed that the toxicity of ammonia decreased with increasing carbon-dioxide concentration. Relatively high concentrations (1 to 2mgl^{-1}) of ammonia are often observed in ponds where fish culture is profitable (Boyd, 1982). Hollerman and Boyd (1980) suggested, that nitrite originated from the reduction of nitrate by bacteria in anaerobic mud or water. .Regardless of the source, ponds occasionally contain nitrite concentrations of 0.5 to 5.0mgl^{-1} of NO_2^--N (Boyd, 1982). Concentrations of NO_2^- as low as 0.5mgl^{-1} were toxic to certain cold water fish (Crawford and Allen, 1977). It was observed that, addition of calcium (Wedeneyer and Yasutake, 1978) and chloride (Perrone and Meade, 1977; Tomasso *et al.*, 1979) reduced the toxicity of nitrite to fish.

Phosphorus is most commonly considered the major limiting nutrient in freshwater, and additions of phosphorus often result in increased primary production, whether in natural (Vallentyne, 1974) or in aquaculture systems (Boyd, 1990; Diana *et al.*, 1991). Phosphorus is mainly available to plants as orthophosphate (Diana *et al.*, 1997) and its concentration increases almost immediately after ponds are fertilized (Boyd,1982).The orthophosphate present in water immediately after fertilization may be absorbed by bacteria, phytoplankton and macrophytes (Rigler,1956 ; Hayes and Phillips,1958; Rigler,1964). However, phosphorus that is not absorbed by plants is rapidly absorbed by mud (Hepher, 1958). Combined inputs of both nitrogen and phosphorus are probably necessary to drive high levels of primary production (Diana *et al.*, 1997).

According to Boyd (1982) potassium is not important in pond fertilization, and nitrogen is not as important as phosphorus. Potassium concentrations in natural waters usually range between 0.5 and 10mgl^{-1} (Moyle, 1946; Arce and Boyd, 1980). Jha *et al.*, (2004) found that application of both cow dung and poultry manure at the rate of 0.26kg m$^{2-1}$ every 10 days is most suitable for better growth of Koi Carp in tanks through maintenance of better water quality and greater abundance of plankton in the system. Njoku (1997) observed, that poultry droppings applied at the rate of 5000 kg ha $^{-1}$ annually gave best yield, higher fish recovery and optimum tolerance level of the physico-chemical parameters of water for fish growth. Ali *et al.*, (1997) assessed the impact of duck excreta nutrient content on fish production in an integrated duck-fish-farming system and found that the maximum contribution to fish production came from excreted organic carbon followed by phosphorus, nitrogen, dry matter, potassium and calcium.

2.6 Organic manure and pond soil quality management

Ponds where aquaculture species depend on natural food organism for their nutrition, the fertility of the pond soil is a key factor regulating the production the production of fish and shrimp because it governs the fertility of the water (Boyd, 1995). Pond soil plays various roles in production of plankton, the most important one being their ability to store the nutrients and release them into water under different mechanisms (Mahajan and Mandloi, 1998). There are two most common problems causing low fish production in fertilized ponds were acidic soils and high concentrations of soil organic matter. Mortimer (1954) reviewed literature on pond fertilization and concluded that reactions between soil and water influenced the response of ponds to fertilizers. A classification of soil organic carbon concentrations for pond aquaculture (Boyd *et al.*, 2002) follows:

Organic Carbon(%)		Comment
> 15	-	Organic soil
3.1 to 15	-	Mineral soil, high organic matter content
1.0 to 3.0	-	Mineral soil, moderate organic matter content, best range for aquaculture
< 1	-	Mineral soil, low organic matter content

Soil organic matter is about 45 to 50% carbon, so a rough approximation of organic matter may be obtained by multiplying soil organic carbon by two.

Ponds that receive high inputs of manure will tend to have higher concentrations of soil organic matter than ponds that receive inorganic fertilizers or feeds (Boyd, 1995). A small amount of organic matter in pond soils is beneficial. However, too much organic matter in pond soils can be detrimental because microbial decomposition can lead to the development of anaerobic conditions at the soil-water interface (Boyd and Bowman, 1997). Banerjea (1967) evaluated the potential of a large number of ponds in India for fish production and found that organic carbon concentrations in soils of less than 0.5 % and greater than 2.5 % resulted in low fish production. Low organic carbon was associated with low productivity of phytoplankton and bottom organisms, whereas high organic carbon caused anaerobic conditions in the pond bottom soils. Average fish production was achieved in ponds with 0.5 % to 1.5 % organic carbon, and 1.5 % to 2.5 % organic carbon was associated with high fish production.

Total alkalinity is an important variable regulating fish production and ponds with acidic bottom soils typically exhibits low total alkalinity levels. Boyd (1974) and Murad and Boyd (1991) stated that ponds should have at least 20mgl^{-1} total alkalinity for good fish production. Banerjea (1967) found that the ponds with soil pH less than 5.5 or above 8.5 had low production. The optimum soil pH for high production was 6.5 to 7.5. Average production was achieved in ponds with soil pH in the ranges 5.5 to 6.5 and 7.5 to 8.5.

Studies on phosphorus adsorption and release by soil revealed that pond soils are not a major source of phosphorus to water because soil-adsorbed phosphorus which is highly insoluble (Boyd and Munsiri, 1996; Boyd *et al.*, 1998, 1999). Phosphorus released by decomposition of organic matter in pond bottoms rapidly adsorbed by soil and little of it enters the water. Soils that are near neutral in pH have less capacity to adsorb phosphorus and a greater tendency to release phosphorus than do acidic or alkaline soils (Boyd, 1995). Most pond waters, regardless of pH and alkalinity, does not contain enough dissolved inorganic nitrogen (nitrate and total ammonia nitrogen) or phosphorus to support adequate primary productivity for high levels of fish production (Boyd and Bowman,1997). Boyd *el al.*, (1994) found about two-thirds of phosphorus applied to ponds in feed accumulates in bottom soils and also showed that most of soil phosphorus was tightly bound, and only a small amount was water soluble Chemical fertilizers or manures can be applied to ponds to enhance the availability of nitrogen concentrations and should exceed 250 ppm. Available phosphorus concentrations should be above 60ppm to support good fish production. According to Boyd (1990) nitrogen plus phosphorus fertilization will provide greater fish production than phosphorus fertilization alone.

Pond bottom soil pH can range from less than 4 to more than 9, but the best pH for pond soils is considered to be about neutral (Boyd, 1995). Maximum availability of soil phosphorus usually occurs at about pH 7. Most soil microorganisms, and especially soil bacteria, function best at pH 7 to 8. Waters in ponds with acidic soils typically have low concentrations of bicarbonate, carbonate, calcium, and magnesium.

Waters with low concentrations of bicarbonate and carbonate will have low total alkalinity, and those with low concentrations of calcium and magnesium have low concentrations of total hardness. Usually, water with low alkalinity also is low in hardness. Such waters are not well buffered against pH change, and they do not have large reserves of inorganic carbon to support phytoplankton photosynthesis. Application of agricultural limestone to acidic ponds can increase soil pH, increase concentrations of total alkalinity and total hardness in water, increase the availability of inorganic carbon for photosynthesis, and buffer waters against wide diurnal changes in pH. Thus, aquaculture ponds with acidic bottom soils and low alkalinity water should be treated with agricultural limestone (Boyd *et al.*, 2002).

2.7 Organic manure and plankton production

Manuring of ponds is one of the well known practices in efficient farm management to boost up its fish food (plankton) production (Govind *et al.*, 1978). Under decomposition, organic manure release inorganic nutrients that stimulate plankton growth at the base of the trophic level of aquatic production cycle. For nursery ponds, raw cow dung is generally considered to be the best organic manure (Alikunhi, 1957). But, a combination of cow dung and poultry droppings has been found to be better than cow dung alone (Banerjee *et al.*, 1969). It was also documented, that the application of organic manure should be restricted since they encourage the growth of filamentous algae (Pearsall, 1923).

Okonji and Obi (1999) evaluated zooplankton productivity resulting from three fertilizer treatments namely, organic, inorganic and combination of organic and inorganic and found that, organic fertilizer produced more of the smaller-size zooplanktons (Rotefers and Cladocerans) while inorganic fertilizer favoured the production of larger-sized zooplanktons (Copepods). Dhawan and Toor (1989) observed, high total phytoplankton in ponds treated with poultry droppings alone and in combination with cow dung, mainly due to the content of phosphates and nitrates. Jhingran (1991) and also Buck and Baur (1980) reported that manuring results in higher zooplankton densities. The total zooplanktons were significantly higher with poultry droppings alone and in combination with cow dung than in ponds with cow dung, supplementary diet and control treatments (Dhawan and Toor, 1989). Rappaport *et al.*, (1977) reported, a general increase in the contribution of Rotifers to zooplankton in ponds manured with chicken droppings and cereals manure but the dominance of Copepods were observed in controls and the ponds receiving liquid cowdung. According to Hickling (1962), organic fertilizers are especially efficient in enhancing production of zooplankton and benthic organisms. However, Rappaport *et al.*, (1977) observed higher content of phytoplankton and Chironomid larvae in organically manured ponds. In a study, Nayak and Mandal (1990) indicated that organic fertilizers might serve as direct sources of food for fish food organisms, or they might get decomposed to release inorganic nutrients that stimulated plankton growth.

According to Boyd (1982), increase in primary productivity following fertilization usually result in greater zooplankton abundance. Wiebe (1929) reported more than a doubling in density of Crustacea and Rotifers in ponds fertilized with phosphorus compared to unfertilized ponds. Motokubo *et al.*, (1988) reported that an increase in zooplankton density in the ponds treated with chicken manure, with a concomitant increase in fish production. Frequent application of low doses of manure resulted in significantly higher number and biomass of *Daphnia* (Jana and Chakraborti, 1997). Manjunatha (1979) carried out an experiment to evaluate the effect of different combinations of organic manures namely poultry manure plus cattle dung, poultry manure plus sewage sludge cake and cattle dung plus sludge cake when used as fertilizers for fish culture. Plankton production (both phytoplankton and zooplankton) was found to be highest in poultry manure and lowest in sludge cake treatment. Garg and Bhatnagar (2000) studied the effects of five (5000, 10000,15000,20000,24000 kg ha $^{-1}$ yr $^{-1}$) different doses of organic fertilizer (cow dung) on pond productivity in terms of plankton production and found that higher doses declined the plankton production. Furthermore, with a decrease in the water temperature from 24^{0}C a decline in plankton population was observed. The nutritional value of natural food organisms in a pond is sufficient to support excellent fish growth (De Silva and Anderson, 1995).

Phytoplankton and zooplankton (rich source of protein), often contain 40 per cent to 60 per cent protein on dry matter basis (Pillay, 1995). The high protein content of natural food organisms is efficiently utilized in the early growth stages of semi-intensively cultured fish. It was reported that common carp utilized about 80 percent to 90 per cent of crude protein content of its important food organisms (Song, 1994).

Zooplankton is very important in the food web of open water ecosystem (Ekelemu, 2010). Hossain *et al.*, (2006) concluded that the treatment with poultry manure was better than cow manure alone and with or without the treatment of mineral fertiliser in combination. Hence, rural people may be encouraged to use poultry manure. Ekelemu and Nwabueze (2011) revealed that poultry droppings, compared to cow dung and pig dung, produced more zooplankton. He also observed that cow dung produced more rotifers, poultry droppings more Cladocera and pig dung more Copepods. Cow dung as well as cattle urine seems to be good for plankton production (Sabir *et al.*, 2007). Sasmal *et al.*, (2008) suggested that duck excreta were good source of nutrient, which were easily soluble in water and available for plankton production. Damle and Chari (2011) observed that lack of zooplankton caused poor survival of spawn in nursery ponds. Poultry manures were found to release soluble salts continuously, resulting in high production of zooplankton (Gaur and Chari, 2007). Yeamin *et al.*, (2006) observed that poultry manure significantly increased the mean abundance of zooplanktons which showed that despite iso-phosphorus content, the nutrient status of poultry manure was found to be significantly superior to cow manure or inorganic fertilisers when these were used alone. Wurts (2004) reported that better abundance of planktons supported large population of fish species.

2.8 Organic manure and Fish production

In an experiment conducted by Singh and Sharma (1999) to determine the efficiency of three organic manures namely, cow dung, pig dung and poultry excreta resulted in ponds treated with poultry excreta having higher fish production (2664 kg ha^{-1} yr^{-1}) as compared to ponds treated with pig dung (2219 kg ha^{-1} yr^{-1}) and cow dung (789 kg ha^{-1} yr^{-1}). Zoccarato *et al.*, (1995) also obtained high fish production (3369 kg ha^{-1} 4 mth^{-1}) when feed supplementation along with fertilization with pig dung were done. Banerjee *et al.*, (1979) conducted an experiment on the manurial potentiality of poultry droppings which revealed a net production of fish of 10.711 kg 0.02 ha^{-1} 90 d^{-1} that is, 535 kg ha^{-1} 90 d^{-1} from the pond manured with cow dung and a net production of 13.40 kg 0.02 ha 90d $^{-1}$ that is, 670 kg ha $^{-1}$ 90 d $^{-1}$ manured with poultry droppings. Rahman *et al.,* (2008) observed that common carp growth, in polyculture with rohu (*Labeo rohita*) was higher in the presence of artificial feed and negatively correlated with natural food availability. Banerjee *et al.,* (2013) concluded that application of organic manure increases the live weight of the Indian Major Carps while, pig dung showed positive influence on *Catla calta* and *Labeo rohita.*

High fish yield were also obtained in Israel, that is 30 kg ha $^{-1}$ d $^{-1}$ with cattle manure (Schroeder, 1975), 40 kg ha $^{-1}$ d $^{-1}$ with duck manure and waste feed (Wohlfarth, 1978) and 20 kg ha $^{-1}$ d $^{-1}$ with chicken manure (Milstein *et al.*, 1995). Hickling (1962) reported that the application of 15,000 kg ha $^{-1}$ of cow manure resulted in an average fish yield of 300 kg ha^{-1} while the control ponds averaged 97 kg ha $^{-1}$ of fish. Collis and Smitherman (1973) obtained an average Tilapia yield of 1,646 kg ha $^{-1}$ in ponds treated with cattle manure twice daily. In another experiment (Dutta and Goswami ,1988) resulted in an average net gain of fish of 781.4 kg ha $^{-1}$ in control, 3013.8 kg ha $^{-1}$ in cow manured and 3030.8 kg ha $^{-1}$ in pig manured ponds. In a study, Patra and Ray (1988) revealed that use of organic manures namely, pigeon droppings, goat droppings and raw cow dung was recommended for increased production of fish in ponds of West Bengal.

Ponds treated with liquid manure give high fish yield (Jhingran, 1991). Fish yield in properly designed and managed manure loaded ponds can reach 5 to 10 tons ha $^{-1}$ yr $^{-1}$ without any supplemental feeding (Schroeder, 1978). In India, the integration of poultry birds with fish culture resulted in fish production of 4,500 to 5000 kg ha $^{-1}$, as reported by various workers.

Manuring is widely practiced in fishponds for natural fish production as it is important for sustainable aquaculture and to minimize expenditure on artificial feeds which form more than 55 percent of the total input cost, (Oribhabor and Ansa, 2006). Moreover, some carps even feed upon the undigested fraction of these manures directly, which may be low in nutrient value but the microorganisms adhering to them are of high protein value (Ansa and Jiya, 2002). Sutar *et al.,* (2012) observed that vermin-compost also can form an abundant alternative natural resource for less expensive manure and fish feed for higher fish yield.

2.9 Economics of Different Integrated Fish Farming Systems

Integrated farming systems involving aquaculture have usually been classified according to the combination of farm enterprises being practiced, namely, rice-cum-fish, pig-cum-fish, poultry-cum-fish and multicomponent systems with three or more enterprises, usually crop-livestock-fish farming system (Pullin and Shehadeh, 1980; Little and Muir, 1987; Mukherjee *et al.*, 1992).The integration of duck and chicken with fish polyculture systems is amongst the most popular in Asian countries (Sin, 1980; Wetcharagrun,1980; Cruz and Shehadeh, 1980) followed by pig-fish and ruminants (cattles)-fish production systems (Chan and Li,1980 ; Cruz and Shehadeh, 1980). The best way to reduce the cost of fish production is to minimize the use of supplemental food; this can be best achieved by exploiting the synergetic interaction between natural food and supplemental feed (Priyadarshini *et al.*, 2011). According to Moav *et al.*, (1977), judicious organic manuring of fish ponds can eliminate the need for supplementary feeding.

Crop-livestock-fish Integrated Farming System (IFS) is an integration of viable technologies within the enterprises. Integration of one or more enterprises with prevailing farming system at a farm, satisfy the necessities of a household as well as for livelihood security of a family. Utilization of resources through IFS increases productivity per unit area, efficient recycling of farm wastes, generates more employment, reduce the risk and ensure environmental safety and sustainability (Sing and Gill, 2010).

Ramrao *et al.*, (2006) indicated an IFS model having 2 bullocks-1cow-1 buffalo-10 goats -10 poultry - 10 ducks along with crop cultivation as best package on the land holding of 1.5 acre in tribal region of Durg District. Ramrao *et al.*, (2005) also recommended integrated farming of 2 bullocks-1cow-1 buffaloes-15 goats - 20poultry - 20ducks along with crop cultivation for optimum production in 3.5 acres of landholding in tribal region of Durg District. In Tamil Nadu rice cropping integrated fish-poultry-rabbit rearing resulted in higher productivity than cropping alone (Murugan and Kathiresan, 2005). Singh (2005) studied different IFS models among which rice-fish-vegetables and berseem (*Trifolium alexandrinum*) on bunds gave significantly higher yield than rice farming alone.

Kannan *et al.*, (2006) studied on the effect of various integrated farming systems on the growth performance of the pigs and found no significant differences suggesting, that varying the farming systems do not have impact on the pig's growth parameters if the kind of feeding management given to each IFS was not varied. Kang'ombe *et al.*, (2006) studied that the use of chicken manure produced higher numbers of zooplankton than cattle and pig manure treatments on unfertilized ponds. Rahman *et al.*, (2006) indicated that common carp naturally ingested mainly zooplankton and benthic macro invertebrate and small quantities of phytoplankton but when offered formulated feed, the latter became the preferred food item; hence feed administration enhanced growth of the common carp.

Pig-cum-fish farming, in general, performed better than duck-cum-fish farming for most of the fishes cultured except silver carp which may be correlated with the literacy level of fish farmers (Singh *et al.*, 2006). They also observed that water and soil quality in different ponds, manured by pig excreta and duck droppings, remained within the favorable range required for carp. Relatively higher value of organic carbon concentration in pig-cum-fish farming indicated its superiority over duck-cum-fish farming. Njoku and Ejiogu (1999) indicated that ponds integrated at 1000 chicken per ha provided the optimum water quality for fish survival and growth. Devasenapathy *et al.*, (1995) indicated that adoption of an IFS combining groundnut-black gram-maize, or groundnut-sesame-ragi with livestock enterprises (poultry, fish, dairy or rabbit production) resulted in higher net returns than the conventional groundnut-cotton or sorgum-cotton cropping system and provides additional employment opportunities.

Sharma *et al.*, (2004) studied the duck-cum –fish farming and observed that the mutual beneficial effect of combined fish culture and duck raising was difficult to assess with accuracy due to complex interaction in the pond ecosystem but experiences showed that this combination increased the production of both animals and decreased the input cost on fish culture considerably. The swimming ducks in the pond in search of food release nutrients from the soil which enhance pond productivity and increase the fish production. Sharma *et al.*, (2005) realized that duck-cum-fish as IFS had become encouraging and economically viable under Indian condition and reduced the chances of environmental pollution. The Droppings of ducks act as a substitute to fish feed and pond fertilizer up to 60% of total feed cost. They also observed that introduction of ducks increased pond soil PH from 6.79 to 7.32, pond soil organic carbon from 0.46% to 0.83%. The value of nitrogen and phosphorus also increased from 1.75 to 3.47mg per 100 gram of soil. The concentration of potash increased from 24.04 to 35.43 mg per 100 gram of soil. The value of pond water pH increased from 6.5 to 7.5 whereas the value of dissolved oxygen ranged from 8.2 to 9.2 ppm. The free carbon dioxide concentration ranged between 7.0 to 8.2 ppm. The plankton concentration showed gradual increase from 0.2 to 1ml per 50 liter water.

Sivasankaran *et al.*, (1995) studied the economics of the IFS in a 1.0 hector of dryland with sorgum-cowpaes- 5female goat-1male goat (stall fed) realized net income significantly greater than the conventional cropping system of sorgum-cowpeas. Panda (2002) indicated that the approach of integration of duck farming was practical, profitable and acceptable to the farmers in the developing world for maximum utilization of land and water resources. A series of experimental trials were made under the Operational Research Project in India, integrating fish culture and livestock farming practices. This farming system, which has also been tested under field conditions, can be modified for adoption in appropriate areas (Dehadrai, 1988; Sharma, 1990; Jhingran, 1991; Singh, 1996).

Experiments and field trials in which pig, duck and poultry farming were integrated had given very encouraging results. It was observed, that the excreta of 35 to 45 pigs, 200 to 300 ducks and 250 to 300 layer poultry birds or 150 to 200 broiler birds produced 6 to 7 tons, 3 to 4 tons and 4 tons of fish yr $^{-1}$ respectively when recycled in one ha of water area under the polyculture of Indian and Exotic fish (Sharma, 1974; Jhingran and Sharma, 1980; Sharma and Olah, 1986; Sharma and Das, 1988). The integration of fish culture and duck farming has proven to be a profitable for small scale rural farmers as well as for commercial entrepreneurs and raising ducks over fish ponds has proven viable also (Woynarovich, 1980; Naidu, 1985; Jhingran, 1986; Ganesan *et al.*, 1991; Zheng *et al.*, 1997). Three types of farming practices exist in case of fish-cum-duck farming – 1) raising large groups of ducks of open water, 2) raising ducks on pond shore and 3) raising ducks on surfaces of fish pond (Hu and Yang, 1984). Fish-cum-duck culture ponds have very effective nutrient processing and retaining capacity, functioning as natural filters and depositing significant amounts of nitrogen in their bottom sediments (Olah *et al.*, 1992; Pekar *et al.*, 1993).

Rice-fish-duck culture system in China resulted in increased rice yield by over 10% and 238.9 – 489.3 kg / ha of adult duck meat by using this co-growth ecosystem. The Nitrogen, Phosphorus, Potassium and organic matter content of paddy soil were increased by 27.9, 44.3, 6.5 and 28.8 % respectively, with remarkably decrease in insect pest in rice fields (Zheng *et al.*, 1997).

According to Francis *et al.*, (2004) integrated chicken-fish farming leads to better utilisation of land and water resources, effective recycling of waste and improved agricultural waste resource utilisation efficiency and reduction in operation expenses usually incurred through the use of feeds and fertilisers in fish ponds. This results into more income for small farmers, which translates into higher living standards for them.

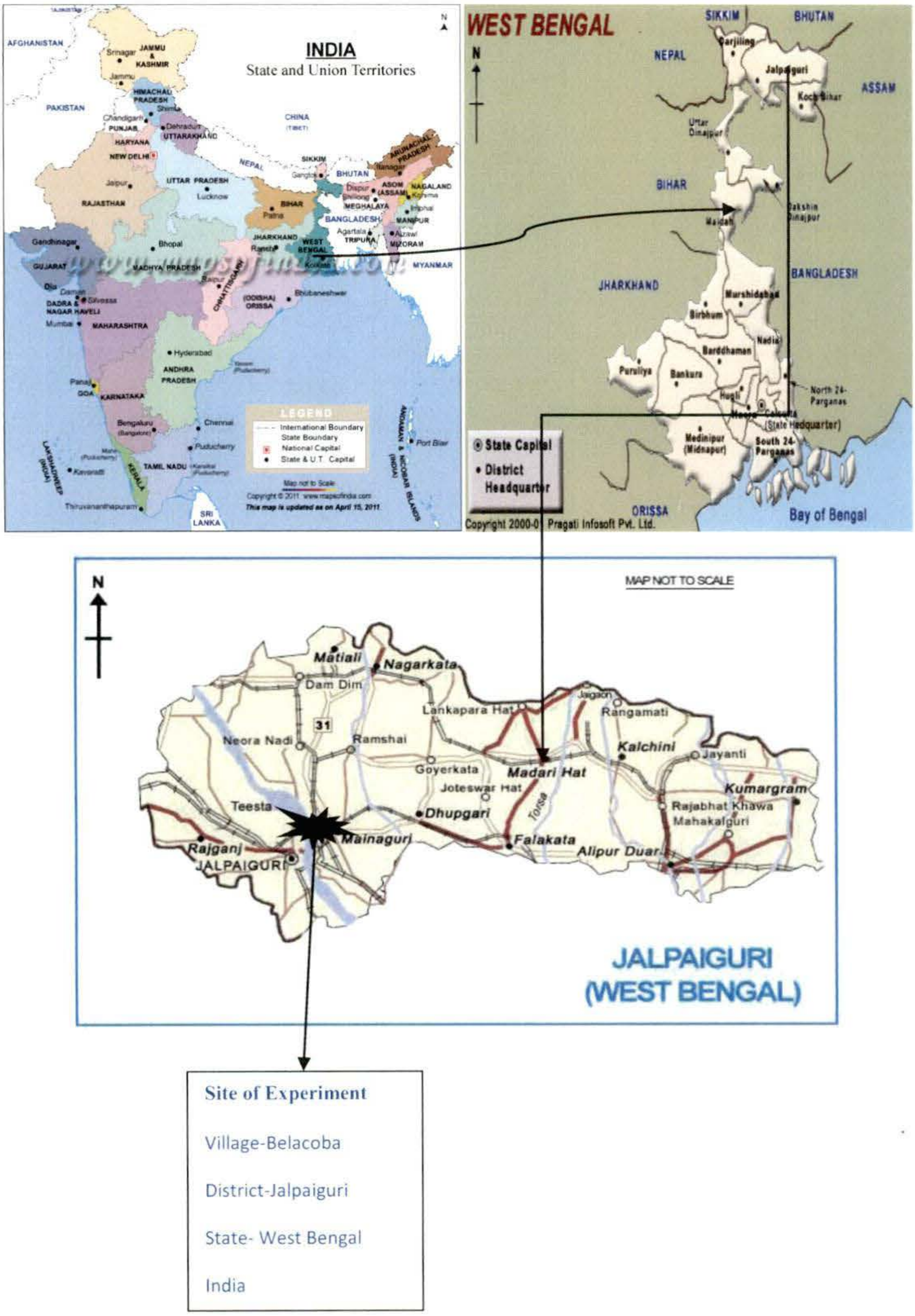
Materials and Methods

3.1 Study Site and Duration of Study

To investigate the potentialities of Crop-Livestock-Fish Integrated Farming, experiments were conducted randomly at selected sites of village Belacoba , Jalpaiguri district (latitude 26°58′N and longitude 88°58′E) within the Terai region of West Bengal (Pic-1). The area is a sub-tropical humid climate and situated 43 m above mean sea level (msl) having sandy-loam soil. The average annual rainfall of the area remained within 2200-2700 mm and average minimum and maximum temperature ranged from 18.5°-20.8°C and 28.5°- 31.5°C, respectively.

Three experiments were conducted from the month of April to September of four consecutive years, 2008 to 2011, as the ponds in this area were mostly seasonal and shrinking in nature. The water in the pond generally stayed from April to September or October depending on two sources of water namely, rainfall and water from the Teesta Barrage. The observations of the said experiment regarding pond soil and water quality, fish growth rate, zooplankton production and total fish production were studied for the period April to September for each of the four consecutive years from 2008 to 2011. The experimental analyses were carried out at Aquaculture and Limnology Research Unit, Department of Zoology, University of North Bengal, Darjeeling District, West Bengal.

Other productions, like production from animal components, was studied round the year from 2008 to 2011 whereas, the productions from turmeric cultivation along the surrounding area of ponds were studied during the period from April to November of the four consecutive years, 2008 to 2011.



Picture – 1: Map showing the Site of Experiment.

3.2 Experimental Design

For determining the potentiality of different Integrated Farming System (IFS) over Non-Integrated Farming System (NIFS) and also developing the location specific IFS packages involving different components, that are locally available from farm resources of marginal farmer, the present investigation was conducted in farmer's field condition considering three different experimental designs. Nine ponds were selected in triplicate for each experiment of same area 0.01 hectare (ha) to carry out the three experiments. Three field experiments, namely Non-Integrated Farming System (NIFS), Integrated Farming System-I (IFS-I) and Integrated Farming System-II (IFS-II) were set up in triplicate. The flow chart of the Experimental Design NIFS, IFS-I and IFS-II are shown in Fig-5, Fig-6 and Fig-7, respectively.

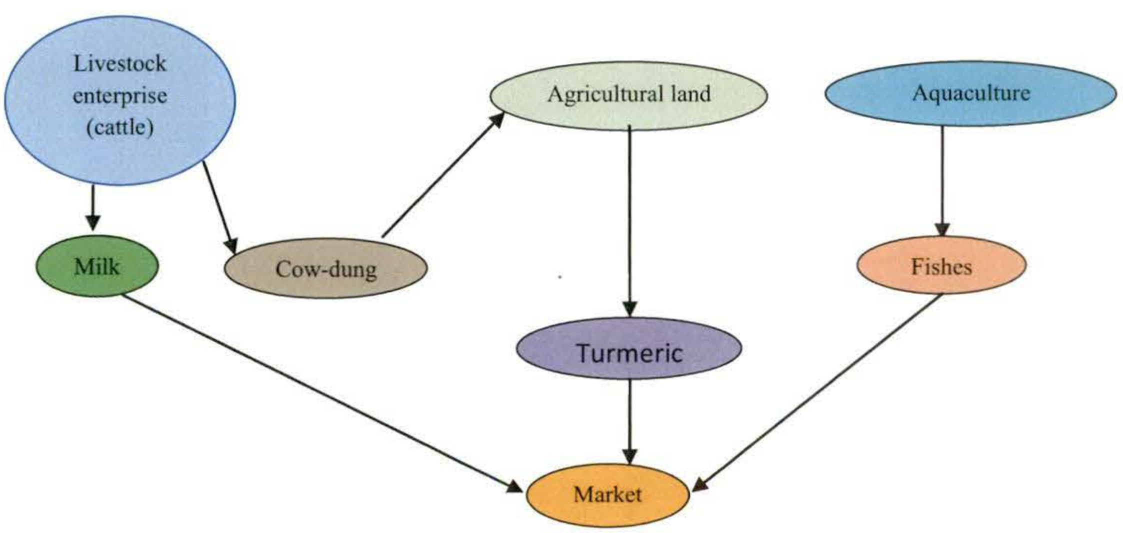


Fig- 5: Flow chart of Experiment-I (Non-Integrated Farming System) showing the non-integration of different components of farming.

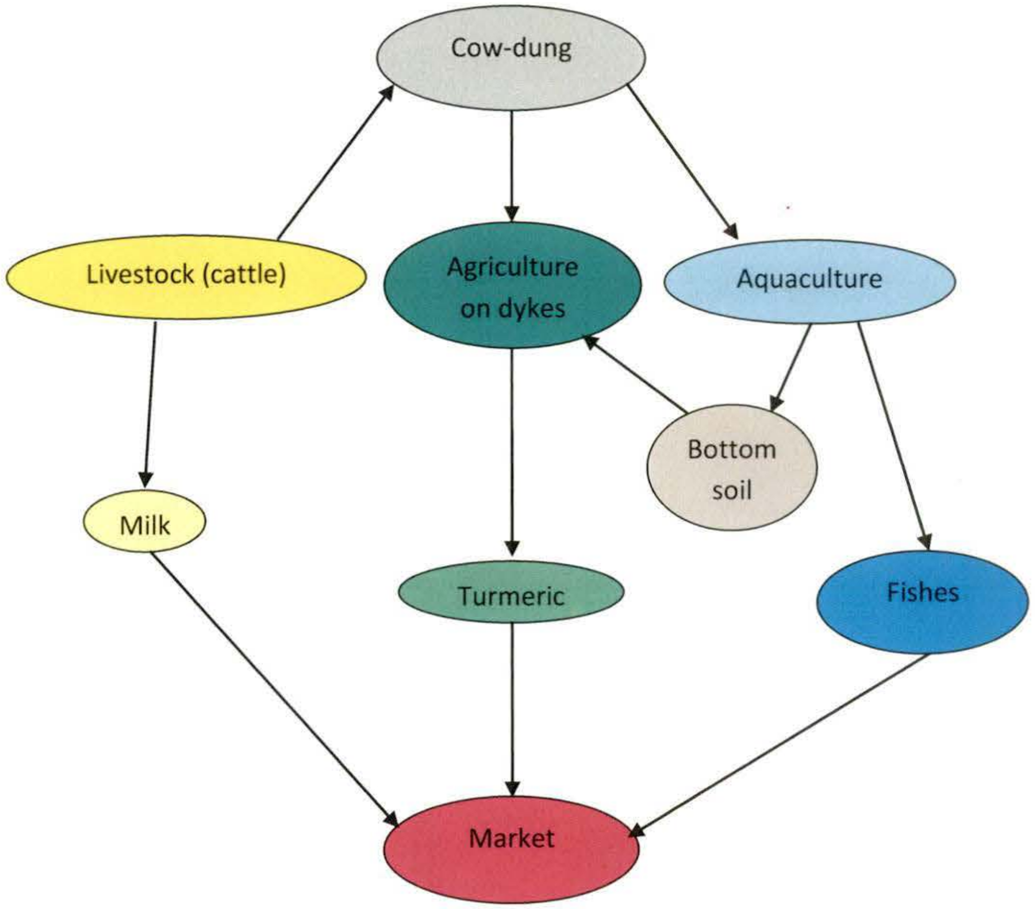


Fig- 6: Flow chart of Experiment-II (Integrated Farming System-I) showing the integration of different components of farming.

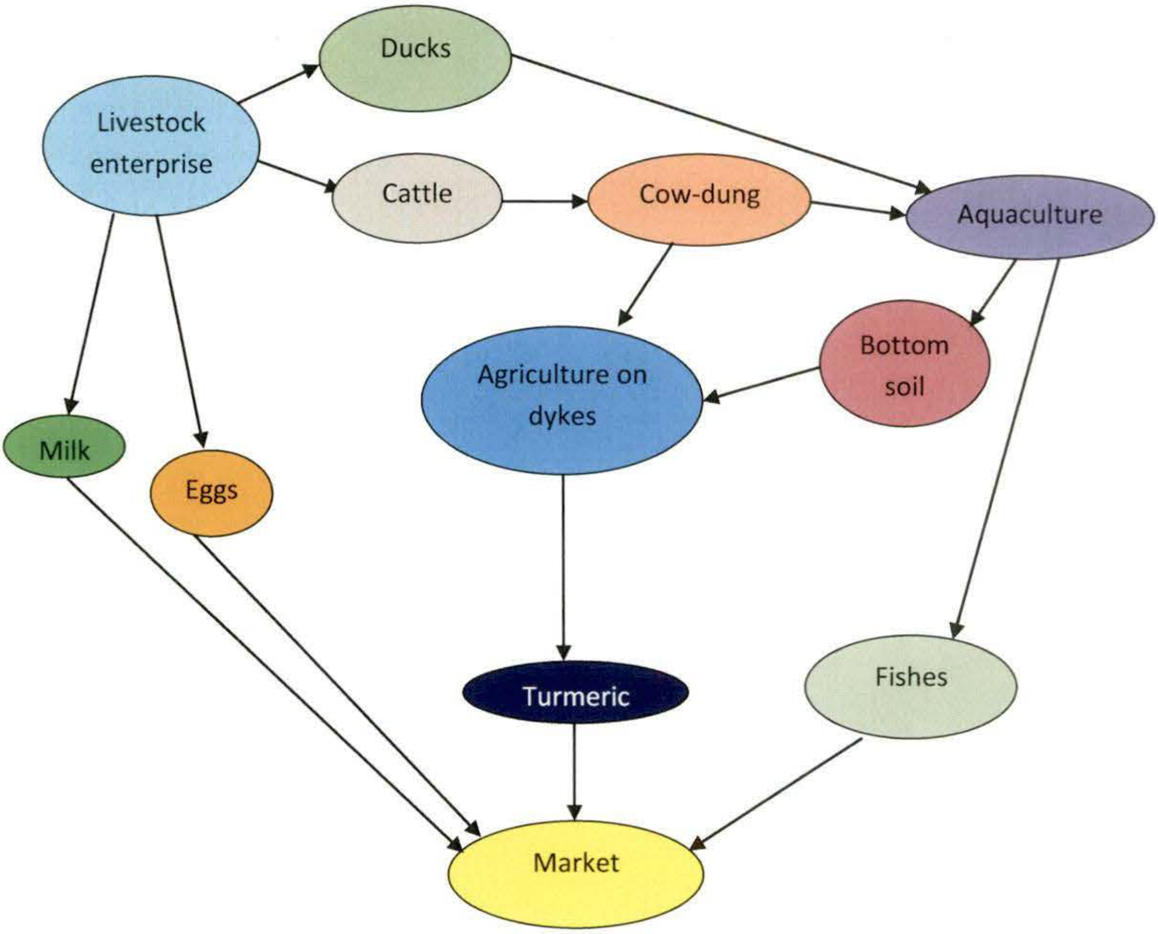


Fig- 7: Flow chart of Experiment-III (Integrated Farming System-II) showing the integration of different components of farming.

The plan of the work conducted in this study is described in Fig-8. The seasonal variation was studied considering the month April and May as summer season, June and July as pre-monsoon season and August and September as monsoon season. The Experimental protocol of the three experiments for the investigation is summarised in Table-2.

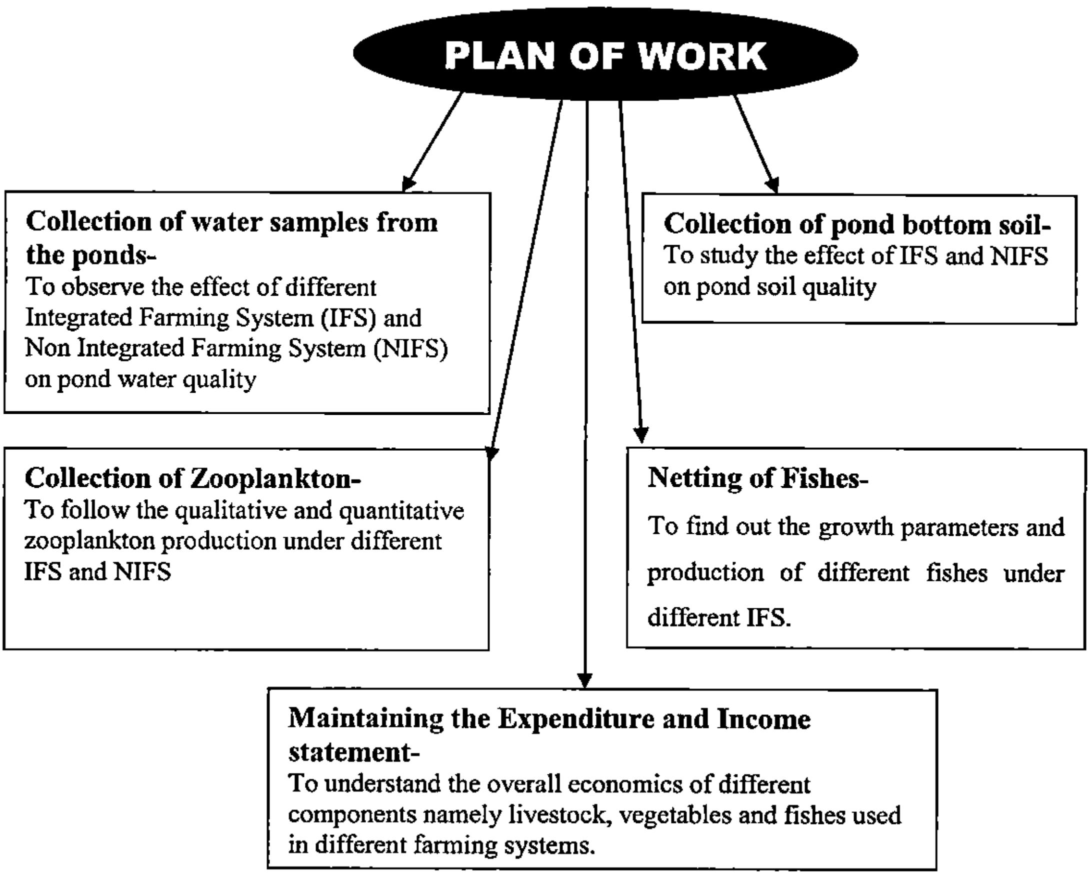


Fig-8: Flow chart explaining the Plan of Work to be executed during the study period (2008 to 2011).

Table-2: Summary of the Experimental Design showing different protocols followed in Experiment-I, II and III.

Protocols	Experiment-I (Control)	Experiment-II	Experiment-III
Components of farming	**Fish , cow and crop**	**Fish , cow and crop**	**Fish ,cow , duck and crop**
Type of farming	**Non-integrated (NIFS)**	**Integrated(IFS-I)**	**Integrated(IFS-II)**
No. of ponds	**3**	**3**	**3**
Average size of pond(ha)	0.01	0.01	0.01
Manuring	**No manuring**	**Manuring @2600kg ha^{-1} 10 d^{-1} with cowdung**	**Manuring @2600kg ha^{-1} 10 d^{-1} with cowdung**
Stocking density of fingerlings/ha	10,000	10,000	10,000
Types of fish stocked	IMC+Grass carp	IMC+Grass carp	IMC+Grass carp
Stocking ratio	3:3:3:1	3:3:3:1	3:3:3:1
Fish feeding schedule(on daily basis)	@ 2% of total body weight with Mustard oil cake and Rice Bran (1:1)	@ 2% of total body weight with Mustard oil cake and Rice Bran (1:1)	@ 2% of total body weight with Mustard oil cake and Rice Bran (1:1)
Type/No. of Cattle per pond	Non descriptive type,1 lactating cow	Non descriptive type,1 lactating cow	Non descriptive type,1 lactating cow
System of cattle rearing	**Extensive**	**Semi extensive**	**Semi extensive**
Feeding schedule of cow	**12 hours grazing with 3-4kg paddy straw**	**6 hours grazing and Concentrate feed and green grass along with paddy straw**	**6 hours grazing and Concentrate feed and green grass along with paddy straw**
System of duck rearing	**Nil**	**Nil**	**Extensive**
Type/No. of ducks per pond	**Nil**	**Nil**	**Non descriptive type, 20 Ducks of 22 wks of age**
Type of crop cultivated	**Turmeric plant(Suranjana Variety)**	**Turmeric plant(SuranjanaVariety)**	**Turmeric plant(Suranjana Variety)**
System of cultivation	**Separately on agricultural field**	**On pond dykes utilizing pond bottom soil**	**On pond dykes utilizing pond bottom soil**
Duration of Study	2008-2011(4 years)	2008-2011(4 years)	2008-2011(4 years)
Harvesting of Fish	After 150 days of stocking	After 150 days of stocking	After 150 days of stocking

Considering the market preferences and judicious exploitation of all the niches available in the ponds, Composite Fish Farming (four species culture) was done using Indian Major Carps (IMC) as *Catla catla, Labeo rohita* and *Cirrhina mrigala* and Exotic Carp as *Ctenopharyngodon idella.* The *Ctenopharyngodon idella* (Grass Carp) was considered along with IMC as the semi-digested excreta of herbivorous fish could be utilised to fertilise the water and produce plankton for filter-feeding fish to consume (Martin *et al.*, 2005). The seeds (fingerlings) were collected from the available local market of the experimental area.

The livestock, considered in this study, was non-descriptive (local variety with no specific breed character) cows (*Bos indicus*) and ducks (Family-Anatidae), mostly prevalent amongst small and marginal farmers of this area with the production potentiality of 500 L to 800 L / lactation and 150-180 eggs / year , respectively. The average live body weight of adult female ducks was found to be 1.8-2.4 kg and that of male ducks was 2.5-3.0 kg. Pic - 2 and 3 showed the locally available cow and ducks, respectively.

Turmeric (*Curcuma longa* , Linn.) of family , Zingiberaceae having a temperature preference of 20°C - 30°C with considerable quantity of rainfall, was cultivated. It is a perennial rhizomatous herb and a native plant of South Africa. Turmeric being a spice and having medicinal value, the market demand of the same was observed to be always high in the local market. In the present study, the turmeric plant 'Suranjana variety' as shown in Pic - 4, was used for cultivation on the dykes of the pond. The productivity of this variety was 3 tons ha $^{-1}$ yr $^{-1}$.

Picture – 2: Feeding concentrate feed to the locally available non descriptive cow reared in Experiment- II and III.

Picture – 3: Locally available non descriptive ducks reared in Experiment- III.

Picture – 4: 'Suranjana variety' of turmeric cultivated in Experiment- II and III.

3.2.1 Experiment- I: Non Integrated Farming System (NIFS)

In this Experiment, the Non Integrated Farming System (NIFS) was considered as the Control (C). Three ponds were taken for fish farming, livestock and crop in isolation without any integration (Fig-5) for this experiment.

Each of the three ponds under the NIFS (Control) were seasonal and shrinking in nature with 10 to 12m of length, 10 to 12m of breath and depth of 1.5 to 2 m. In the month end of March, all aquatic weeds and existing stock of fishes were removed by repeated netting, and raw cow-dung at 3 tons ha^{-1} was applied as the basal dose 15 days prior to stocking of the fingerlings. Lime @250 kg ha^{-1} was applied three to four days prior to stocking every year. The reason for liming in fish ponds was to neutralize soil acidity and increase total alkalinity and total hardness concentrations in water.

Ponds were stocked with Indian Major Carps (IMC) (*Catla catla, Labeo rohita* and *Cirrhina mrigala*) and Exotic Carp (*Ctenopharyngodon idella*) in the stocking ratio of 3:3:3:1 (Srivastava, 2009; Jena *et al.* 2007) @ 10,000 fingerlings ha $^{-1}$ having an average weight of 14.75±3.86 grams and average length of 9-10 cm. For the three ponds under the NIFS, supplementary feed was given in the form of Mustard Oil Cake and Rice Bran (1:1 ratio) @ 2% of total body weight of the fishes once daily after stocking the fingerlings. Netting was done twice a month to observe the growth rate parameters of the fishes, whereas desilting of the pond was not followed every year.

Livestock, as cattle, and non-descriptive in nature (without any specific breed characteristics) was selected for isolated practice. The productivity of the cattle, which was local, was found to be 500-600kg per lactation.

The cattle in the NIFS were reared as extensive system, thereby meaning that the cattle were allowed to graze whole day in the open pasture and at night only, night shelter was provided along with some 3-4 kg paddy straw and water. The cow dung was not collected during daytime for integration with aquaculture. Milking of the cow was done twice daily and daily milk records were used for estimation of milk production. De-worming of cattle was done routinely thrice in a year.

Under this experiment, no duck was maintained and the pond dyke was not utilized for any crop cultivation. Dykes were maintained to prevent the overflow of the pond water in the rainy season and thereby protecting the fishes.

A small field of area 100 m^2 (10m of length and 10m of breath) was prepared for the NIFS only to cultivate turmeric in isolation after applying cow dung @ 4 tons ha^{-1}. The recommendations for turmeric cultivation are given in Table – 3 (Kumar *et al.*, 2003). The use of extra fertilizer was not done. All the products namely fishes, turmeric and milk were collected and sold to the wholesaler without any value addition.

Table- 3: The recommendations per year calendar activities for turmeric cultivation.

Date/month	Activities
28 march	3-4 ploughing 8-10 inches deep and leveling properly to make the soil fine.
30 march	For Non- Integrated Farming System adding only cowdung @4 ton $bigha^{-1}$. For Integrated Farming System-I and Integrated Farming System-II Adding whole pond humous along with cowdung @4 ton $bigha^{-1}$
19 April	Final land preparation, seed bed preparation and seed treatment
20 April	Sowing of seed
21 April	Irrigation followed by Mulching
5 June	Weeding, irrigation if necessary
21 July	Weeding
20 Nov	Harvesting

3.2.2 Experiment-II: Integrated Farming System-I (IFS-I)

The enterprise selected for integration of the experiment IFS-I was livestock (local cow), fish and crop (turmeric). The integration of cow dung with fish culture along with turmeric cultivation on the pond dykes utilizing the bottom soil of ponds was the main objective of the study (Fig-6). For this treatment, three numbers of ponds were selected which were seasonal and shrinking in nature with an average size with 10 to 12m of length, 10 to 12m of breath and depth of 1.5 to 2 m. Single local cow per unit of pond was maintained for integration. No duck was maintained to integrate with the fish culture. Cultivation of turmeric was done considering total 100 m of length and 1 m of breath surrounding the pond dykes (100m X 1m= 100m^2).

In the end of March, ponds were dried to reduce the moisture content of soil so that air could enter the pore spaces among soil particles .The bottom soil along with aquatic weeds were removed (de-silted) and spread over the dykes of the pond to prepare for the cultivation of turmeric. The existing stock of fish in all the three ponds under this experiment were removed for drying and raw cow-dung at 3 tons ha $^{-1}$ was applied as the basal dose 15 days prior to stocking. Lime @250 kg ha $^{-1}$ was applied three to four days prior to stocking of the fingerlings every year. The reason for liming in fish ponds was to neutralize soil acidity and increase total alkalinity and total hardness concentrations in water. This could enhance conditions for productivity of food organisms and increase aquatic animal production (Boyd and Tucker, 1998).

Ponds were stocked with IMC and Grass Carp same as it was mentioned in NIFS. Application of cow-dung @ 2600kg ha $^{-1}$ once in ten days (Jha *et al.*, 2004) was followed for the ponds under this experiment. The supplementary feed recommended was same as followed in the NIFS. Netting was done twice every month to observe the growth rate parameters of the fishes. Desilting of pond was done once in every year so that the pond bottom soil containing organic waste after cultivation of the fish can be utilised for cultivation of turmeric on the pond dykes.

Livestock selected for integration was also local cattle mentioned earlier in NIFS but, under IFS-I one local lactating cow of 3-4 years old was selected for integration with each unit of the pond size area. They were maintained under semi-intensive system and fed with 1kg of concentrate daily for maintenance along with 3-4 kg paddy straw and water. Table-4 describes the composition of concentrate feed (kg ton $^{-1}$) which was fed to the cattle. The manure obtained was used to fertilize the ponds @ 2600kg ha $^{-1}$ once in ten days. De-worming of the cow was done routinely thrice in a year.

Table-4: Composition of concentrate feed (kg ton $^{-1}$).

S.No.	Ingredients	Amount (kg ton $^{-1}$)
1	Maize	250
2	Soya bean	100
3	De-oiled Rice Bran	450
4	Mustard Oil Cake	170
5	Salt	10
6	Vitamin and Minerals	5(gram)

Milking of the cow was done twice daily and daily milk records were used for estimation of milk production.

The surrounding pond dykes considered for cultivation of turmeric was 100 m^2 as describe earlier. The dykes of the ponds under this experiment were ploughed 3 to 4 times and leveled properly to make the soil fine by the end of March. After applying whole pond bottom soil with cow dung @ 4 tons ha $^{-1}$ the dyke was made ready for cultivation. The recommendations for turmeric cultivation are described in Table-3. The use of extra fertilizer was not recommended. Only the excavated bottom soil of pond containing manure was used once in a year during the month of March.

All the products namely fishes, turmeric and milk were collected and sold to the wholesale market without any value addition.

3.2.3 Experiment-III: Integrated Farming System-II (IFS-II)

For the experiment IFS-II, integration of livestock (local cow and local ducks) with fish culture and crop (turmeric) were practiced. The main objective of the study was to integrate cow dung and local ducks rearing on the pond with fish culture along with turmeric production on the dykes utilizing the bottom soil of ponds. Three seasonal ponds having an average size 10 to 12m of length, 10 to 12m of breath and depth of 1.5 to 2 m were selected for IFS-II. Ponds were dried and bottom soil with aquatic weeds were utilized on the dykes for turmeric cultivation same as it was done in IFS-I (Pic - 5, 6 and 7). Raw cow-dung application @ 3 tons ha $^{-1}$ as the basal dose 15 days prior to stocking. Lime @250 kg ha $^{-1}$ three to four days prior to stocking of the fingerlings every year so as neutralize soil acidity and increase total alkalinity and total hardness concentrations in pond water. Ponds were stocked with IMC and Grass Carp in the same way as mentioned earlier in NIFS and IFS-I.

Picture – 5: Dried pond to excavate to pond bottom soil.

Picture – 6: Spreading pond bottom soil on the dykes.

Picture – 7: Preparation of pond dykes for cultivation.

Application of cow-dung for the ponds under IFS –II was also followed similarly as it was followed in IFS-I. The supplementary feeds recommended were the same as mentioned in NIFS and IFS-I. Netting and desilting of pond was done as it was mentioned for IFS-I earlier. Integration of local lactating cattle was also done similarly as was mentioned earlier under experiment IFS-I.

In addition to cattle, in this experiment, about 22 weeks old local ducks having 1200 ± 50 gm were introduced @ 20 ducks pond $^{-1}$ after 2 months of stocking of fish that is, from June to September. After one year, the old ducks were replaced again by 22weeks old ducks in the month of June. The ducks were allowed to go to the ponds under IFS-II in the morning (9.00 a.m) and come back to their habitat (farmer's house) in the evening (5.00 p.m). Scavenging mode or wild grazing practice was adopted. Ducks were fed (average 100g) with fresh kitchen leftovers and agricultural by-products such as rice bran and broken grains. The ducks were housed in cleaned, dried and well-ventilated place. De-worming and vaccination for cattle and ducks were carried out from time to time.

Fig-7 (as shown earlier) describes the flow chart of the Experiment-III (IFS-III) showing the different integration established amongst the different components.

The dykes of the ponds under this experiment were also cultivated as described earlier in IFS-I.

All the products namely fishes, duck eggs, duck meat, turmeric and milk were collected and sold to the wholesale without any value addition.

3.3 Experimental Procedure

3.3.1 Pond Water Sampling

Water samples from each experimental pond under NIFS, IFS-I and IFS-II were collected in sterile bottle during 7am to 8am on a bimonthly (2008 to 2011) basis and the same were transported to the Aquaculture and Limnology Research Unit, Department of Zoology, University of North Bengal, within 2 hours of collection and used for estimation of the water quality parameters.

3.3.2 Water Quality Analysis

The water quality parameters, namely Temperature (^{o}C), pH, Dissolved Oxygen (mgl^{-1}), Free Carbondioxide (mgl^{-1}), Total Alkalinity (mgl^{-1}), Chloride (mgl^{-1}), Total Hardness (mgl^{-1}), Ammonium-N (mgl^{-1}), Nitrite-N (mgl^{-1}), Nitrate-N (mgl^{-1}) and Phosphate-P (mgl^{-1}) from each of the experimental ponds were monitored following the Standard Methods (APHA, 2005).

3.3.2.1 Temperature

Temperatures of air and water were recorded by using mercury Celsius (^{0}C) thermometer on spot.

3.3.2.2 Potential (Puissance) of Hydrogen in concentration (pH)

The pH was measured by using a portable pH meter (Multi-parameter PCS Testr 35, Eutech Instruments, Oakton) immediately after sampling the water in a beaker.

3.3.2.3 Dissolved Oxygen (Modified Winkler's Iodometric Method)

Dissolved Oxygen (DO) levels in natural and wastewaters reflect the physical, chemical and biochemical processes prevailing in the water body. The actual quantity of dissolved oxygen that water can hold under most favourable condition is much less than that constantly present in the atmosphere. The concentration of dissolved oxygen in the water varies in different seasons and reaches its peak in summer season when photosynthesis is high. However, the amount of dissolved oxygen present depends on the factors like sunlight, temperature, transparency, current, eutrophication, phytoplankton and salinity. The analysis for DO is a key test in water pollution and waste treatment process control.

The iodometric method is a titrimetric procedure based on the oxidizing property of DO. The manganous sulphate ($MnSO_4$) reacts with the alkali (KI or NaOH) to form a white precipitate of manganous hydroxide which in the presence of oxygen gets oxidized to a brown colour compound. In the strong acid medium (H_2SO_4) manganic ions are reduced by iodide ions which get converted to iodine equivalent to the original concentration of oxygen in the sample. The iodine can be titrated against N/40 sodium thiosulphate using starch (1%) as an indicator (APHA, 2005).

Water samples were collected in narrow-mouth glass-stoppered BOD bottles of 300 ml capacity, taking all necessary precautions to avoid air bubbles. 2ml of Winkler's A (Manganese sulphate) and Winkler's B (Alkaline potassium iodide) reagents were used to immediately fix the samples. The resultant precipitate thus formed was dissolved by 2ml concentrated Sulpuric Acid. The sample was then titrated against N/40 Sodium thiosulphate ($Na_2S_2O_3$) solution using starch as an indicator. The concentration of Dissolved Oxygen (mgl^{-1}) was calculated using the following formula:

$$\frac{ml\ of\ Na_2S_2O_3 consumed\ X\ 0.025 X 8 X 1000}{Volume\ of\ the\ sample\ titrated}$$

Where,

8 = Molecular weight of Oxygen

Volume of the sample titrated = 101.35 ml

As calculated using the formula,

$$\frac{100X300}{(300-4)}$$

When,

Original sample to be taken as per procedure =100ml

Volume of the BOD bottle =300 ml

Total volume of the Winklers'A and Winklers'B = 4 ml.

3.3.2.4 Free Carbon dioxide

Free Carbon dioxide (Free CO_2) levels below 10 $mgl^{-1}$are thought to be well tolerated by fish, although sensitivity to the gas varies between species. The level of free CO_2 in the water varies with the respiratory and photosynthetic activity of animals and plants in incoming water, the level of decomposition of organic material in that water and the respiration of the fish themselves. Free CO_2 can build up to significantly high levels in systems with large numbers of fishes and relatively slow water turnover.

Free CO_2 can be determined by titrating the sample using a strong alkali N/44 NaOH to pH 8.3. At this pH all the free CO_2 is converted into bicarbonates.

The concentration of free CO_2 (mgl^{-1}) in 100 ml sample water was analyzed using 6 drops of 1% Alcoholic phenolphthalein as indicator and N/44 NaOH as titrant as described by Golterman *et al.,* (1978) and Trivedy and Goel (1984). It was calculated using the following formula,

$$= \frac{Vol.of \frac{N}{44} NaOH\ solution\ consumed\ X\ 1000}{Vol.of\ sample\ taken}$$

3.3.2.5 Total alkalinity

Alkalinity of the water is its capacity to neutralize a strong acid and is characterized by the presence of all hydroxyl ions capable of combining with the hydrogen ion. Alkalinity in natural waters is due to free hydroxyl ions and hydrolysis of salts of carbonates, bicarbonates, phosphates, nitrates, borates, silicates etc. formed by weak acids and strong bases. However, most of the waters are rich in carbonates and bicarbonates with little concentration of other alkalinity imparting ions.

Total alkalinity, carbonates and bicarbonates can be estimated by titrating the sample with a strong acid (HCl or H_2SO_4), first to pH 8.3 using phenolphthalein as an indicator and then further to pH between 4.2 and 5.4 with methyl orange or mixed indicator. In the first case, the value is called as phenolphthalein alkalinity (PA) and in second case it is Bicarbonate alkalinity (BA).The sum of total of PA and BA is the

Total Alkalinity. Values of carbonates, bicarbonate and hydroxyl ions can be computed from these two types of alkalinity.

Total alkalinity present in the 100 ml water samples were estimated as mgl^{-1} using 5 drops phenolphthalein and 2drops of methyl orange as indicators and then titrated against N/50 H_2SO_4 (Golterman et al.,1978) and Phenolphthalein alkalinity was estimated only when free carbon-dioxide were found to be absent (Trivedy and Goel ,1984). The concentration (mgl^{-1}) of each alkalinity was calculated by using the following formula,

$$\frac{\textbf{ml of titrant} \times \textbf{1000}}{\textbf{Volume of sample used}}$$

3.3.2.6 Total Hardness

Total Hardness is generally caused by the calcium and magnesium ions present in water. Polyvalent ions of some other metals like strontium, iron, aluminum, zinc and manganese, etc are capable of precipitating the soap and thus contributing to the hardness. However, the concentrations of these ions are very low in natural waters.

Hardness is generally measured as concentration of only calcium and magnesium as calcium carbonate, which are far higher in qualities over other hardness producing ions. Calcium and magnesium form a complex of wine red colour with Eriochrome Black T at pH of 10.0±0.1.The EDTA has got a stronger affinity towards Ca^{++} and Mg^{++} and therefore by addition of EDTA the former complex is broken down and a new complex of blue colour is formed.

EDTA Method (APHA, 2005) was followed to estimate the Total hardness of the 100 ml water samples as mgl^{-1}. It was estimated by titrating the water sample against Ethylene diamine tetra acetic acid (EDTA) after adding 0.5ml ammonium buffer and 6 drops Eriochrome Black-T as indicator. The end point was indicated by blue colour.

The concentration (mgl^{-1}) was calculated using the following formula,

$$\frac{\textbf{ml of EDTA used} \times 1000}{\textbf{Volume of sample used}}$$

3.3.2.7 Chloride

Chloride, in the form of chloride (Cl^-) ion, is one of the major inorganic anions in water and wastewater. The most important source of chlorides in the waters is the discharge of domestic sewage. Man and other animals excrete very high quantities of chlorides together with nitrogenous compounds.

Silver nitrate reacts with chloride to form very slightly soluble white precipitate of AgCl. At the end point when all the chlorides are precipitated, free silver ions react with chromate to from silver chromate of reddish brown colour.

The Chloride content of 100 ml water samples were determined following Argentometric Method, adding 2 ml K_2CrO_4 and titrating it against 0.02N $AgNO_3$ until a persistent red tinge appeared as described by (APHA, 2005) and was expressed as mgl^{-1}.

The concentration (mgl^{-1}) was calculated using the following formula,

$$\frac{(\textbf{ml} \times \textbf{N})\textbf{of } AgNO_3 \times 1000 \times 35.5}{\textbf{Volume of sample used}}$$

3.3.2.8 Ammonium-N

The most important source of ammonia is the ammonification of organic matter. In this study, the organic matter like cow-dung and duck droppings were utilised to fertilize the pond for fish culture under different integrated farming systems. Hence, disposal of such organic matters tends to increase the ammonia content of the waters. Occurrence of ammonia in the waters indicates the evidence of organic pollution. Ammonia in higher concentration is harmful to fish and other biota. The toxicity of ammonia increases with pH because at higher pH most of the ammonia remains in the gaseous form. The decrease in pH decreases its toxicity due to conversion of ammonia into ammonium ion which is much less toxic than the gaseous form.

An intensely blue compound, indophenols , is formed by the reaction of ammonia, Sodium Oxidising solution (10ml alkaline citrate solution with 2.5ml sodium hypochlorite) , and Alcoholic Phenol catalyzed by Sodium Nitropruside.

Ammonium nitrogen (NH_4-N) of 25ml filtered sample of pond water was estimated by Phenol-hypochlorite method (APHA, 2005). 1ml of each Alcoholic Phenol solution, Sodium Nitropruside solution and Oxidizing solution (10ml alkaline citrate solution with 2.5ml sodium hypochlorite) were added to the samples. The samples were then wrapped with aluminium foil and kept at room temperature (22 – 27 ^{0} C) in subdued light for at least 1 hour. A blue colour appeared which was stable for 24 hours. The NH_4-N concentration of the samples was directly estimated through a double beam UV – Visible Spectrophotometer (Ray Leigh UV-2601) at 640nm wavelength. A standard curve was prepared by using Stock Ammonium Chloride

Solution (0.3819g anhydrous NH4Cl in 100ml DW) to estimate the Ammonium-N concentration of the water samples in mgl^{-1}.

3.3.2.9 Nitrite-N

Nitrite represents an intermediate form during denitrification and nitrification reactions in nitrogen cycle. Nitrite is very unstable ion and gets converted into either ammonia or nitrate depending upon the conditions prevailing in the water. Presence of even a small quantity of nitrite will indicate the organic pollution and the availability of partially oxidized nitrogenous matter. Lethal effects of nitrite in pond were studied by Tilak *et al.*, (2007) and obtained the value to be 171.06 ppm (0.17 mgl^{-1}) for 24 hr.

Nitrite forms a diazonium salt with sulphanilic acid in acid medium (2.0-2.5 pH), which combines with ά-naphthylamine hydrochloride to form a pinkish dye. The colour so produced obey Beer's Law and can be determined spectrophotometrically at 520 nm.

Nitrite- nitrogen (NO_2-N) content of 50ml filtered sample water was estimated using the α-Napthalamine and Sulphanilic Acid Method as described in APHA (2005). The estimation was done using a double beam UV – Visible spectrophotometer (Ray Leigh UV-2601). 1ml of each Ethylene diamine tetra acetic acid (EDTA), Sulphanilic-acid and α-naphthalamine hydrochloride were added to the sample in sequence. A pinkish colour developed and after 10 minutes, observations were taken through a double beam UV – Visible Spectrophotometer at 520 nm wavelength. The concentration was obtained through a standard curve prepared by dissolved $NaNO_2$ in 1 litre of distilled water.

3.3.2.10 Nitrate-N

Nitrate represents the highest oxidized form of nitrogen. The most important source of the nitrate is biological oxidation of organic nitrogenous substances which come in sewage and industrial wastes or produced indigenously in the waters. In the waste treatment systems, high amounts of nitrate denote the aerobic conditions and high stability of the wastes. Although high concentration are useful in irrigitation but their entry into the water resources increases the growth of nuisance algae and triggers eutrophication.

Nitrate and Brucine react to produce a yellow colour, the intensity of which can be measured at 410nm. The reaction is highly dependent upon the heat generated during the test. However, it can be controlled by carrying out the reaction for a fixed time at a constant fixed temperature. The method is suitable for the samples having a very wide range of salinity.

Brucine Method was followed to estimate the Nitrate-nitrogen (NO_3-N) concentration present in the water samples in mgl^{-1} (Trivedy and Goel ,1984). After proper filtration, the residual chloride was removed from the water samples by adding one drop of Sodium Arsenite solution. 10ml of water sample was then placed in cool water bath and 2 ml 30% NaCl solution was added. 10ml H_2SO_4 solution (500ml concentrated H_2SO_4 in 125ml distilled water) was added after mixing the contents thoroughly swirling by hand. 0.5 ml Brucine reagent (Brucine- Sulfanilic acid solution) was added to the samples and then placed in hot water bath for 20 minutes. After cooling the NO_3-N of the water samples were directly estimated through a double beam UV – Visible Spectrophotometer (Ray Leigh UV-2601) at 410 nm wave length. A standard curve was prepared using standard KNO_3 solution in distilled water and the NO_3-N concentration of the water samples were estimated from the standard curve.

3.3.2.11 Phosphate-P

Phosphorus in the natural freshwaters is present mostly in inorganic forms such as $H_2PO_4^-$, HPO_4^{-2} and PO_4^{-3}. Phosphorus being an important constituent of biological systems, may also be present in the organic forms. The phosphorus content of natural freshwaters is low. The major sources of phosphorus are domestic sewage, detergents, agricultural effluents with fertilizers and industrial waste waters. The higher concentration (greater than 0.5 mgl^{-1}) of phosphorus, therefore, is indicative of pollution.

The phosphate in water react with Ammonium Molybdate and form a complex heteropoly acid (MolybydoPhosphoric Acid), which gets reduced to a complex of blue colour in the presence of Stannous chloride ($SnCl_2$). The absorption of light by this blue colour can be measured at 690nm to calculate the concentration of phosphates.

The Phosphate (PO_4-P) content of water samples were determined by following Stannous Chloride Method (APHA, 2005). 2 ml Ammonium Molybdate solution(25.0 g Ammonium Molybdate + 280 ml of conc H_2SO_4+ upto 1000ml distilled water) and 5 drops Stannous Chloride in glycerol were subsequently added to the properly filtered 50 ml water samples. A blue colouration appeared. The samples were estimated through a double beam UV – Visible Spectrophotometer (Ray Leigh UV-2601) at 690 nm wavelength in between 10 to 12 minutes. A standard curve was prepared through known concentrations of PO_4-P solution (10mg P/lml) and the PO_4-P concentration of the water samples were determined and expressed in mgl^{-1}.

3.3.3 Pond Soil Quality Analysis

In aquatic ecosystems, the sediments are in a complex milieu with the overlying water, they affect water chemistry and are being affected by it. Using an Ekmann's dredger, the pond bottom soil was collected from 10 places and mixed well. The soil samples were then air dried, pulverized with pestle and mortar and sieved through 150μm mesh size sieve and stored in labelled polythene bags before estimation of different parameters.

3.3.3.1 Soil pH

pH of soil is the measure of the 'hydrogen ion activity' and depends largely on relative amounts of the absorbed hydrogen and metallic ions. Thus, it is a good measure of acidity and alkalinity of a soil-water suspension and provides a good identification of the soil chemical nature. pH of soil suspension highly depends on the soil : water ratio and increases with dilution. The soil pH was measured with electrically operated pH meter using soil: water (1:1) suspension (Jackson, 1967).

3.3.3.2 Organic Carbon

The Organic matter present in the soil is digested with excess of potassium dichromate and sulphuric acid, and the residual unutilized dichromate is then titrated with ferrous ammonium sulphate. One ml of 1N $K_2Cr_2O_7$ solution is approximately equal to 0.003g of carbon. It has been estimated, only 77% carbon of the organic compound in soil was oxidized by normal potassium dichromate solution. So, 0.003 should be multiplied by 1.3 to get the total % of carbon present in the soil.

For estimation of Organic Carbon, by Walkley-Black Oxidation Method (Walkley and Black, 1934), 2 gram of air-dried powdered sediment sample treated with 10 ml of 1 N $K_2Cr_2O_7$ and 20 ml of concentrated Sulphuric acid was mixed well. The sample was then agitated for 30 minutes in a mechanical shaker. The agitated sample was then diluted with 170 ml distilled water and then 10 ml Phosphoric acid and 1 ml Diphenyl amine indicator were added. This was then titrated against 0.4 N Ferrous Ammonium Sulphate (Mohr's salt) solution until brilliant green colour appeared (Jackson, 1967). A blank with same quantity of chemicals but without soil was also run simultaneously. The % of the Organic Carbon was calculated using the following formula:

$$\% \text{ of Organic Carbon} = \frac{(B-T) X\ F X 0.003 X\ 100}{w}\ X\ 1.3$$

Where, B= ml $FeSO_4$ solution required for Blank

T= ml $FeSO_4$ solution required for soil sample.

W= weight of the soil sample

F= normality factor (0.4)

1.3.3.3 Total Nitrogen

Nitrogen in the soil is present mostly in the organic form, together with small quantities of ammonium and nitrates. The total nitrogen of the soil was determined by Kjeldahl Method (Kjeldahl, 1883) modified by Cope (1916).

The procedure involves three main steps namely, digestion, distillation and titration as discussed latter.

a) Digestion

10 grams of sample was digested in 30 ml concentrated Sulphuric acid in the presence of 1g Salicylic Acid. 5g of Sodium thiosulphate was then added and heated

for 5 minutes. After cooling, 20ml of water was added along with 10 g of catalyst mixture (100g K_2SO_4 + 10g $CuSO_4.5H_2O$+1g selenium powder) for digestion until a blue colour appears.

b) Distillation

After cooling the contents, 50ml water was added to the digestion flask and swirled for 2 minutes. The supernatant liquid was then collected in a distillation flask. This process was repeated four times. 10ml of Sodium Sulphide was then added followed by 135ml of 40% Sodium Hydroxide solution. Ammonia gas was then distilled and collected in a receiver flask containing 25 ml Boric Acid and mixed indicator (Bromocresol green and 0.1 g of methyl red in 100ml).

c) Titration

The unreacted Boric Acid solution was back titrated with standard sulphuric acid till the blue colour disappeared. A blank without the soil sample was also carried out.

The % of Nitrogen was calculated using the following formula:

$$\text{\% of Nitrogen} = \frac{a-b}{S} \times N \times 1.4$$

Where, **a**= ml H_2SO_4 required for sample

b = ml H_2SO_4 required for sample

S = Sample weight in grams

N= Normality of H_2SO_4

3.3.3.4 Carbon Nitrogen ratio (C: N ratio)

Carbon to Nitrogen ratio in balance is a term used to describe a type of nitrogen deficiency in soil. When an organic material is applied to a field, it adds nutrients and organic matter to the soil. The organic matter contains about 60%

organic carbon. The Carbon: Nitrogen (C:N) ratio shows the proportion of organic carbon to total nitrogen of a manure or organic material.

In this present study, cow dung and duck excreta were utilized for fish production. The C: N ratio of pond bottom soil was analyzed because it was utilized to cultivate turmeric on the pond dykes.

Nitrogen is a food source for the micro-organism while they breakdown organic carbon. The nitrogen can come from the added organic material or it can come from the soil. During the process of carbon breakdown soil microbes die and decomposed. The microbial nitrogen is then returned to the soil and becomes available to the plants. This adds to the organic nitrogen pool within the soil along with the added organic material. How long the carbon breakdown process takes depends on the ratio of carbon to nitrogen in the material and in the soil.

The carbon to nitrogen ratio of soil is about 10:1. Solid cattle manure has 20:1 to 40:1 C:N ratio range and solid poultry manure has 5:1 to 10:1 C:N ratio range. When solid manure or other organic material having C:N ratio of greater than 30:1 is added which arises higher risk that soil microbes will steal nitrogen from the soil and tie it up so that the nitrogen become unavailable to the plant.

The Carbon Nitrogen ratio was calculated in this study, by dividing the value of carbon content of the pond bottom soil with the value of the nitrogen content of the same pond bottom soil (Boyd, 1995).

3.3.4 Zooplankton Analysis

Samples of zooplankton were collected with plankton net made of standard bolting silk cloth (No.21 with 77mesh/cm²). About 10 litres of water was collected randomly from selected locations and pooled together for filtering through the plankton net. Collected plankton were concentrated to 20ml, and preserved in 4% formalin for further estimation. Qualitative and quantitative determinations of zooplanktons were made under binocular compound microscope (Magnus make) using 1 ml concentrated solution preserved sample. Sedgwick-Rafter Counter Cell was used to count the planktons. The numbers were expressed in numbers per litre.

It was reported, that irrespective of different feed habits, the IMC and Grass Carp prefer to feed on zooplanktons (Rahman *et al.*, 2006). Jha *et al.*, (2006) also observed that introduction of zooplankton into a fish culture increases the growth rate of carp species. Hence, in the present study, only the zooplanktons were identified with the aid of Needham and Needham (1962), Edmondson (1992) and Battish (1992).

The diversity of individual zooplankton species was calculated using Shannon- Wiener Diversity index (Shannon and Weaver, 1949; after Krebs, 1999) which is expressed as (H′).

$$(\mathbf{H'}) = -\sum_{i=1}^{S}(\mathbf{pi})(\mathbf{Log2pi})$$

Where,

H′ = Index of species diversity (bits/individual)

S= Number of species

pi= proportion of total sample belonging to ith species (ni/N) ni=number of individuals of species i in the sample

N= Total number of individuals in the sample= $\sum ni$

The evenness of the zooplankton was calculated using Index of Evenness (Pielou, 1966) as follows:

$$J' = \frac{H'}{H'Max}$$

Where

J′= Evenness measure (range 0-1)

H′= Shannon-Wiener function

H'_{MAX} = Maximun value of H′= $\log_2 S$

3.3.5 Fish Growth

Fishes were randomly sampled from each pond at an interval of 30 days for studying the fish growth parameters and then returned to the pond. Before netting, fishes were starved for 24 hours to avoid stressful effect of netting and handling (Ricker, 1968).

All the fishes from the ponds under the three experimental schedules were harvested after 150 days, which was at the end of September of each year (2008-2011) with stocking of fingerlings in April of each year too.

The Absolute Growth of fish, Growth Increment of fish/day and Total weight gain by fish were calculated using the following formulae:

(a) The Absolute Growth = $W_2 - W_1$

where, W_2 = Initial body weight and

W_1 = Final body weight

(b) The Growth Increment in fish per day= $\frac{W_2 - W_1}{Number\ of\ culture\ days}$

where, W_1 = Initial body weight and

W_2 = Final body weight

(c) The Total Weight Gain by fish = $\frac{W_2 - W_1}{W_1}$

where, W_1 = Initial body weight and

W_2 = Final body weight

3.3.6 Economics

The expenditure incurred during each farming activity was recorded and was compiled for calculation of average expenditures incurred on different components of the farming system for assessment. Similarly, the income received by selling each farm produce was recorded and compiled for calculation of average income from different component of the farming system.

Cost-benefit analysis of the data was carried out on the basis of current market prices for the procurement of advanced fry of fish and returns of fish species following the simple procedure as suggested by Jolly and Clonts (1993).

Profit (Benefit) = Gross Output –Total Cost

Benefit achieved per unit expenditure, that is, Benefit (B) : Cost (C) ratio, from the different farming systems was calculated as per the following formula :

B: C ratio = Benefit : Cost

3.4 Statistical Analysis

The value of Mean and Standard Deviation of all the studied parameters under different treatment was done. To verify the significant differences of the data between the three treatments, One-way Analysis of Variance (ANOVA) was done as described by Gomez and Gomez, (1984). If the main effect was found significant, the ANOVA was followed by a Least Significant Difference (LSD) using Duncan's Multiple Range Test (DMRT). Pearson's correlation was used to establish the relation between the different parameters. All statistical tests were performed at a 5% probability level using the statistical package SPSS (Version-18).

Results

Based on the objectives of this study, the observations were made from 2008 to 2011 and given below as measurement of Pond Water and Soil Quality parameters, measurement of qualitative and quantitative Zooplankton, Growth and Production of Indian Major Carps (IMC) and Grass Carp and also the Estimation of Economics.

4.1 Measurement of Pond Water and Soil Quality Parameters

4.1.1 Pond Water

The summery values of the Mean ±SE pond water quality are given in Table -5.

Table-5: Mean ± SE of different physico-chemical parameters studied under Experiments-I, II and III during the period (2008-2011).

Parameters	Experiment-I (NIFS/Control)	Experiment-II(IFS-I)	Experiment-III (IFS-II)
Temperature (°C)	27.3 ± 0.22^{a}	28.8 ± 0.23^{c}	28.1 ± 0.24^{b}
pH	7.7 ± 0.04^{c}	6.5 ± 0.03^{a}	6.7 ± 0.05^{b}
Dissolved oxygen (mg l^{-1})	$6.43\pm.05^{c}$	5.73 ± 0.06^{a}	6.26 ± 0.10^{b}
Free carbon dioxide (mg l^{-1})	1.80 ± 0.10^{a}	2.87 ± 0.07^{b}	3.14 ± 0.10^{b}
Total alkalinity (mg l^{-1})	30.64 ± 0.59^{a}	68.54 ± 0.77^{b}	73.29 ± 0.72^{c}
Total hardness (mg l^{-1})	51.47 ± 0.69^{a}	77.70 ± 0.66^{b}	82.47 ± 0.58^{c}
Chloride (mg l^{-1})	17.14 ± 0.54^{a}	24.17 ± 0.70^{b}	29.18 ± 0.67^{c}
Ammonium-N (mg l^{-1})	0.16 ± 0.013^{a}	0.29 ± 0.018^{b}	0.36 ± 0.002^{c}
Nitrite-N (mg l^{-1})	0.02 ± 0.001^{a}	0.024 ± 0.001^{b}	0.036 ± 0.002^{c}
Nitrate-N (mg l^{-1})	0.22 ± 0.014^{a}	0.368 ± 0.019^{b}	0.459 ± 0.022^{c}
Phosphate-P (mg l^{-1})	0.24 ± 0.023^{a}	0.41 ± 0.03^{b}	0.59 ± 0.02^{c}

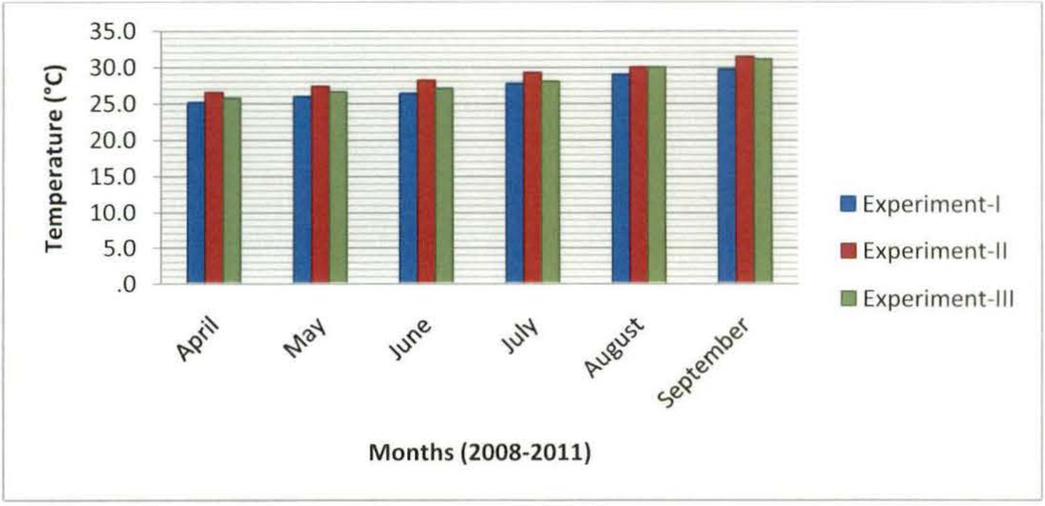
Different superscripts (a, b and c) denotes significant difference between Experiment-I, II and III at 0.05 level of significance for n=216.

4.1.1.1 Temperature

The pond water temperature ranged from 23.7° C to 32.2°C in NIFS (Control), 24° C to 32.6°C in Experiment-II and 25.0°C to 32.0°C in Experiment-III during the experimental period which was found to be optimum for Grass Carp and IMC production. The mean water temperature (Table-5) during the study period was found to be significantly higher ($p \leq 0.05$) in Experiment-II (28.8°C) and Experiment- III (28.1°C) than Experiment-I (27.3°C). The air temperature during the study period (2008 to 2011) ranged from 20 to 38°C with the mean value of 27.5°C. The monthly variation of air temperature showed increasing trend from the month April to September with peak temperature in the month of June (38°C).

The seasonal variations in temperature of water body had a great influence upon its productivity. In this present study, an increasing trend of water temperature was observed (Fig-9) in all the experimental ponds from summer (April to May) followed by pre monsoon (June to July) and monsoon (August to September) with peak value in the month of September.

Fig-9: Diagram showing the seasonal mean fluctuations of pond water temperature (°C) recorded during the period 2008-2011 in different Experiment-I (NIFS), Experiment- II(IFS-I) and Experiment- III(IFS-II). (n=12).



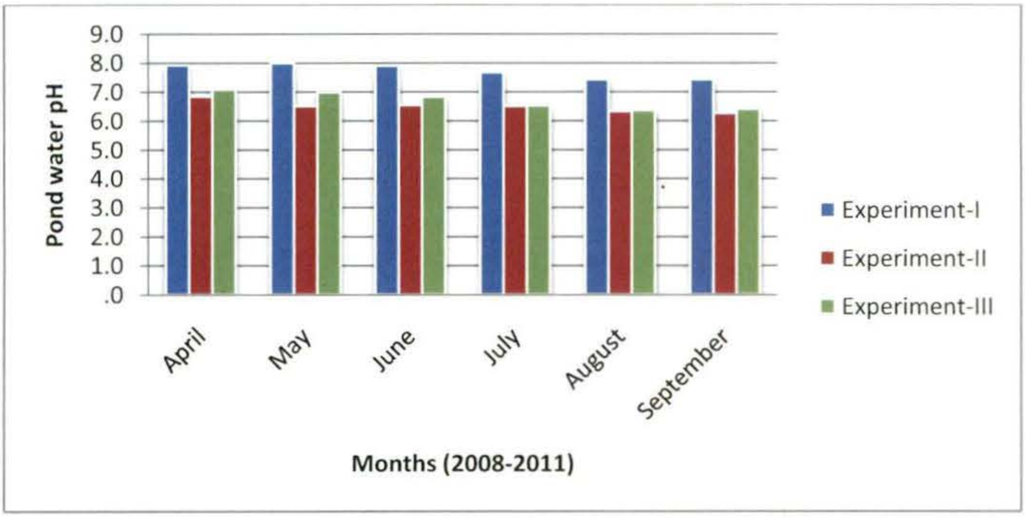
Pond water temperature of all the experimental ponds was found to be inversely correlated with dissolved oxygen concentration ($r = -0.486$; $p \leq 0.01$).

4.1.1.2 Water pH

The pH of the pond water in the Experiment I, II and III were found to be ranged from 6.8 to 8.2, 5.8 to 7.0 and 6.1 to 7.8, respectively. From Table-5 it can be realized that Mean±S.E of pH in IFS-I (6.5±0.03) and IFS-II (6.7±0.05) was significantly ($p \leq 0.05$) lower than followed by NIFS (7.7±0.04). In the Control (NIFS), the pond water pH was observed to be slightly towards alkaline than the IFS-I and IFS-II where the animal wastes were utilized to fertilize the pond water.

Seasonal pH variation (Fig-10) of the ponds under NIFS, IFS-I and IFS-II shows a decreasing trend of pH in the rainy season that is, pre-monsoon and monsoon than in the summer season.

Fig-10: The trend of Monthly mean water pH recorded during the period 2008-2011 in different Experiment-I (NIFS), Experiment-II(IFS-I) and Experiment-III(IFS-II). (n=12).



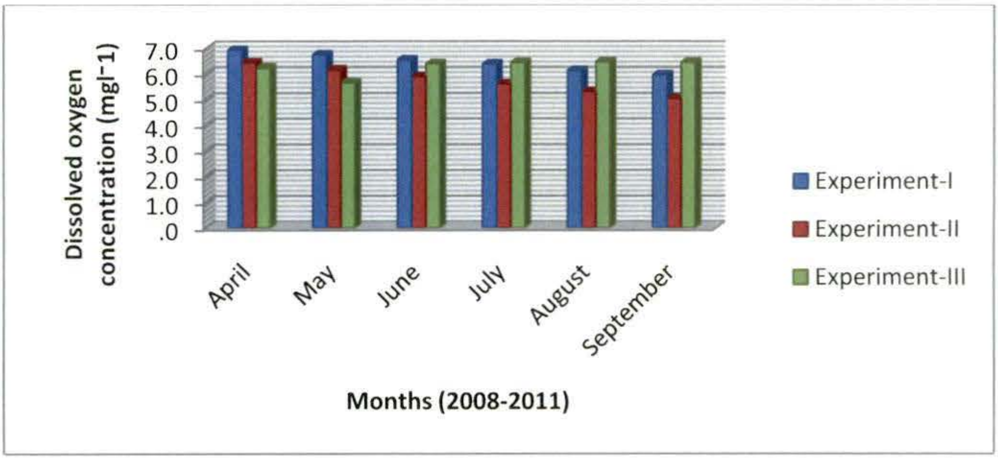
In this study a negative correlation was found with the pH of the water versus free CO_2 ($r = -0.796$; $p \leq 0.01$) and Total Alkalinity ($r = -0.877$; $p \leq 0.01$) of the experimental ponds.

4.1.1.3 Dissolved oxygen concentration

The Dissolved Oxygen concentration in Experiment-I (NIFS) ranged from 5.2 to 7.2 mgl^{-1}, in Experiment-II (IFS-I) from 5.2 to 7.2 mgl^{-1} and in Experiment-III (IFS-II) the range was observed to be 5.2-7.1 mgl^{-1} throughout the study period. Mean Dissolved Oxygen concentration of Experiment-I (NIFS) (6.43mgl^{-1}) was found to be significantly higher ($p \leq 0.05$) followed by IFS-II (6.26mgl^{-1}) and IFS-I (5.73mgl^{-1}), respectively.

A decreasing trend of dissolved oxygen was observed from the month of April to September in the ponds under NIFS (Experiment-I) and IFS-I (Experiment-II). On the contrary, the ponds under IFS-II showed a decreasing trend in the summer season (April and May) but, after May when the ducks were allowed to graze on the ponds the dissolved oxygen were found to increase thereafter and maintained stability in the pre-monsoon and monsoon season (Fig-11).

Fig-11: Seasonal variation of pond water dissolved oxygen concentration (mgl^{-1}) recorded during the period 2008-2011 in different Experiment-I (NIFS), Experiment-II(IFS-I) and Experiment- III(IFS-II). (n=12).



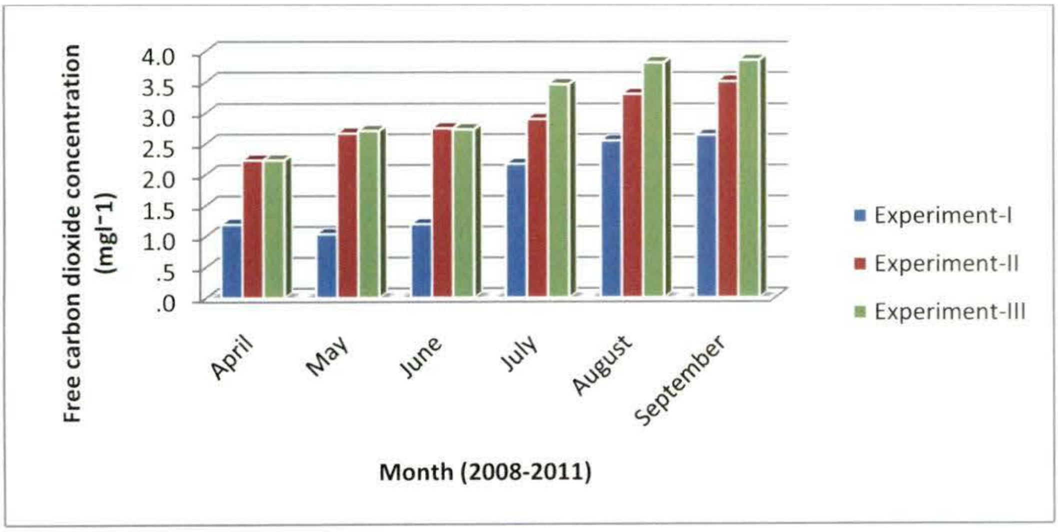
In the rainy season it was observed that IFS-II had higher dissolved oxygen in the pond water than that in the Control and IFS-I. Statistical analysis showed that dissolved oxygen was negatively correlated with water temperature ($r = -0.486$; $p \leq 0.01$) and ammonium-N concentration of pond water ($r = -0.387$; $p \leq 0.01$).

4.1.1.4 Free Carbon- dioxide concentration

The free carbon dioxide concentration under Experiment- III , Experiment –II and Experiment –I ranged between 1.1- 4.5mgl^{-1}, 1.6-4.1 mgl^{-1} and 0.5-3.5 mgl^{-1}, respectively. The mean value of free carbon dioxide concentration available in the pond water varied during the study period and was observed to be significantly higher ($p \leq 0.05$) in Experiment-III (3.14mgl^{-1}) followed by Experiment-II (2.87mgl^{-1}) and Experiment-I (1.80mgl^{-1}) as presented in Table-5.

Three different and distinct trends of seasonal fluctuations in pond water free carbon dioxide concentration were observed from April to September (Fig-12). In the summer and middle of the pre-monsoon season (April to June) the mean free carbon dioxide concentration of IFS-I and IFS-II was similar and higher than NIFS. After the middle of the pre- monsoon season that is, from the month of July all the experiments showed an increasing trend. IFS-II had the highest free carbon dioxide concentration followed by IFS-I and NIFS in rainy season.

Fig-12: Monthly mean fluctuations of pond water free carbon dioxide concentration (mgl^{-1}) recorded during the period 2008-2011 in different Experiment-I (NIFS), Experiment-II(IFS-I) and Experiment- III(IFS-II). (n=12).



The free carbon dioxide concentration was found to be positively correlated with the Total alkalinity ($r = 0.730$; $p \leq 0.01$) and negatively correlated with pH ($r = -0.796$; $p \leq 0.01$).

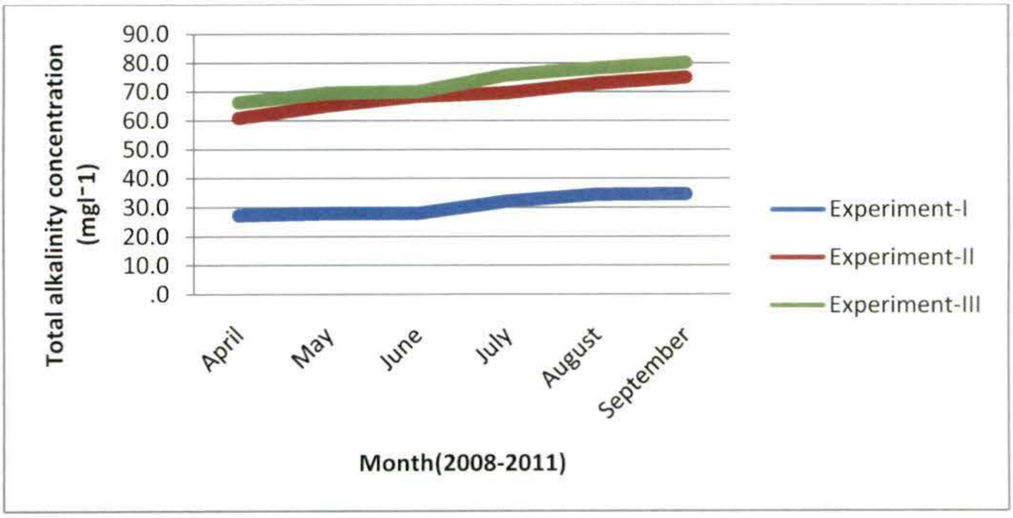
4.1.1.5 Total alkalinity

In the present study, the mean Total alkalinity concentration of the pond water samples under three experiments was found to be more than 20 mgl^{-1} (ranging from 21.5 mgl^{-1} to 85 mgl^{-1}). The range of the Total alkalinity in Experiment-I, II and III was found to be 21.5 to 41 mgl^{-1}, 49 to 82 mgl^{-1} and 60 to 85 mgl^{-1}), respectively. From Table-5, it was also observed that Experiment-III (73.29±0.72 mgl^{-1}) and

Experiment–II (68.54±0.77 mgl^{-1}) had significantly ($p \leq 0.05$) higher Mean±SE of total alkalinity than Experiment-I (30.64±0.59mgl^{-1}).

After the summer season that is April and May month an increased trend was observed regarding the mean Total alkalinity concentration in all the ponds (Fig-13) in pre-monsoon and monsoon season.

Fig-13: Showing mean fluctuations of pond water total alkalinity concentration (mgl^{-1}) recorded during the period 2008-2011 in different Experiment-I (NIFS), Experiment-II(IFS-I) and Experiment- III(IFS-II). (n=12).



Total alkalinity was found to be positively correlated with Total Hardness ($r = 0.956$; $p \leq 0.01$) and negatively correlated with the pH($r = - 0.877$; $p \leq 0.01$) in this study.

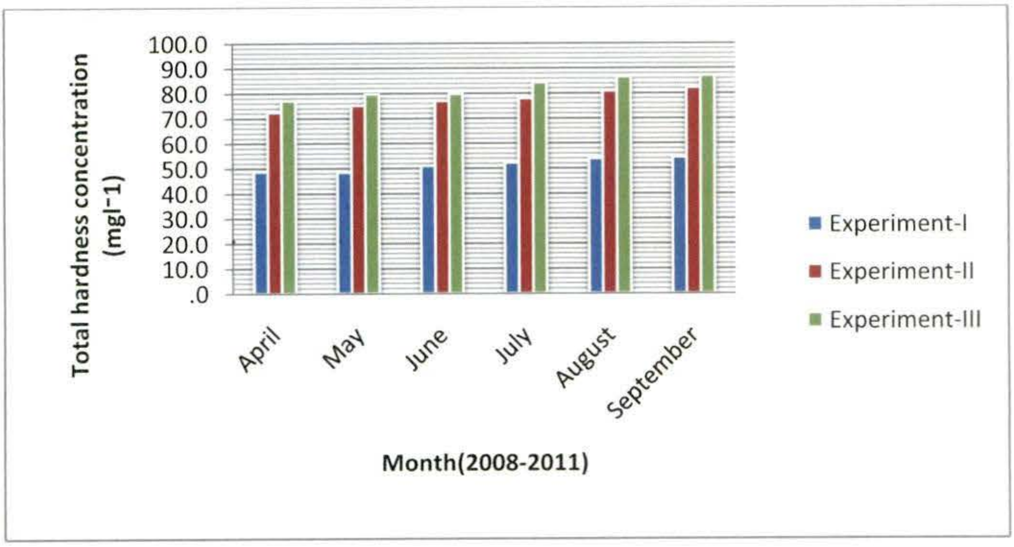
4.1.1.6 Total hardness

Mean ±S.E of Total hardness of the pond water remained significantly ($p \leq 0.05$) different during the study period in Experiment-I, II and III with the range of 42 to 65 mgl^{-1}, 58 to 88 mgl^{-1} and 70 to 92 mgl^{-1}, respectively. Ponds under Experiment-III (IFS-II) had higher Total hardness (82.47±0.58 mgl^{-1}) than Experiment-II (IFS-I) (77.70±0.66 mgl^{-1}) followed by Experiment-I (NIFS) as 51.47±0.69 mgl^{-1}.

Seasonal fluctuation of Total hardness (Fig-14) showed an increasing trend after summer season that is, after the month of May.

Positive correlation was observed within the Total hardness and Total Alkalinity of the experimental pond water ($r = 0.956$; $p \leq 0.01$).

Fig-14: Seasonal fluctuations of pond water total hardness concentration (mgl^{-1}) recorded during the period 2008-2011 in different Experiment-I (NIFS), Experiment-II(IFS-I) and Experiment- III(IFS-II). (n=12).



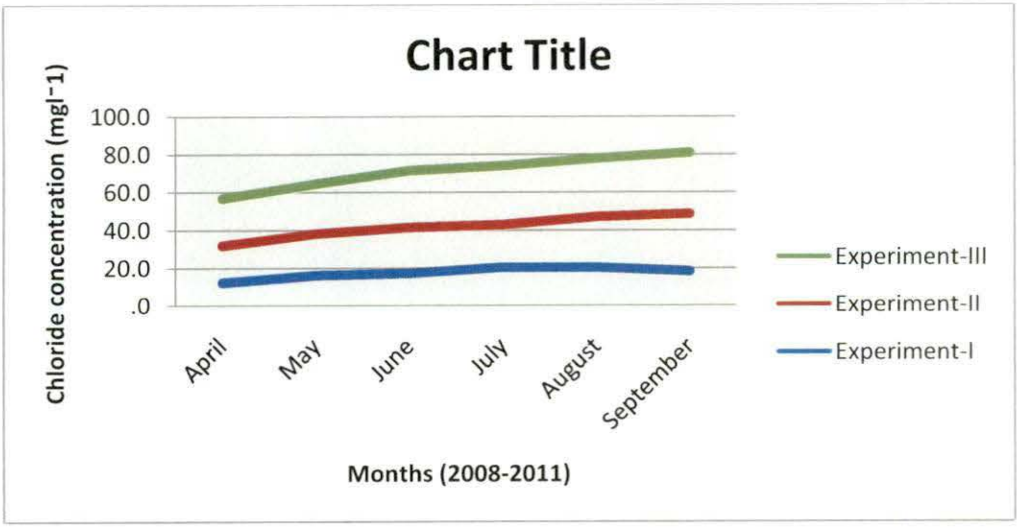
4.1.1.7 Chloride

Utilization of animal waste in this present study had a tendency to increase the pollution of the experimental pond water. Chloride concentration can be treated as an indicator of pollution.

It was also realized that the Mean±S.E of chloride content of the pond water under the three experiments varied significantly ($p \leq 0.05$) throughout the study period (Table-4). Ponds under Experiment-III were found to be significantly higher average chloride content (29.18 mgl^{-1}) ranging from 18 to 40 mgl^{-1} than in Experiment-II (24.17mgl^{-1}) ranging from 10 to 40 mgl^{-1} followed by Experiment-I (17.14mgl^{-1}) which was from 5 to 28 mgl^{-1} range.

An increasing trend of chloride concentration of pond water under Experiment-I, II and III was observed throughout the experimental period (Fig-15) from summer to monsoon.

Fig-15: Showing the trend of pond water Chloride concentration (mgl^{-1}) recorded during the period 2008-2011 in different Experiment-I (NIFS), Experiment-II(IFS-I) and Experiment- III(IFS-II). (n=12).

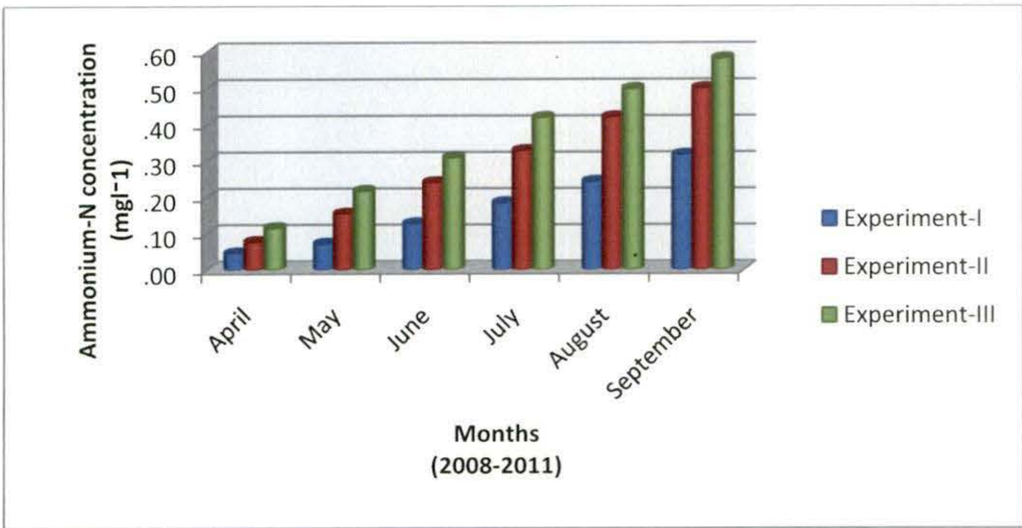


4.1.1.8 Ammonium-N ($NH_4 - N$) concentration

In this study, the average Ammonium-N concentration was observed to be significantly ($p \leq 0.05$) different in the three Experiments NIFS, IFS-I and IFS-II as 0.16±0.013 mgl^{-1}, 0.29±0.018 mgl^{-1} and 0.36±0.002 mgl^{-1}, respectively (Table-5). The minimum and maximum value of the Ammonium-N concentration was observed to be 0.01 to 0.50 mgl^{-1}, 0.02 to 0.57mgl^{-1} and 0.04 to 0.69 mgl^{-1} in NIFS, IFS-I and IFS-II, respectively. It was observed that manuring the ponds with animal wastes in IFS-I and IFS-II significantly increased the Ammonium-N concentration.

The seasonal fluctuations of pond water Ammonium-N concentration (mgl^{-1}) was recorded in different Experiment-I (NIFS), Experiment-II (IFS-I) and Experiment- III (IFS-II) and presented as Fig-16.

Fig-16: Monthly mean fluctuations of pond water Ammonium-N concentration (mgl^{-1}) recorded during the period 2008-2011 in different Experiment-I (NIFS), Experiment-II (IFS-I) and Experiment- III (IFS-II). (n=12).



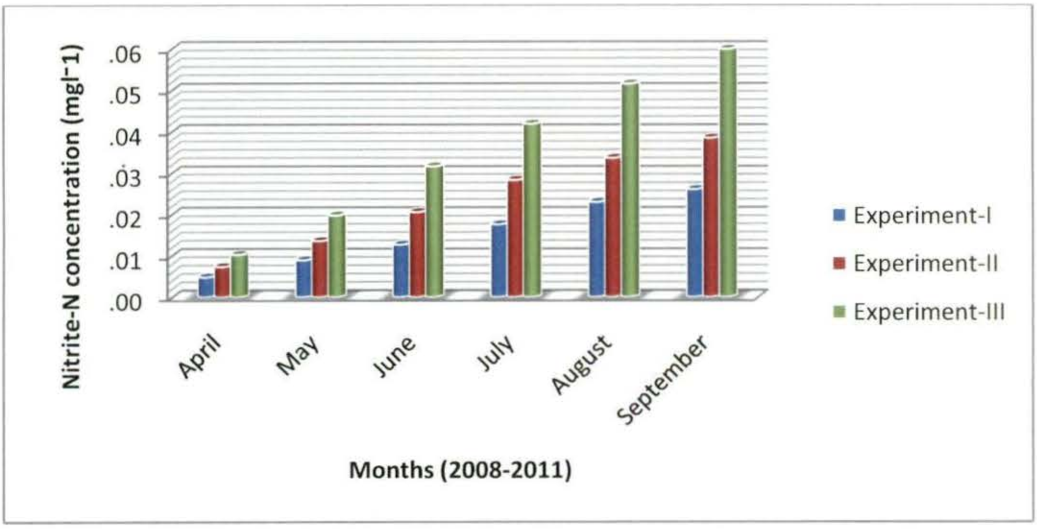
An increasing trend of ammonium-N concentration was observed from the summer to monsoon months that is, April to September in all the three experiments.

4.1.1.9 Nitrite-N (NO_2 –N) concentration

The minimum and maximum Nitrite-N content of the water samples was observed to be 0.00 to 0.03 mgl^{-1} , 0.00 to 0.05 mgl^{-1} and 0.00 to 0.07 mgl^{-1} in Experiment-I, II and III, respectively . The average Nitrite-N content in Experiment-I (0.02 mgl^{-1}) was significantly lower ($p \leq 0.05$) than Experiment-II (0.024mgl^{-1}) followed by Experiment-III (0.036 mgl^{-1}) as summarized in Table-5.

The seasonal fluctuations of Nitrite-N under three treatments NIFS, IFS-I and IFS-II was recorded and a sharp increasing trend was observed which was highest in IFS-II, followed by IFS-I and NIFS from the summer season to monsoon season that is, from April to September (Fig-17). However, no nitrite toxicity was observed during the study period.

Fig-17: Monthly mean fluctuations of pond water free Nitrite-N concentration (mgl^{-1}) recorded during the period 2008-2011 in different Experiment-I (NIFS), Experiment-II(IFS-I) and Experiment- III(IFS-II). (n=12).

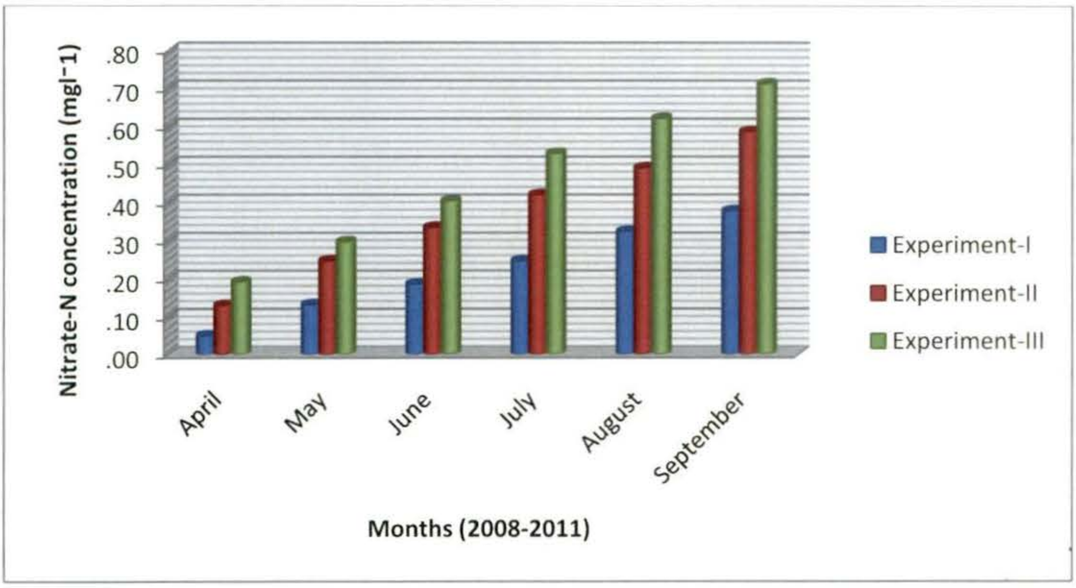


4.1.1.10 Nitrate-N (NO_3–N) concentration

Nitrate-N concentration of pond water samples under Experiment-I, II and III was found to be within the range of 0.01 to 0.49 mgl^{-1}, 0.08 to 0.66 mgl^{-1} and 0.08 to 0.79 mgl^{-1} , respectively . The average Nitrate-N was found to be significantly higher in IFS-II (0.459 mgl^{-1}), followed by IFS-I (0.368 mgl^{-1}) and then NIFS (0.22mgl^{-1}).

Like Ammonium-N and Nitrite-N, Nitrate-N also showed an increasing trend from the month of April to September (Fig-18).

Fig-18: Seasonal variation of pond water Nitrate-N concentration (mgl^{-1}) recorded during the period 2008-2011 in different Experiment-I (NIFS), Experiment-II (IFS-I) and Experiment- III (IFS-II). (n=12).

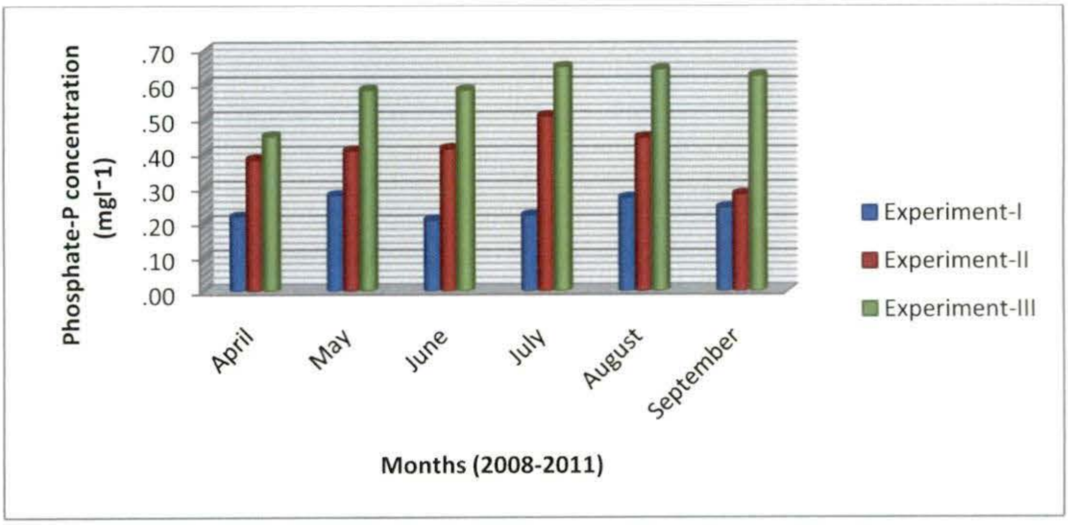


4.1.1.11 Phosphate-P concentration

The Mean ±S.E of Phosphate-P concentration in the pond water under Experiment-III (0.59 ± 0.02 mgl^{-1}) was found to be significantly higher ($p \leq 0.05$) followed by Experiment-II (0.41 ± 0.03 mgl^{-1}) and then Experiment-I (0.24 ± 0.02 mgl^{-1}).

The trend of seasonal variation of phosphate-P varied differently in the three experiments. IFS-II showed a more or less stable value of phosphate-P concentration in the month of July, August and September(pre-monsoon and monsoon) in comparison to IFS-I. This indicates that duck grazing and its manuring maintain the phosphate-P level (Fig-19). However, in IFS-I, a decreasing trend of phosphate-P concentration was observed in the monsoon season.

Fig-19 Monthly fluctuations of pond water free Phosphate-P concentration (mgl^{-1}) recorded during the period 2008-2011 in different Experiment-I (NIFS), Experiment-II(IFS-I) and Experiment- III(IFS-II). (n=12).



4.1.2 Pond Bottom Soil

Overall Mean±SE of pond bottom soil quality recorded during the four years of study (2008 to 2011) for the Experiments-I, II and III are presented in Table-6.

Table-6: Mean ± SE of pond bottom soil quality in three Experiments-I, II and III during the period (2008-2011).

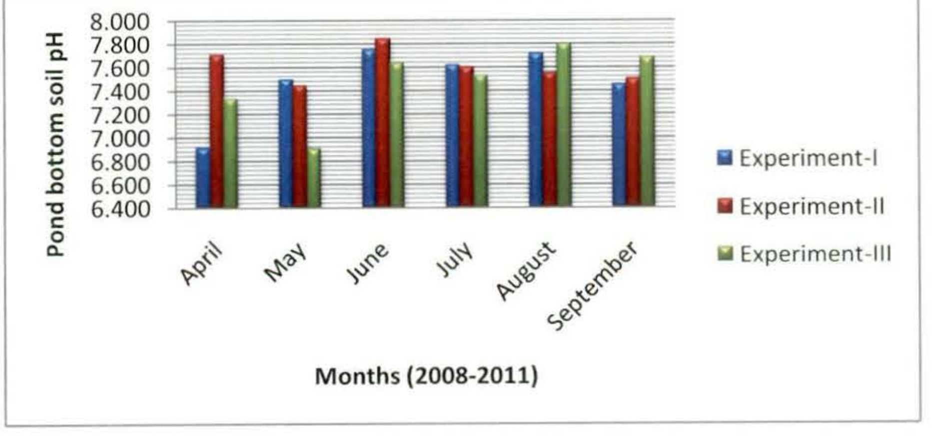
Parameters	Experiment-I/NIFS(Control)	Experiment-II/IFS-I	Experiment-III /IFS-II
Bottom Soil pH	7.48±0.116[a]	7.60±0.084[a]	7.47± 0.089[a]
Organic Carbon (%)	0.83±0.01[a]	0.97±0.01[b]	0.95±0.02[b]
Total Nitrogen (%)	0.078± 0.001[a]	0.096±0.002[b]	0.099± 0.001[b]
Carbon Nitrogen Ratio	10.61±0.14[a]	11.09±1.13[a]	9.68±0.10[a]

Different superscripts (a, b and c) denotes significant difference and similar superscripts denote non-significant difference between Experiments at 0.05 level of significance. n=216 for all the parameters.

4.1.2.1 Soil pH

As observed from the Table-5, the average pH of the pond bottom soil was not significantly different ($p \geq 0.05$) amongst the Experiments-I, II and III (7.48, 7.60 and 7.47, respectively). The pH of the pond bottom soil was found to be within the range of 5.5 to 9.3, 6.2 to 9.4 and 5.7 to 9.6 in Experiment-I, II and III, respectively. Fig-20 shows a considerable fluctuation in the average value of bottom soil pH throughout the study period from April to September in all the treated ponds.

Fig-20: Monthly mean fluctuations of pond bottom soil pH recorded during the period 2008-2011 in different Experiment-I (NIFS), Experiment-II(IFS-I) and Experiment- III(IFS-II). (n=12).

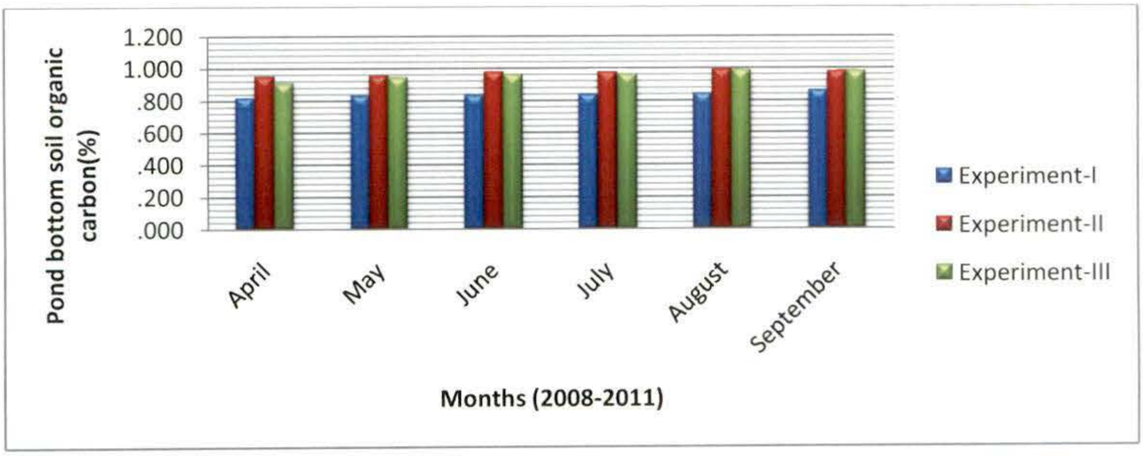


4.1.2.2 Soil Organic Carbon

The mean value of Organic carbon (%) available throughout the study period in the bottom soil of the treated pond was found to be significantly higher ($p \leq 0.05$) in Experiment-II (0.966%) and III (0.950 %) than Experiment-I (0.8307%).

The range of organic carbon percentage (%) was found to be 0.66 to 1.11 in NIFS, 0.86 to 1.30 in IFS-I and 0.75 to 1.33 in IFS-II. The organic carbon content of the bottom soil showed slightly increasing trend from April to September in all the treated ponds (Fig-21).

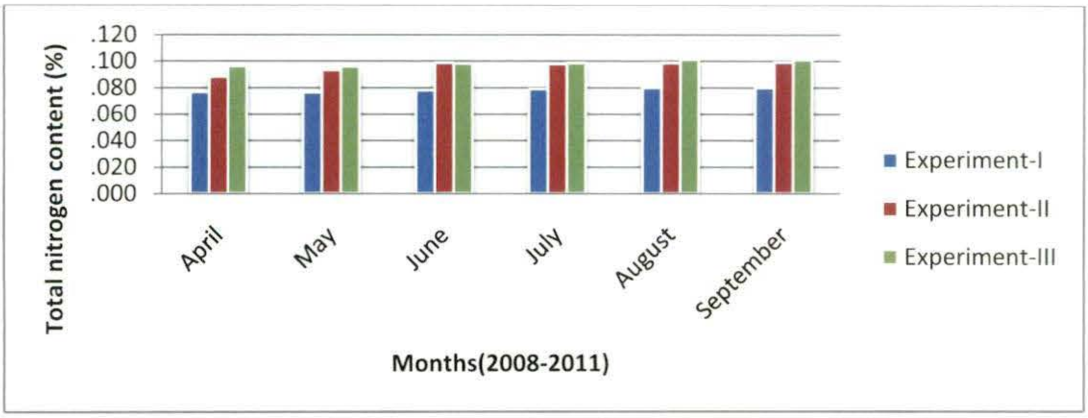
Fig-21: Variation of pond bottom soil organic carbon recorded during the period 2008-2011 in different Experiment-I (NIFS), Experiment-II(IFS-I) and Experiment-III(IFS-II). (n=12).



4.1.2.3 Total Nitrogen (Kjeldahl-N) Content

The results of Mean±S.E of Total nitrogen percentage (%) present in the bottom soil of the pond under Experiment-II and Experiment-III was significantly ($p \leq 0.05$) higher (0.095±0.002 % and 0.0985± 0.001%) than Experiment-I (0.078± 0.001%). Total nitrogen content of the pond bottom soil ranged from 0.07 to 0.09%, 0.01 to 0.13 % and 0.08 to 0.13% in NIFS, IFS-I and IFS-II, respectively. Fig-22 reflects that Total nitrogen % increased from April to September in all the treated ponds, NIFS, IFS-I and IFS-II.

Fig-22: Monthly mean fluctuations of pond bottom soil Total nitrogen content was recorded during the period 2008-2011 in different Experiment-I (NIFS), Experiment-II(IFS-I) and Experiment- III(IFS-II). (n=12).



4.1.2.4 Carbon to Nitrogen Ratio (CN ratio)

In this present study, the Carbon to Nitrogen Ratio (CN ratio) was observed to be below 20:1. During the study period the value of CN ratio ranged from 9.3 to 13.8, 8.0 to 9.9 and 6.2 to 10.8 in Experiment-I(NIFS) , II(IFS-I) and III(IFS-II), respectively. The average value of CN ratio 10.61, 11.09 and 9.68 was found to be non- significantly different in NIFS, IFS-I and IFS-II, respectively, as presented in Table-6.

4.2 Production of Zooplanktons

4.2.1 Qualitative

Yearly abundance (%) of zooplanktons from 2008 to 2011 are presented in Table-7, 8, 9 and 10 respectively, indicated that Experiment-III had seven types of zooplanktons namely *Daphnia* sp, *Moina* sp, *Cyclops* sp., *Brachionus* sp, *Diaptomus* sp., *Keratella* sp. and *Bosmina* sp. Under Experiment-II, six types of zooplankton were identified as *Daphnia* sp., *Moina* sp., *Cyclops* sp., *Brachionus* sp., *Diaptomus* sp. and *Keratella* sp.. But four types of zooplankton were identified in Experiment-I namely, *Daphnia* sp., *Moina* sp., *Cyclops* sp. and *Brachionus* sp. *Daphnia* sp. and *Cyclops* sp. were dominantly observed in all the three experiments.

The average relative abundance (%) of different zooplanktons available during the study period (2008-2011) was observed and shown in Table-11. The Experiment-II and III had higher % of relative abundance of different zooplanktons than Experiment-I.

Further, estimated Shannon-Wiener Diversity Index (H') of zooplankton in the ponds ranged from 1.87 bits/individual to 2.65 bits/individual with an average 2.35bits/individual. Lowest diversity was found to be in Experiment-I (H'= 1.87) followed by Experiment-II (H'= 2.54) and III (H'= 2.65). However, Zooplankton Evenness Index (J') in the ponds of three experiments during the study period (2008-2011) ranged from 0.935 to 0.983. Highest species evenness index was found in Experiment-II (J'= 0.983) followed by Experiment- III (J'= 0.943) and Experiment-I (J'= 0.935).

Seasonal effect on zooplankton concentrations was observed and a sharp increase in the average zooplankton count was found in all the pond waters during summer season following a declining trend of zooplankton concentration in the pre-monsoon and monsoon seasons (Fig-23).

Table-7: The seasonal abundance (%) of Zooplanktons in the pond water under Experiment-I, II and III in the year 2008.

Taxon/Genus	2008								
	Experiment-I			Experiment-II			Experiment-III		
	S	P	M	S	P	M	S	P	M
Cladocera									
Daphnia sp	++	+++	+++	++	++	++	++	++	+++
Moina sp	+++	+++	+++	++	++	++	++	++	+
Bosmina sp	0	0	0	0	0	0	+	+	++
Rotifera									
Brachionus sp	+++	+++	+++	++	++	++	++	++	+
Keratella sp	0	0	0	++	++	++	++	++	+
Copepoda									
Cyclops sp	+++	+++	+++	++	+++	+++	++	+++	+++
Diaptomus sp	0	0	0	+++	++	+++	++	++	+

(-) absent, (+) upto10%, (++) upto 20%, (+++) above20%, (S) summer, (P) premonsoon,(M)monsoon,

Table-8: The seasonal abundance (%) of Zooplanktons in the pond water under Experiment-I, II and III in the year 2009.

Taxon/Genus	2009								
	Experiment-I			Experiment-II			Experiment-III		
	S	P	M	S	P	M	S	P	M
Cladocera									
Daphnia sp	+++	+++	+++	+++	+++	++	+++	+++	+++
Moina sp	+++	++	+++	+	++	++	+	++	+
Bosmina sp	0	0	0	0	0	0	+	+	+
Rotifera									
Brachionus sp	++	++	+	++	++	++	++	++	++
Keratella sp	0	0	0	++	++	++	+	+	+
Copepoda									
Cyclops sp	+++	+++	+++	+++	+++	+++	+++	+++	+++
Diaptomus sp	0	0	0	++	++	++	++	++	++

(-) absent, (+) upto10%, (++) upto 20%, (+++) above20%, (S) summer, (P) premonsoon,(M)monsoon,

\

Table-9: The seasonal abundance (%) of Zooplanktons in the pond water under Experiment-I, II and III in the year 2010.

Taxon/Genus	2010								
	Experiment-I			Experiment-II			Experiment-III		
	S	P	M	S	P	M	S	P	M
Cladocera									
Daphnia sp	+++	+++	+++	++	+++	++	++	+++	+++
Moina sp	++	++	++	+	++	+	++	++	++
Bosmina sp	0	0	0	0	0	0	+	+	+
Rotifera									
Brachionus sp	++	++	+	++	++	++	++	++	++
Keratella sp	0	0	0	++	++	++	++	+	+
Copepoda									
Cyclops sp	+++	+++	+++	++	+++	+++	+++	+++	+++
Diaptomus sp	0	0	0	+++	++	++	++	++	++

(-) absent, (+) upto10%, (++) upto 20%, (+++) above20%, (S) summer, (P) premonsoon,(M)monsoon,

Table-10: The seasonal abundance (%) of Zooplanktons in the pond water under Experiment-I, II and III in the year 2011.

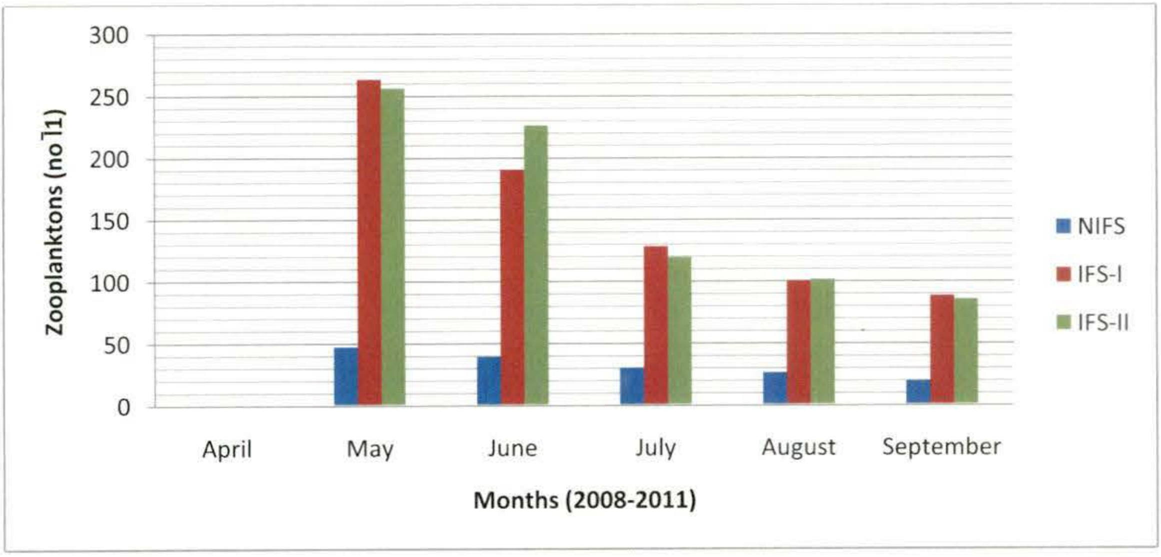
Taxon/Genus	2011								
	Experiment-I			Experiment-II			Experiment-III		
	S	P	M	S	P	M	S	P	M
Cladocera									
Daphnia sp	+++	+++	+++	+++	+++	+++	++	+++	+++
Moina sp	++	++	+++	++	++	++	++	+	++
Bosmina sp	0	0	0	0	0	0	+	+	+
Rotifera									
Brachionus	++	++	+	++	++	++	++	++	++
sp	0	0	0	++	+	+	++	+	+
Keratella sp									
Copepoda	+++	+++	+++	+++	+++	+++	++	+++	+++
Cyclops sp	0	0	0	++	++	++	++	++	+
Diaptomus sp									

(-) absent, (+) upto10%, (++) upto 20%, (+++) above20%, (S) summer, (P) premonsoon, (M) monsoon,

Table 11: Species diversity of zooplankton and its average relative abundance in NIFS, IFS-I and IFS-II (n=216).

Group	Species	Relative abundance (%)		
		Experiment-I(NIFS)	Experiment-II(IFS-I)	Experiment-III(IFS-II)
Cladocera	*Daphnia* sp	11.8	44.6	43.6
	Moina sp	19.4	43.3	37.3
	Bosmina sp	0	0	100
Rotifera	*Brachionus* sp	9.8	55.2	34.9
	Keratella sp	0	59	41
Copepoda	*Cyclops* sp	17	43.7	39.9
	Diaptomus sp	0	63.6	36.4

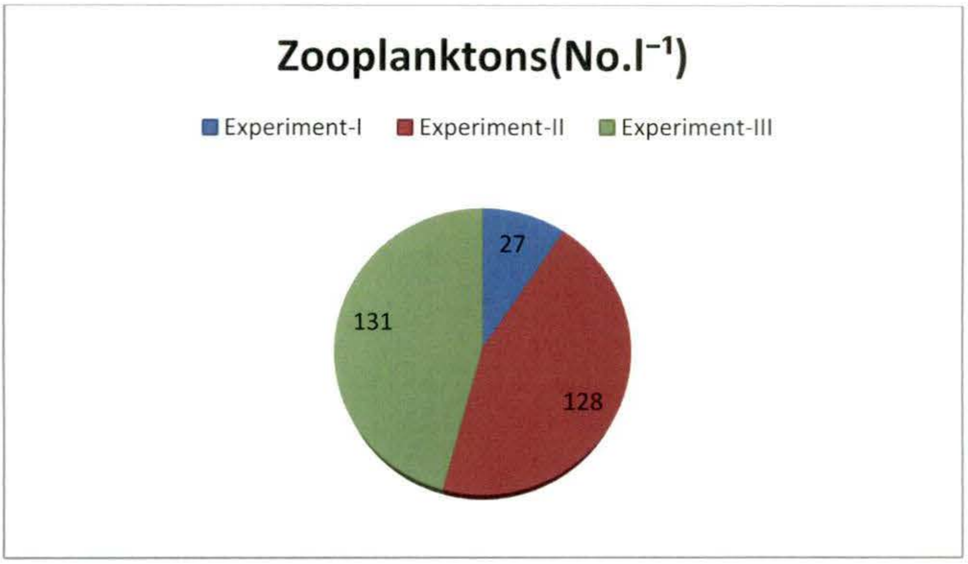
Fig-23: Trend of total mean zooplankton production no.l^{-1} in the pond water during the study period from April to September (2008-2011) under NIFS, IFS-I and IFS-II.



4.2.2 Quantitative

Quantitative study of zooplanktons was found to be significantly higher ($p \leq 0.05$) in the Experiment- III (131 ± 12 no.l^{-1}) and II (128 ± 11 no.l^{-1}) than Experiment-I (27 ± 2 no.l^{-1}) as shown in Fig-24. The numbers of zooplankton present in the pond water sample ranged from 10 to 68 no.l^{-1} in NIFS, 37 to 310 no.l^{-1} in IFS-I and 27 to 395 no.l^{-1} in IFS-II.

Fig-24: Zooplanktons concentration in Experiments-I (NIFS), II (IFS-I) and III (IFS-II) form the year (2008-2011).



Average value of *Daphnia* sp., *Moina* sp., *Cyclops* sp. and *Brachionus* sp. was significantly higher ($p \leq 0.05$) in Experiment II (26, 16, 29 and 20, respectively) and III (30, 15, 31 and 18, respectively) than Experiment I(8, 5, 10 and 3, respectively) whereas *Daptomus* sp. under Experiment-III(16) was found to be significantly lower ($p \leq 0.05$) than Experiment-II (22). However, *Keratella* sp. was found to be not significantly different in Experiment-II (14) and III (12).

4.3 Growth and Production of IMC and Grass Carp

The summary of the absolute monthly growth rate of different fishes under the different Experiments-I, II and III are given in Table-12. The monthly growth rate of IMC namely, *Catla catla*, *Labeo rohita* and *Cirrhina mrigala* was found to be significantly higher ($p \leq 0.05$) in Experiment- III and Experiment- II than Experiment-I.

Table-12: Mean±SE of absolute monthly growth rate of different species of fish under Experiment-I (NIFS), Experiment-II (IFS-I) and Experiment-III (IFS-II) during the four years (2008 to 2011).

Fish Species	Experiment-I/ NIFS	Experiment-II/ IFS-I	Experiment-III/ IFS-II
Catla catla **(g m^{-1})**	72.06±4.87^{a}	91.78±5.94^{b}	107.96±6.97^{b}
Labeo rohita **(g m^{-1})**	58.60±3.93^{a}	67.21±4.92^{ab}	75.33±6.01^{b}
Cirrhina mrigala **(g m^{-1})**	4.81±0.89^{a}	15.43±1.74^{b}	20.42±2.47^{b}
Ctenopharyngodon idella **(g m^{-1})**	69.99±4.01^{a}	73.25±4.15^{a}	76.01±4.28^{a}

Different superscripts (a, b and c) denotes significant difference and similar superscripts denote non-significant difference between treatments at 5% level. n=54

However, in case of *Ctenopharyngodon idella* (Grass Carp), no such significant difference was observed ($p \geq 0.05$) in Experiment I, II and III .The Mean±SE of monthly growth rate (g m^{-1}) of *Catla catla* under Experiment-I, II and III was found to be 72.06±4.87, 91.78±5.94 and 107.96±6.97, respectively. *Labeo rohita* (g m^{-1}) in Experiment-III was observed to be 75.33±6.01 followed by Experiment-II (67.21±4.92) and then Experiment-I (75.33±6.01). The growth of *Cirrhina mrigala* (g m^{-1}) in Experiment I, II and III was achieved as 4.81±0.89, 15.43±1.74 and 20.42±2.47, respectively. However, in case of *Ctenopharyngodon idella* (Grass Carp) the monthly growth rate (g m^{-1}) was found to be non-significantly higher ($p \geq 0.05$) in Experiment-III followed by Experiment-II and then Experiment-I (76.01±4.28, 73.25±4.15 and 69.99±4.01, respectively).

The average individual weight of *Catla catla* after 5 months of culture was found to be 360g, 459g and 540g in Experiments-I, II and III, respectively. The weight of *Labeo rohita* was observed in Experiments-I, II and III as 290g, 336g and 376, respectively. *Cirrhina mrigala* was found to weigh 25g in Experiment-I, 77g in Experiment-II, 102 in Experiment-III. Grass Carp obtained average weight of 350g, 366g and 380g in Experiments-I, II and III, respectively. The weight of *Catla catla* , *Labeo rohita* , *Cirrhina mrigala* was increased by 27.5%,15.9% and 76%, respectively in IFS-I and 50%, 29.7%, 311%, respectively in IFS-II. Whereas, Grass Carp increased 13.1% and 8.6% in IFS-I and IFS-II, respectively.

Throughout the study period, it was again observed that irrespective of any farming system followed as NIFS, IFS-I and IFS-II, the average monthly absolute growth rate pattern was higher for *Catla catla* (72.06 g m^{-1} , 91.78 g m^{-1} and 107.96 g m^{-1}, respectively) followed by *Ctenopharyngodon idella* (69.99 g m^{-1} , 73.25 g m^{-1} and 76.01 g m^{-1}, respectively), *Labeo rohita* (58.60 g m^{-1} , 67.21 g m^{-1} and 75.33 g m^{-1}, respectively) and *Cirrhina mrigala* (4.81 g m^{-1} , 15.43 g m^{-1} and 20.42 g m^{-1}, respectively), respectively (Table-12).

Zooplankton concentration in the pond water was observed to be positively related with the growth of *Catla catla* ($r=0.598$; $p \leq 0.01$), *Labeo rohita* ($r=0.487$; $p \leq 0.01$), *Cirrhina mrigala* ($r=0.625$; $p \leq 0.01$) and *Ctenopharyngodon idella* ($r=0.510$; $p \leq 0.01$).

The Mean ± S.E of production of fishes (kg $ha^{-1}yr^{-1}$) from pond after harvesting (160 days) is shown in Table-13. It was observed that the production achieved by IMC was significantly higher ($P \leq 0.05$) in Experiment-III followed by II and I. Production from *Catla catla* was observed to be 1259 ± 26 kg $ha^{-1}yr^{-1}$, 948 ± 19 kg $ha^{-1}yr^{-1}$ and 493 ± 11 kg $ha^{-1}yr^{-1}$ from the ponds under Experiment-III, II and I, respectively. *Labeo rohita* production under Experiment-III was 884 ± 17 kg $ha^{-1}yr^{-1}$ followed by Experiment-II (665±14 kg $ha^{-1}yr^{-1}$) and Experiment-I (365 ± 22 kg $ha^{-1}yr^{-1}$). *Cirrhina mrigala* production in was 342 ± 15 kg $ha^{-1}yr^{-1}$, 307 ± 14 kg $ha^{-1}yr^{-1}$ and 161 ± 11 kg $ha^{-1}yr^{-1}$, respectively.

Table-13: Mean± SE of different fish productions (kg $ha^{-1}yr^{-1}$) under Experiment-I (NIFS), Experiment-II (IFS-I) and Experiment-III (IFS-II) during the four years (2008 to 2011).

Experiments	*Catla catla*	*Labeo rohita*	*Cirrhina mrigala*	*Ctenopharyngodon idella*
I(NIFS)	493 ± 11^a	365 ± 22^a	48 ± 4^a	161 ± 11^a
II(IFS-I)	948 ± 19^b	665 ± 14^b	137 ± 11^b	307 ± 14^b
III(IFS-II)	1259 ± 26^c	884 ± 17^c	293 ± 15^c	342 ± 15^b

Different superscripts (a, b and c) denotes significant difference and similar superscripts denote non-significant difference between treatments at 5% level. n=12 for all the parameters.

Regarding the production of *Ctenopharyngodon idella,* it was observed that in Experiment-III (342 ± 15 kg $ha^{-1}yr^{-1}$) and Experiment-II (307±14 kg $ha^{-1}yr^{-1}$) the production was significantly higher ($p \leq 0.05$) than that in Experiment-I (161±11 kg $ha^{-1}yr^{-1}$). However, no such significant difference was observed in the production of *Ctenopharyngodon idella* under Experiment-II (IFS-I) and Experiment-III (IFS-II) as presented in the Table-13.

4.4 Estimation of Economics

Table-14 describes the total annual production (Mean±SE) achievement from different farming systems studied as Experiment-I (NIFS), Experiment-II (IFS-I) and Experiment-III (IFS-II) during the four years (2008 to 2011). The production of fishes from one ha pond was significantly ($p \leq 0.05$) higher in IFS-II (2778 ± 50 kg yr^{-1} ha^{-1})

followed by, IFS-I (2057 ± 33 kg yr^{-1} ha^{-1}) and NIFS (1067± 033 kg yr^{-1} ha^{-1}). The production of total fishes was observed to be 92.8% higher in IFS-I and 160.4% higher in IFS-II than the NIFS.

Table-14: Mean±SE of productions like, fish along with milk, turmeric and eggs under Experiment-I (NIFS), Experiment-II (IFS-I) and Experiment-III (IFS-II) during the four years (2008 to 2011).

Experiments	Total fish production (kg yr^{-1} ha^{-1})	Milk (l yr^{-1}100cow^{-1})	Turmeric (t ha^{-1} yr^{-1})	Eggs (no. yr^{-1} 2000 ducks^{-1})
I(NIFS)	1067 ± 33^{a}	21900 ± 556^{a}	16 ± 2.2^{a}	-
II(IFS-I)	2057 ± 33^{b}	40542 ± 2781^{b}	21.1 ± 2.7^{b}	-
III(IFS-II)	2778 ± 50^{c}	44125 ± 1842^{b}	22.2 ± 3.7^{b}	293900 ± 3241

Different superscripts (a, b and c) denotes significant difference and similar superscripts denote non-significant difference between treatments at 5% level. n=12 for all the parameters.

The Mean±SE of milk yield from 100 cows in one ha was also observed to be significantly higher in IFS-II (44125±1842 l yr^{-1}100cows^{-1}) and IFS-I (40542 ± 2781 l yr^{-1}100cows^{-1}) than NIFS (21900±556 l yr^{-1}100cows^{-1}). However, no such significant result was observed in IFS-I and IFS-II regarding the milk production (Table-14). The milk yield was found to be 85.1% and 101.5% higher in IFS-I and IFS-II respectively than the NIFS.

Regarding turmeric production on the pond dykes from one ha it was observed that Experiment-III (22.2 ± 3.7 t ha^{-1} yr^{-1}) and II (21.1 ± 2.7 t ha^{-1} yr^{-1}) had significantly higher ($p \leq 0.05$) production than Experiment-I (16 ± 2.2 t ha^{-1} yr^{-1}). Non significant production of turmeric was observed between IFS-I and IFS-II. Turmeric production was 31.3% higher in IFS-I and 37.3% higher in IFS-II than NIFS.

Experiment-III had additional production of 293900 number duck eggs from 2000 ducks grazing on one ha pond per year as reflected in Table-14.

Cost benefit analysis was done considering the expenditure incurred on the fingerling (@250 Rs kg^{-1}), feed (@14 Rs kg^{-1}) and turmeric seed (20 Rs kg^{-1}). The Mean±SE of total expenditure along with gross income and profit in Rupees are given in Table-15. It has been observed, that Experiment-III had achieved significantly ($p \leq 0.05$) higher profit (Rs 28.5 ± 0.4 lakhs yr^{-1} ha^{-1}) followed by Experiment-II (Rs 12.9 ± 0.2 lakhs yr^{-1} ha^{-1}) and Experiment-I (Rs 7.3±0.2 lakhs yr^{-1} ha^{-1}), respectively.

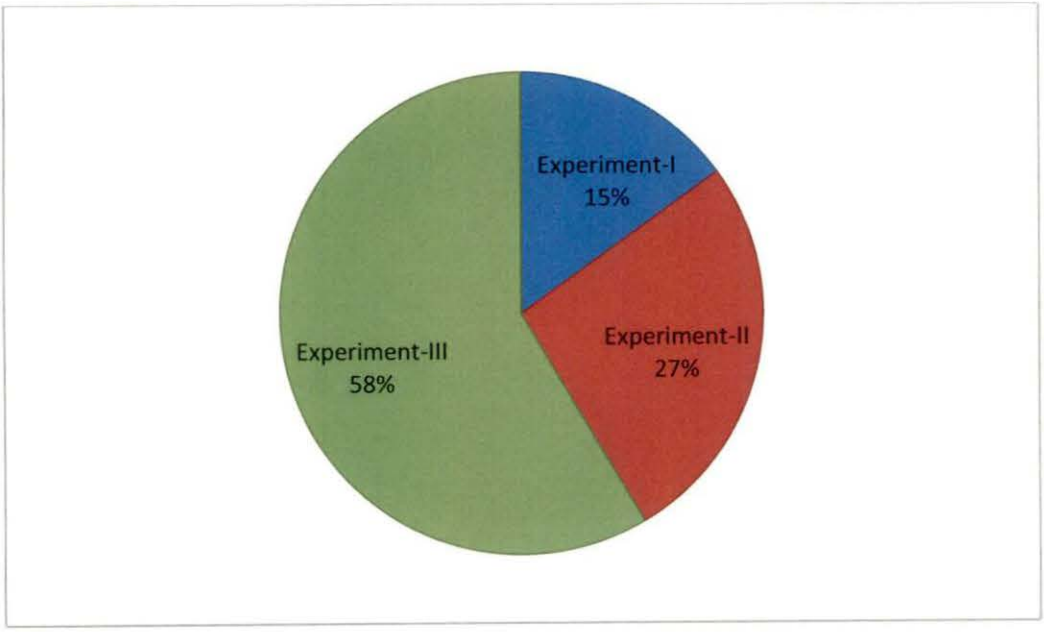
Table-15: Mean ± SE of total expenditure, gross income and net income (profit) under Experiment-I (NIFS), Experiment-II (IFS-I) and Experiment-III (IFS-II) during the four years (2008 to 2011).

Experiments	T E (Rs in lakhs yr^{-1} ha^{-1})	GI(Rs in lakhs yr^{-1} ha^{-1})	NI(Rs in lakhs yr^{-1} ha^{-1})	BC ratio
I(NIFS)	1.34 ± 0.1^{a}	8.7 ± 0.2^{a}	7.3 ± 0.2^{a}	6.5^{b}
II(IFS-I)	3.0 ± 0.1^{b}	15.9 ± 0.3^{b}	12.9 ± 0.2^{b}	5.3^{a}
III(IFS-II)	4.0 ± 0.2^{c}	32.5 ± 0.5^{c}	28.5 ± 0.4^{c}	8.1^{c}

Different superscripts (a, b and c) denotes significant difference between treatments at 5% level. n=12 for all the parameters. TE= Total Expenditure, GI=Gross Income,NI= Net Income and BC ratio= GI/TE.

About 58% of total net income was achieved from Experiment-III followed by Experiment-II (27%) and Experiment-I (15%) during the study period as reflected in Fig-25. On the contrary, the Benefit to Cost ratio (BC ratio) was not found to follow the similar trend as it was observed regarding net profit. In this present study the BC ratio was significantly lower in IFS-I followed by NIFS and then IFS-II.

Fig-25: Total sum of net income (profit) in percentage under Experiment-I (NIFS), Experiment-II (IFS-I) and Experiment-III (IFS-II) during the four years (2008 to 2011).



Discussion

The integration of aquaculture with livestock and crop farming offers great efficiency in resource utilization, reduces risk by diversifying crop, and provides additional food and income. This system involves recycling of wastes or by-products of one farming system as an input for another system and efficient utilisation of available farming space for maximum production. The livestock waste was used as source of nutrients in aquaculture which enters food-web in several ways namely, as food, as a source of mineral required for autotrophic production, and as organic substrates and minerals for heterotrophic microorganisms which are generally consumed directly by fish or by zooplankton. The bottom dwelling fishes, namely, common carp and mrigal directly utilises bacteria-coated organic particles in manure. In this era of technology, researchers from different corners of the world realize that intensive agriculture with indiscriminate use of agricultural inputs in the irrigated areas and cultivation of highly fragile lands in the rain fed areas have caused serious problems to sustainability of the agriculture. Judicious utilisation of natural resources, proper recycling of agricultural waste and reduction of production costs through different farming systems became the most important towards the sustainability in agriculture and environment. Hence, Integrated Farming System (IFS) can be considered as an important tool to increase farm productivity and sustainability of marginal farmers who have scarce resource in respect to land, finance and knowledge.

Suitable bottom soil condition and high quality water are essential ingredients for successful IFS. Higher amount of nutrients and organic matter as a result of excessive organic manuring and feed wastage often lead to poor water quality and bottom soil conditions. Therefore, the soil and water quality problems are common in aquaculture ponds under IFS.

Livestocks are an integrated and important part of most marginal farmers. About 84% of total draught power used in agriculture throughout the world is still provided by animals (Smith, 1979) and traditionally, animal wastes are used for fertilizer and fuel. With the increase in the demand of protein, the integrated aquaculture has been considered to be relevant and befitting to the rural poor. The use of large amount of wastes by aquaculture is often found to be more reliable, acceptable and profitable than the alternatives of removal and use in terrestrial cropping, or disposal by dumping.

The carp culture mainly involves two groups, such as, the three Indian Major Carps as Catla (*Catla catla*), Rohu (*Labeo rohita*) and Mrigal (*Cirrhinus mrigala*), and three domesticated exotic carps such as Silver Carp (*Hypophthalmichthys molitrix*), Grass Carp (*Ctenopharyngodon idella*) and Common Carp (*Cyprinus carpio*) . Carp culture in India was restricted only to a homestead backyard pond activity in Eastern Indian states of West Bengal and Orissa until late 1950s, with seed procured from riverine sources as the only input, resulting in very low levels of production. Though importance of fish culture as an economically promising enterprise was gradually realized, non-availability of quality fish seed and lack of scientific culture know-how constrained development of carp farming (ICAR, 2006).

In India, pond dykes are usually not used, but in China these are being used for multipurpose production. The top, inner and outer dykes of ponds as well as adjoining areas can be best utilised for horticulture crops. The success of the system depends on the selection of plants. Pond water is used for irrigation and silt, which is high-quality manure and contains several nutritive elements, as base manure for crops, vegetables and fruit bearing plants.

The results from the IFS vary as per the agro-climatic condition of the location where it is practised. Hence, proper assessment and refinement of this technology through different adaptive research can help in developing the location specific IFS packages, which can increase the overall farm productivity.

A typical marginal farmer of the Terai region of West Bengal, generally possesses a unit of small pond, a small unit of livestock such as cow and buffalo, duck and poultry, pig, sheep and goat along with less then 1-2 ha of land for crop production. Keeping in view the limited resources of the marginal farmers of the Terai region of West Bengal, three experiments were executed namely, Experiment-I, II and III. Out of these, as observed in Table-2, Experiment-I was considered to be Control (C), where Non Integrated Farming System (NIFS) was considered. Experiment-II and III were the different Integrated Farming Systems (IFS) followed in the farmer's field. The observations regarding the pond water quality, pond bottom soil quality, zooplankton production, fish growth and production and the economics of the different farming systems are discussed below.

5.1 Physico-Chemical Parameters of Pond Water and Pond Soil

5.1.1 Pond Water

In Integrated Fish Farming System, water is an important natural resource which should be utilised judiciously in order to conserve the same for future. It has been reported that conventional aquaculture consumes 5m^3 of water to produce 1 kg of fish (Avnimelech *et al.*, 2008). Water quality attributes like water temperature, light penetration, dissolved oxygen, total alkalinity and total hardness are the representatives of the seasonal fluctuation (Tepe *et al.*, 2005). The limiting factor in waste fed pond is the unstable quality of the water itself. Certain types of wastes are more likely to adversely overload or underload the pond system, causing a reduction in the fish yield. Boyd (1982) emphasised, that the goal of water quality management is to regulate environmental conditions so that they are within desirable range for survival and growth of fish. The waste-fed eutrophic pond was found to be more productive than a natural pond, but at the same time was less stable. This instability can be reduced by judicious management. It was evident that a balanced variety of fish species reduced the volatile and undesirable changes in water utilizing the different pond food organisms which typically triggered large changes in water quality (Little and Muir, 1987). As a result of deterioration in water quality, the fish become "stressed" and vulnerable to diseases. Therefore, it is very important to know about water quality parameters and their influence on growth and survival of fishes.

The water quality parameters like water temperature, pH, dissolved oxygen, total alkalinity and total hardness remain within the suitable range under the influence of organic manure (Rahman *et al.*, 2004). But the higher doses of manure more than 100kg DM (Dry Manure) ha $^{-1}$d $^{-1}$ deteriorate the water quality like water colour, total suspended solids that inhibit the light penetration and planktonic biomass productivity (Shevgoor *et al.*, 1994). However, Parvez *et al.*, (2006) reported non-significant difference among the physico-chemical parameters of pond water manured with organic waste and with and without inorganic fertilizers (Sayeed *et al.*, 2007).

In the present study, significant variation was observed regarding the different water quality parameters of the pond water in Experiment-I, II and III. It has been observed, that within Experiment-I (NIFS), Experiment-II(IFS-I) and Experiment-III(IFS-I), the values of all water quality parameters of pond waters were significantly different ($p \leq 0.05$) indicating that ponds manured with cowdung in IFS-I and additional duck grazing with cowdung manuring in IFS-II significantly changed all the studied water quality properties of the pond water.

5.1.1.1 Temperature

It is known, that water temperature sets the pace of fish metabolism by controlling molecular dynamics (diffusibility, solubility, fluidity) and biochemical reaction rates. It was reported, that the optimum temperature range for several coldwater and warm water fishes were 14° to18°C and 24° to 30°C, respectively. The optimum temperature required for growth of carp was reported to be 27-32°C (ICAR, 2006). In this study, the temperatures were found to be within the range from 23.7° C to 32.2°C in NIFS (Control), 24° C to32.6°C in Experiment-II and 25.0° to 32.0°C in Experiment-III, maintaining more or less the favourable condition for fish growth (Jana *et al.*, 2012).

In Experiment-I (NIFS) the average temperature was found to be significantly lower than Experiment-II (IFS-I) and Experiment-III (IFS-I) indicating that ponds under IFS-I and IFS-II had significantly higher mean water temperature. The process of decomposition, accumulation of different metabolites and increased biomass may be indicative for such increasing trend of temperature (Boyd, 1990 and 1995). The increased rate of biochemical activity of micro biota during increased temperature was found to be very significant (Rath, 2011). Sheri *et al.*, (1987) in his studies reported that the best growth of Major Carps can be achieved at water temperature ranging from 26°C to 29°C. Oyugi *et al.*, (2012) also revealed maximum growth in common carp when the temperature was between 24°C to 28°C. It was also reported by Rath (2000) that Grass Carp can withstand temperature up to 40°C and IMC can thrive well in the temperature range of 18.3°C to 37.8°C.

As the experiment progressed, the temperature of the pond varied with climate charge under NIFS, IFS-I and IFS-II and an increasing trend was observed in summer followed by pre-monsoon and monsoon. This result might be due to the influence of the environmental temperature as in summer and rainy seasons. Ahmad and Garnett (2011) also observed that water temperature follow the air temperature. Similar findings of Lashari *et al.*, (2009) and Tidame and Shinde (2012) supported the present study that water temperature in the monsoon season was higher than the summer season due to the climatic changes.

5.1.1.2 pH of the pond water

pH is a measure of hydrogen ion concentration in water and indicates level of is acidity. Lopes *et al.*, (2001) realised water pH as an important factor to ensure good fish production. Water pH affects metabolism and physiological processes of fish. It also exerts considerable influence on toxicity of ammonia as well as solubility of nutrients and thereby water fertility (ICAR, 2006). According to Wurts and Durborow (1992), the recommended pH range for aquaculture farming is 6.5 to 9.0. Again, Heydarnejad (2012) found that the best range of pH for carp production was 7.5 to 8.0.

In the present study, the pH of the pond water in Experiment I, II and III were found to in the range of 5.8 to 8.2 maintaining favourable environment for fish production. This corroborates with the report given by ICAR, (2006) on the optimum pH for carp growth as 7.5 to 8.3. The pond water pH was found to be significantly lower in the present study when the manure was applied to the ponds under IFS-I and IFS-II than the Control. This result was supported by similar findings of Jha *et al.*, (2008) that utilisation manure lowered the pH of the pond water.

Seasonal variation of the pH observed in this study (Fig- 8) was found to be decreased in the monsoon season than in the summer. A similar result was observed by Shiddamallayya and Pratima (2008).

5.1.1.3 Dissolved Oxygen

Variation in water quality, especially in dissolved oxygen concentration, may be harmful to fish growth, or even cause acute mortalities. In this study Experiment-I had significantly higher dissolved oxygen concentration (Table-4) followed by Experiment-III and Experiment-II reflecting, that manuring decreases the dissolved oxygen in IFS-I whereas duck grazing in the ponds under IFI-II increases the same (Little and Muir, 1987). Dissolved oxygen is removed from the water through decomposition of organic matter that enters into the pond through cowdung (Jana and Sarkar, 2005). Grazing ducks in IFS-II had aerated the pond water and helped in maintaining more favourable condition in the pre-monsoon and monsoon season.

In Experiment-I (NIFS), the dissolved oxygen concentration ranged from 5.2 to 7.2 mgl^{-1}, whereas, in Experiment-II (IFS-I), where cow dung was used to fertilise the ponds the dissolved oxygen concentration was lowered and ranged from 4.7 to 6.9 mgl^{-1}. In Experiment-III (IFS-II), the higher range of dissolved oxygen concentration was found (5.2 to 7.1 mgl^{-1}) as the duck was allowed to graze and swim in the pond along with the cow dung fertilisation. The optimum dissolved oxygen concentration in fish pond was reported to be more than 4 mgl^{-1} by ICAR (2006). Rath (2011) also expressed that decrease in dissolved oxygen is directly related to increase in temperature.

It was also revealed from Table-5 that manuring decreased the dissolved oxygen concentration thereby maintaining the optimum level for fish farming in IFS-I and IFS-II. High doses of cow dung and poultry manuring were found to reduce the value of dissolved oxygen (DO), while optimum dose that is, 0.26 kg m^{-3} maintained the better water quality and abundance of planktonic biomass, which improved the growth of carps species (Jha *et al.*, 2004).

It was also known that low dissolved oxygen concentration enhanced the toxic effect of ammonium-N in fish pond. Hence, duck rearing on the ponds under IFS-II helped to reduce the toxicity of increased ammonium-N by increasing the dissolved oxygen concentration. Sharma *et al.,* (2005) obtained similar result in his study on duck-cum-fish in IFS where the value of dissolved oxygen increased and ranged from 8.2 to 9.20 mgl^{-1} .

A decreasing trend of dissolved oxygen was observed from the month of April (summer season) to September (monsoon season) in the experimental ponds of IFS-I and NIFS as presented in Fig-9. However, the ponds under IFS-II showed decreasing trend in the summer season but; by introduction of ducks to swim in the ponds, the dissolved oxygen concentration was found to be increased and was maintained stable till the month of September (Fig-10). In the monsoon it was found that IFS-II had dissolved oxygen more than the Control and IFS-I. This result might be due to the fact that grazing ducks had aerated the pond water and helped in maintaining more favourable condition in the month of July, August and September (pre-monsoon and monsoon season). Mustapha (2008) in his study also found dissolved oxygen to be the maximum in wet season than in dry season.

5.1.1.4 Free Carbon dioxide

Significantly higher values of Free carbon dioxide concentration in the treated ponds were observed in Experiment-III (IFS-I) followed by Experiment-II (IFS-II) and Experiment-I (NIFS) and ranged between 0.5 to 4.5mgl^{-1}, respectively (Table-5). Decomposition of the organic manure and respiration of the aquatic organisms in the IFS-I and IFS-II may be the cause of this increased value of average free carbon dioxide (2.87mgl^{-1} and 3.14mgl^{-1}, respectively) than the Control (1.80 mgl^{-1}). Wurts and Durborow (1992) similarly reported, that carbon dioxide concentrations can become high as a result of respiration. In the present study, the value of free carbon dioxide concentration was below 8 mgl^{-1}. As mentioned by ICAR (2006), that fresh water fish ponds should contain low concentration of free carbon dioxide, that is, less than 8 mgl^{-1}.

Carbon dioxide rarely causes direct toxicity to fish. However, a high concentration of carbon dioxide lowers the pond pH and affects the fish production. There was a negative correlation ($r = -0.796$; $p \leq 0.01$) observed between free carbon dioxide and pH in this study. Aeration and pH of water by hydrated lime (calcium hydroxide) can control high free carbon dioxide concentration.

In the pre-monsoon and monsoon season higher level of free carbon dioxide concentration was observed than the summer season. It may be perceived that the increased temperature in the month of July, August and September enhanced the decomposition of the waste in pond and the respiration of the growing aquatic organisms including fishes resulted in the increased value of free carbon dioxide. In this present study, positive correlation ($r=0.652$; $p \leq 0.01$) was found between the water temperature and free carbon dioxide concentration. On the contrary, the lowest amount of free carbon-dioxide was recorded by Narayan *et al.*, (2007) in monsoon and the highest in summer suggesting that the decomposition of organic matter was fast during summer whereas it was low during monsoon.

5.1.1.5 Total alkalinity

Murad and Boyd (1991) stated that ponds should have at least 20 mgl^{-1} of total alkalinity for good fish production. Pond water with a low alkalinity (less than 20 mgl^{-1}) has a very low buffering capacity and consequently is much vulnerable to fluctuations in pH, especially during rainfall when phytoplankton blooms. In the present study, the mean total alkalinity was found to be more than 20 mgl^{-1} in the three treatments throughout the experiment. However, Experiment-III ($73.29\pm0.72 mgl^{-1}$) had significantly higher total alkalinity than Experiment-II (68.54 ± 0.77 mgl^{-1}) and Experiment-I (30.64 ± 0.59 mgl^{-1}). The ideal range of total alkalinity of water for freshwater fish pond is reported to be 60-300 mgl^{-1} (ICAR, 2006). Hence, it is observed that use of organic inputs increased the total alkalinity at higher levels and even resulted in increase in alkalinity compared to use of inorganic inputs (Knud Hansen *et al.*, 1991; Teichert-Coddington *et al.*, 1992; Diana *et al.*, 1994a).

It was observed that alkalinity potentially limited primary production and fish yield, since inorganic carbon was necessary for photosynthesis (Diana *et al.*, 1997). Boyd (1990) showed that alkalinity below 30mgl^{-1}, as $CaCO_3$, limited primary production in well-fertilized ponds, while in unfertilized ponds alkalinities below 120mgl^{-1} could reduce primary production. Diana *et al.*, (1997) also mentioned that use of organic inputs probably reverses the trend of carbon extraction during photosynthesis because of added CO_2 inputs and decomposition of manure in pond soils.

In the pre-monsoon and monsoon season the trend of alkalinity was found to be increased (Fig-12), which may be due to the increased rate of decomposition of organic matter in water body. This result was supported by the findings of

Shiddamallayya and Pratima (2008) and Tidame and Shinde (2012) that the decomposition of organic matter increased the value of alkalinity in water.

5.1.1.6 Total Hardness

The ponds under IFS-II showed significantly higher total hardness (82.47±0.58 mgl^{-1}) in this study followed by IFS-I (77.70±0.66 mgl^{-1}) and the NIFS (51.47±0.69 mgl^{-1}). This result revealed that organic loads like cowdung and duck droppings increased the pond water hardness in the IFS-II and IFS-I. Similar result was achieved by Jha *et al.*, (2008). Rajagopal *et al.*, (2010) in their study mentioned that the increase in total hardness can be attributed to the decrease in water volume and increase in the rate of evaporation at high temperature, high loading organic substances, detergents, chlorides and other pollutants.

NIFS showed slightly increasing trend of mean Total hardness in the pond water (Fig-13) after the summer season. On the other hand, in IFS-I and IFS-II increasing trend was followed from the month of April onwards when temperature were high ($r = 0.389$; $p \leq 0.01$). Kaur and Sharma (2001) and Tidame and Shinde (2012) also reported highest total hardness in summer and lowest in winter.

5.1.1.7 Chloride

Ponds under Experiment-III were found to have significantly higher Chloride content (29.18±0.67 mgl^{-1}) than that under Experiment-II (24.17±0.70 mgl^{-1}) and Experiment-I (17.14±0.54 mgl^{-1}); indicating that the animal excreta used in this study increased the chloride level of the pond water. It is known, that the most important source of chloride in the water is considered to be from the discharge of the domestic sewage and animal excreta. Man and other animals excrete very high quantities of chlorides together with nitrogenous compounds (Trivedy and Goel, 1984). Therefore, in this study chloride content can be considered as an indicator of pollution occurring due to the animal excreta being utilised in the pond water. However, its concentration up to 1500 mgl^{-1} is harmless (Trivedy and Goel, 1984). In this study, Experiment- III had higher chloride content indicating that the excreta of cow and ducks together increased the chloride content of the pond water. However, the range of chloride concentration remained within optimum level 5 to 40 mgl^{-1} in all the experiment and 5 to -28 mgl^{-1} for NIFS, 10 to 40 mgl^{-1} for IFS-I and 18 to 40 mgl^{-1} for IFS-II throughout the study period.

A steady increased trend of chloride concentration was observed from the month of April to September in IFS-II and IFS-I than the Control (NIFS) suggesting increased level of chloride concentration in monsoon season. Shiddamallayya and Pratima(2008); Venkatesharaju *et al.*, (2010) and Tidame and Shinde (2012) also observed highest concentrations of chloride in monsoon.

5.1.1.8 Ammonium-N

The means of Ammonium-N concentration was observed to be significantly ($p \leq 0.05$) different in the three experiments conducted. The Mean±S.E of the ammonium-N concentration in the treated ponds under IFS-II (0.36±0.002 mgl^{-1}) was found to be significantly higher followed by IFS-I (0.29±0.018 mgl^{-1}) and then NIFS (0.16±0.013 mgl^{-1}). Biswas, *et al.* (2006) expressed three different concentration levels of ammonium (a) favourable concentration range : 0.262 to 0.294 mgl^{-1}, (b) growth-inhibiting concentration range : 0.313 to 0.322 mgl^{-1} and (c) lethal concentration range : 0.323 to 0.422 mgl^{-1}. All the average values of ammonium-N concentration in the ponds under IFS-I and NIFS remained lower than the value of threshold concentration ammonium-N (0.313 mgl^{-1}) but in IFS-II the value was found to be slightly above the threshold concentration. This might be due to the utilization of both cow and duck waste in the ponds under IFS-II. Lloyd and Herbert (1960) showed that the toxicity of ammonia decreases with increasing carbon dioxide concentration. In the present study, the average value of free carbon dioxide (mg l^{-1}) in IFS-II was also higher which might have managed the toxicity of ammonia and created desirable environment for aquatic production. High dissolved oxygen, high carbon dioxide and high phytoplankton concentrations reduce the toxicity of the ammonia (ICAR, 2006). In the present study, it was observed that duck swimming in the ponds treated with IFS-II increased the concentration of the dissolved oxygen and the free carbon dioxide and as a result the toxicity of the ammonia might have reduced to maintain favourable condition for fish growth.

A sharp increasing trend of ammonium-N concentration was observed from the month of April to September in all the three experiment (Fig-15) indicating that in the pre- monsoon and monsoon ammonium-N concentration increased considerable than summer season. This may be due to low photosynthesis and high organic waste decomposition during the period of experiment.

5.1.1.9 Nitrite-N

Nitrite-N represents the intermediate form of nitrification and denitrification reactions in nitrogen cycle. Under normal conditions, well-oxygenated ponds have negligible concentration of nitrite. Nitrite-N is a very unstable ion and gets converted into either ammonia or nitrate depending on the prevailing situation in the water (Trivedy and Goel, 1984). Boyd (1982) observed, that regardless the source; ponds occasionally contain nitrite-N of 0.5 to 5.0 mgl^{-1}. Again, concentrations of nitrite-N as low as 0.5 mgl^{-1} were found to be toxic to certain cold water fish (Crawford and Allen, 1977). In the present study, average nitrite-N content was observed to be significantly higher ($p \leq 0.05$) in Experiment-III (0.036 mgl^{-1}) followed by

Experiment-II (0.024 mgl^{-1}) and Experiment-I (0.02 mgl^{-1}). The concentration of the nitrite-N was found to be higher in the IFS-I and IFS-II experimented ponds but, maintaining the favourable condition for fish growth. Effective removal of organic wastes, adequate aeration and correct application of fertilizers are the methods to prevent accumulation of nitrite to a toxic level in pond culture (ICAR, 2006). Hence, periodical pond manuring with cow dung and ducks swimming on the ponds maintained the nitrite-N below the toxic level in the integrated farming system.

5.1.1.10 Nitrate-N

Nitrate represents the highest oxidised form of nitrogen. The most important source of the nitrate is the biological oxidation of the organic nitrogenous substances which comes from the livestock waste in this study. High amount of nitrate denotes the aerobic conditions and high stability of the waste (Trivedy and Goel, 1984). In the present study, nitrate-N concentration ranges from 0.01 to 0.79 mgl^{-1} with an average value of 0.459 mgl^{-1} in IFS-II, 0.368 mgl^{-1} in IFS-I and 0.22 mgl^{-1}NIFS. It was observed in this study that utilisation of manure significantly increased the nitrate-N concentration of the pond water in IFS-I and IFS-II.

As the experiment proceeded, sharp increasing trend of nitrate-N concentration was observed from summer to rainy season. The increased oxidation of the nitrogenous compounds of animal waste associated with the increased temperature from April to September may be the indication of present result (Fig-17).

5.1.1.11 Phosphate-P

Phosphorus is commonly considered the major limiting nutrient in freshwater, and additions of phosphorus often result in increased primary production, whether in natural (Vallentyne, 1974) or in aquaculture systems (Boyd, 1990; Diana *et al.*, 1991).

Phosphorus is mainly available to plants as orthophosphate (Diana *et al.*, 1997) and its concentration increases almost immediately after ponds are fertilized (Boyd,1982).The orthophosphate present in water immediately after fertilization may be absorbed by bacteria, phytoplankton and macrophytes (Rigler,1956 and 1964; Hayes and Phillips, 1958). However, phosphorus that is not absorbed by plants is rapidly absorbed by mud (Hepher, 1958). Combined inputs of both nitrogen and phosphorus are necessary to drive high levels of primary production (Diana *et al.*, 1997). In this study, Experiment-III had significantly the highest ($p \leq 0.5$) Phosphate- P concentration (0.59 ± 0.02 mgl^{-1}), indicating that duck grazing might have affected the Phosphate-P concentration in pond water. Kang'ombe *et al.*, (2006) also observed that poultry manure mainly donates nitrogen and phosphates to pond water, which boosts the pond productivity (natural food of fish) and in turn enhances the weight increment in fish. In IFS-II of this study, it showed a stable value of phosphate-P concentration in the month of July, August and September in comparison to IFS-I indicating that duck manuring maintained the phosphate-P level (Fig-17).

5.1.2 Pond Bottom Soil

The productivity of a fish pond depends on the physical, chemical and biological properties of the pond soil. Pond bottom acts as the laboratory, where process of mineralization of organic matter takes place and nutrients are released to overlying water column. Physical properties of soil, like texture and water retention ability, and chemical properties like pH, organic carbon, available nitrogen and available phosphorus are important parameters, which require considerable attention for effective pond management (Boyd, 2008).

5.1.2.1 Soil pH

Slightly acidic to neutral soil, with pH 6.5 to7.0 is considered productive. However, the ideal range for soil pH is 6-8 as reported by ICAR (2006) and 7.5 to 8.5 according to Boyd (2008). In the present study, the average pH value 7.48, 7.60 and 7.47 of the bottom soil was observed to be non-significant ($p \geq 0.05$) amongst the Experiments-I, II and III, respectively maintaining favourable condition for fish production. Silapajarn *et al.*, (2004), in their study, explored that soil pH averaged 7.15, but the minimum value was 5.05 and the maximum was 8.10. However, in the present study, the minimum and maximum value of soil pH was found to be 5.5 to 9.3, 6.2 to 9.4 and 5.7 to 9.6 in Experiment-I, II and III, respectively which corroborates with the findings of Boyd *et al.*, (2002) that pond bottom soil pH can range from less than 4 to more than 9.

Banerjea (1967) mentioned that best pH value for pond soils to be 6.5 to 7.5 and pH value of 5.5 to 8.5 was considered to be acceptable. But, Boyd (1995) argued, that aquaculture pond soil should not have pH below 7.0 and the average value of soil pH in all the treated ponds was observed to be above 7.0. According to Boyd *et al.*, (2002) maximum availability of soil phosphorus usually occurs at about pH 7.0 and most soil microorganisms, and especially soil bacteria, function best at pH 7.0 to 8.0. In this study, the average pH value was within 7.0 to 8.0 in all the three experiments maintaining favourable condition for fish production.

5.1.2.2 Pond Soil Organic-C

The average values of Organic-C, 0.97%, 0.95% and 0.83% were found to be significantly higher ($p \leq 0.05$) in manure fed ponds under Experiment-II followed by III and Experiment-I, respectively. In the present study, Organic- C was found to be in the range from 0.66 to1.11% in Experiment-I (Control), 0.86 to 1.30% in Experiment-II, where cow manuring was done and 0.75 to 1.33% in Experiment-III where the ponds were treated with cow manuring along with the duck manuring indicating that the organic –C range were maintained for the achievement of average or medium fish production.

Banerjea (1967) evaluated the potential of a large number of ponds in India for fish production and found that organic carbon concentrations in soils of less than 0.5 % and greater than 2.5 % resulted in low fish production. Low organic carbon was associated with low productivity of phytoplankton and bottom organisms; whereas high organic carbon caused anaerobic conditions in the pond bottom soils. According to Banerjea (1967), average fish production was achieved in ponds with 0.5 % to 1.5 % organic carbon, and 1.5 % to 2.5 % organic carbon was associated with high fish production. Adhikary (2003) also mentioned in his study that organic carbon acts as a source of energy for bacteria and other microbes that release nutrients through various biochemical processes. Pond soils with less than 0.5% organic carbon was considered unproductive while those in the range of 0.5-1.5% and 1.5-2.5% to have medium and high productivity, respectively (Rath, 2011). Organic carbon content of more than 2.5% may not be suitable for fish production, since it may lead to an excessive bloom of microbes and oxygen depletion in the water.

Boyd *et al.*, (2002) gave a general recommendation that organic carbon concentration in pond bottom soils should be between 1 and 3 percent, but in ponds where fish are fed, organic matter concentrations below 1 percent are acceptable. In the present study, the ponds were treated with organic waste along with fish feed and had average organic-C less than 1% in all the three experiments which was acceptable in aquaculture.

The organic-C content of all the treated pond bottom soil in the present study increased slightly from the month of April to September during the experiment. Boyd (2002) agreed with the fact that organic matter concentrations in pond soils do not continue to increase indefinitely. If aquaculture practices remained about the same, the annual input of organic matter and the rate of organic matter decomposition also remain about the same (Avnimelech *et al.*, 1984 and Boyd, 1995).

New ponds usually have little organic matter in bottom soil, and the labile organic matter added each year will largely decompose, while a considerable proportion of refractory organic matter will accumulate (Boyd, 1995). Every year removal of the desilted pond bottom soil for crop production on the pond dykes might have maintained the favourable organic-C content for fish growth in the present study.

5.1.2.3 Total Pond Soil Nitrogen

It was observed that the total nitrogen percentage ranged from 0.068% to 0.088%, 0.011%-0.130% and 0.081% to 0.133% in Experiment-I (Control), Experiment-II (IFS-I) and Experiment-III (IFS-II), respectively. Again, the average value of total percentage of nitrogen present in the bottom soil of the manure treated pond under Experiment-II and Experiment-III was significantly ($p \leq 0.05$) higher (0.095% and 0.0985%) than Experiment-I (0.078%).

Silapajarn *et al.*, (2004) found in their study that the average concentration of total nitrogen was 0.08 % and were in the range between 0.01 to 0.50 %. They realised that low concentrations of total nitrogen are normal in soils with low organic matter concentrations, because nitrogen is present in pond soil primarily as a component of organic matter.

Banerjea (1967) suggested that 0.05-0.075% of total nitrogen of soil may be taken as relatively more favourable for aquaculture. But, in the present study average value of the total nitrogen was found to be above 0.075% and maintained favourable condition of for aquaculture.

5.1.2.4 Carbon to Nitrogen Ratio (C: N Ratio)

The carbon to nitrogen (C: N) ratio of soil influences the activity of soil microbes to a great extent. This in turn affects the rate of release of nutrients from decomposing organic matter. The rate of breakdown (mineralization) is very fast, moderately fast and slow at C: N in the range of less than 10, 10-20 and more than 20 respectively (Adhikary, 2003). In the present study, the average value of C: N ratio was found to be nonsignificantly higher in IFS-I (11.09±1.13), NIFS (10.61±0.14) and IFS-II (9.68±0.10).

Adhikary (2003) reported that in general, soil C: N ratios between 10-15 were considered favourable for aquaculture and a ratio of 20:1 or narrower gives good results. Banerjea (1967) also reported that fish production was lower in ponds with carbon: nitrogen ratios below 10 than in those with ratios above 10. He also mentioned that the range of C: N ratio between 10-15 was best for fish production. In the present study, the average C: N ratio was found to be approximately around 10-11 in all the treated pond bottom soil which was favourable for aquaculture.

In a study conducted by Silapajarn *et al.*, (2004) it was reflected that Carbon: Nitrogen ratios ranged from 5.4 to 75 with an average of 18.4. Boyd *et al.*, (2002) mentioned, that pond soils with low Carbon: Nitrogen ratios tend to have highly decomposable organic matter, and anaerobic conditions at the soil-water interface may be a common problem.

5.2 Productions of Zooplankton

In the present study, qualitative and quantitative analysis of the zooplankton of the Experimental ponds were done because it was reported by Rahman *et al.*, (2006) that the IMC and Grass Carp prefer to feed on zooplanktons. Similarly, Ekelemu (2010) emphasised, that zooplankton is very important in the food web of open water ecosystem. In the present study, ponds under IFS-II and IFS-I were found to contain significantly higher concentration of zooplanktons (131±12 no l^{-1} and 128±11 no l^{-1}, respectively) than NIFS (27 ± 2 no l^{-1}). However, no significant difference was observed regarding the mean value of zooplankton count found in IFS-II and IFS-I. This result indicated that the organic manuring of the ponds had positive effect on zooplankton production. The present finding is, therefore, in agreement with the findings of Wohlfarth and Schroeder (1979); Delmendo (1980); and Little and Muir (1987) that, manuring enhances the zooplankton production.

Jha *et al.*, (2004) found that application of both cow dung and poultry manure, at the rate of 0.26kg $m^{2\ -1}$ 10 d^{-1}, is most suitable for better growth of Koi Carp in tanks through maintenance of better water quality and greater abundance of plankton in the system. Other workers like, Hickling (1962), Buck and Baur (1980), Motokubo *et al.*, (1988), Jhingran (1991), reported that organic manuring results in higher zooplankton densities in the ponds. Hence, it can be concluded that in the given IFS-I and IFS-II, zooplankton population improved significantly with the application of the manure and maintenance of the water quality was favourable for fish production.

There was also significant difference in the mean zooplankton production under different farming systems throughout the summer and monsoon months. A pattern of sharp increase in the zooplankton production up to May month (2008 -

2011) was observed in all the three treated ponds. This may be due to the fact, that the fingerlings were small and required to graze less on the zooplankton in the month of April. From the month of June onwards the zooplankton count was observed to be decreasing sharply. This may due to the increased intake of zooplanktons by the growing fishes in the pond (Little and Muir, 1987).

Qualitative analysis of zooplanktons were done and identified zooplanktons in this study were under 3 orders namely Copepoda, Rotifera, and Cladocera. Dominant groups of the zooplankton available in all the samples were observed to be Copepoda (*Cyclops sp.* and *Diaptomus sp.*) and Cladocera (*Daphnia sp.*). The population of the same was observed to have increased in the samples of IFS-I and IFS-II indicating, that manure had a favourable effect on the production of Copepoda and Cladocera. In this study it was also observed that organic manure, such as cowdung, significantly increased the production of *Daphnia, Moina*, *Cyclops*, *Brachionus* along with *Diaptomus* and *Keratella* in Experiment-II(IFS-I). In Experiment-III(IFS-II), where combination of cowdung and duck rearing in the pond was followed, significant increase of *Daphnia, Moina*, *Cyclops*, *Brachionus*, *Diaptomus, Keratella* along with *Bosmina* was observed. This result indicated that, in the IFS-II duck grazing along with cowdung application appeared to be more effective when compared to cowdung application alone. This is in agreement with earlier findings by Singh and Sharma (1999) that duck dropping helped to increase the zooplankton population and its diversity.

Okonji and Obi (1999) , agreed that organic fertilizer produced more of the smaller-size zooplanktons (Rotifers, Cladocerons), while inorganic fertilizer favoured the production of larger-sized zooplanktons (Copepods). Rappaport *et al.*, (1977), reported a general increase in the contribution of Rotifers to zooplankton in ponds manured with chicken droppings and cereals manure; but the dominance of Copepods were observed in Control and the ponds receiving liquid cowdung. On the contrary, Dhawan and Kaur (2002a) reported a decrease in Cladoceran population with increased organic manure application. Frequent application of low doses of manure resulted in significantly higher number and biomass of *Daphnia* (Jana and Chakraborti, 1997).

Ekelemu and Nwabueze (2011) revealed that poultry droppings, compared to cow dung and pig dung, produced more zooplanktons. They also observed, that cow dung produced more rotifers, poultry droppings more Cladocera and pig dung more Copepods. In the present study, cowdung produced more Rotifera and Copepoda but duck droppings produced more Cladocera. Sasmal *et al.*, (2008) suggested, that duck excreta was a good source of nutrient as it was easily soluble in water and available for plankton production. Damle and Chari (2011) observed that lack of zooplankton caused poor survival of spawn in nursery ponds. Poultry manures were found to release soluble salts continuously, resulting in high production of zooplankton (Gaur and Chari, 2007). Wurts (2004) reported, that better abundance of planktons supported large population of fish species. This finding was also reflected, in Experiment-III with greater abundance of zooplanktons the production of the fishes was also significantly high as 2778 ± 50 kg yr^{-1} ha^{-1}.It was also opined that introduction of live zooplankton into a fish culture unit increases the growth rate of carp species (Jha *et al.*, 2006).

Further, was also observed that except water temperature and pond bottom soil pH, zooplankton concentration was found to be significantly correlated ($p \leq 0.01$) with all the physico-chemical parameters of pond water and bottom soil as summarized in Table-12. Negative correlation was observed with water pH and dissolved oxygen concentration in this study. Similar inverse relationship was also observed between zooplankton and dissolved oxygen by Shayestehfar *et al.*, (2010). However, Yamada and Ikeda (1999) observed that zooplankton of freshwater was sensitive to acidic pH. Again, Koli and Muley (2012) observed positive correlation of pH- value with rotifers whereas, a negative correlation of pH-value with copepods.

In the present study, it can be concluded that ponds under IFS-I and IFS-II the zooplankton diversity and production was significantly higher than NIFS indicating that utilization of cow dung and duck manure for aquaculture can successfully increase the availability of the natural food to support the growing fishes in the integrated fish farming systems followed in the Terai region of West Bengal and thus help to reduce the feed cost. It was also observed, that from April to May there was a sharp increase in the availability of the zooplanktons but after June continuous decreasing trend was followed along with the growing fishes in the cultured ponds. The findings of the present study will thus help to improve the management strategies of the ponds culture under different farming system so that the input cost can be reduced by the utilization of the farm wastes which in turns can control environmental pollution maintaining pond water favourable for aquaculture.

5.3 Growth and production of the Indian Major Carps (IMC) and Exotic Carp

Animal manure is often used in semi-intensive systems to improve the primary production of the ponds and fish growth (Nwachukwu, 1997). Manure input and fish yield are directly related with each other (Diana and Lin, 1998; Ansa and Jiya, 2002). Accordingly, in this study also application of manure in IFS-I and IFS-II showed significantly positive effect on the monthly growth rate of IMC. Jha *et al.*, (2004) found, that application of both cow dung and poultry manure, at the rate of 0.26kgm^{2} $^{-1}$10 d^{-1}, are most suitable for better growth of Koi Carp in tanks. Significantly higher

($p \leq 0.05$) monthly growth rate of IMC was found in Experiment-III and II than the Control (Experiment-I) as presented in Table-14.

Similarly, Sughra *et al.*, (2003) and Kanwal *et al.*, (2003) observed that cow dung was an effective source of organic fertilization, which positively influenced the growth performance of Major Carps in respect of fish production. As also evident by workers in Israel (Moav *et al.*, 1977), the high fish yields are obtainable using cattle slurry and the cattle waste inputs into the pond.

However, in case of *Ctenopharyngodon idella* (Grass Carp) the monthly growth rate was found to be non-significantly ($p \geq 0.05$) higher in Experiment-III, followed by Experiment-II and then Experiment-I. Similarly, Parvez *et al.*, (2006) found that *Cirrhinus mrigala* and *Cyprinus carpio* responded best in manured ponds with homestead organic wastes while *Ctenopharyngodon idella* did not show any marked response .

Throughout the study period, it was also observed that irrespective of any farming system followed as NIFS, IFS-I and IFS-II, the average monthly growth rate pattern was highest in *Catla catla* followed by *Ctenopharyngodon idella*, *Labeo rohita* and *Cirrhina mrigala*, respectively. This indicated, a quick and high return in *Catla catla* followed by *Ctenopharyngodon idella*, *Labeo rohita* and *Cirrhina mrigala* production under village condition. However, Rahman *et al.*, (2008) observed that Common Carp growth in polyculture with *Labeo rohita* was higher in the presence of artificial feed and negatively correlated with natural food availability. *Cirrhinus cirrhosus* and *Cyprinus carpio* showed maximum growth in manured ponds than control ponds (Dhawan and Kaur, 2002a and 2002b).

High fish yield was also obtained in Israel, @ 30 kg ha $^{-1}$d $^{-1}$ with cattle manure (Schroeder, 1975), @40 kg ha $^{-1}$d $^{-1}$ with duck manure and waste feed (Wohlfarth, 1978) and @20 kg ha $^{-1}$d $^{-1}$ with chicken manure (Milstein *et al.*, 1995). However, in the present study, 17.36 kg ha $^{-1}$d $^{-1}$ was achieved in the IFS-II, having duck rearing on the pond along with cowdung manuring (Experiment-III); 12.86 kg ha $^{-1}$d $^{-1}$ was achieved in the IFS-I having only cowdung manuring (Experiment-II) and 6.67 kg ha $^{-1}$d $^{-1}$ was achieved in the Control (NIFS) with no periodical cowdung manuring (Experiment-I). This may be due to the fact that though cowdung manuring improved the nutritional status of the pond but it also resulted in decreased dissolved oxygen content in the treated ponds. This condition might have been improved by the ducks swimming on the manure fed ponds and as a result positive effect was achieved regarding the monthly growth rate of the fishes.

Buentello *et al.*, (2000) also studied the effect of dissolved oxygen on daily feed consumption, feed utilization and growth of channel catfish. They observed that higher dissolved oxygen levels produced increased feed consumption and as dissolved oxygen declined from 100% to 30% there was a progressive reduction in feed intake.

It was further observed in this study, that the total production of fishes was achieved as 1067kg, 2057 kg and 2778 kg in Experiment-I, II and III within 5 months from 1.0 ha of pond. The total fish production was found to be significantly ($p \leq 0.05$) higher in IFS-II (Experiment-III) followed by IFS-I (Experiment-II) where the organic manure was utilised for aquaculture than NIFS (Experiment-I) as summarised in Table-17. In an experiment conducted by Singh and Sharma (1999) it was revealed that ponds treated with poultry excreta showed higher fish production (2663.50 kg ha $^{-1}$ yr $^{-1}$) as compared to ponds treated with pig dung (2219 kg ha $^{-1}$ yr $^{-1}$) and cow dung (789 kg ha $^{-1}$ yr $^{-1}$). Banerjee *et al.*, (1979) also revealed a net production of fish as 535 kg ha $^{-1}$ 90 d $^{-1}$ when the pond was manured with cow dung and an increased net production of 670 kg ha $^{-1}$ 90 d $^{-1}$ manured with poultry droppings. In another experiment, Dutta and Goswami (1988) showed an average net gain of fish of 781.4 kg ha $^{-1}$ in control, 3013.8 kg ha $^{-1}$ in cow manured and 3030.8 kg ha $^{-1}$ in pig manured ponds.

It was also reported by Schroeder (1978), that manures could achieve75% of the yields by using supplementary feeding of grains and 60% of the yields are possible with protein-rich pellets. Schroeder (1978) admitted that fish yield in properly designed and managed manure loaded ponds can reach 5 to 10 tonnes/ ha /yr, without any supplemental feeding. Patra and Ray (1988) revealed, that the use of organic manures namely pigeon droppings, goat dung and raw cow dung were recommended for increased production of fish in ponds of West Bengal.

Sharma (1974), Jhingran and Sharma (1980), Sharma and Olah (1986) and Sharma *et al.*, (1988) observed, 200 to 300 ducks and 250 to 300 layer poultry birds produced 3 to 4 tonnes and 4 tonnes of fish /year respectively, when recycled in one hectare of water area under the polyculture of Indian and exotic fish. This results is because of the fact that the nutritional value of natural food organisms present in a pond is sufficient to support excellent fish growth (De Silva and Anderson, 1995). Phytoplankton and zooplankton (rich source of protein), often contain 40 per cent to 60 per cent protein on dry matter basis (Pillay, 1995). The high protein content of natural food organisms is efficiently utilized in the early growth stages of semi-intensively cultured fish. Song (1994) reported that common carp utilized about 80 percent to 90 per cent of crude protein content of its important food organisms.

5.4 Economics of NIFS, IFS-I and IFS-II

Cost benefit analysis was done considering the expenditure incurred on the fingerling (@ Rs250/kg), feed (@Rs14/kg) and turmeric seed (@Rs 20/kg), when $1 = Rupees 50. The cost of labour was not taken into consideration as farmers and their family were involved in all the aquaculture and agricultural practices. It has been observed, that Experiment-III (IFS-II) has achieved significantly ($p \leq 0.05$) higher net profit of Rs 28,467 followed by Experiment-II (IFS-I) of Rs 12,907 and Experiment-I (NIFS) of Rs 7,322 .This result indicates, that the undigested fraction in animal waste was eaten by fish which may have reduced the feeding cost in aquaculture. The finding is also in agreement with that of Delmendo (1980) along with the higher zooplankton production which further facilitates the fish growth rate resulting in, maximum profit in Experiment-III followed by Experiment-II and Control.

Studies of Bhakta *et al.*, (2004), Afzal *et al.*, (2007), and Sarkar *et al.*,(2011) on animal wastes, revealed, that fish yield in ponds, fertilised with animal excreta, was 5-7 times higher than normal fish pond. In the present study also, the fish yield was achieved approximately 2 to 3 times higher after application of cowdung and duck swimming on the ponds, indicating good scope of integrated farming system in the Terai region of West Bengal. Panda (2002) also indicated, that the approach of integration of duck farming is profitable and acceptable to the farmers in the developing world for maximum utilization of land and water resources. Sharma *et al.*, (2005) again realized that duck-cum-fish as IFS has become encouraging and economically viable under Indian condition and reduces the chances of environmental pollution. The droppings of ducks act as a substitute to fish feed and pond fertilizer up to 60% of total feed cost resulting more net profit.

Organic manuring proves to benefit the farmer economically as it serves to reduce 50 % cost of inorganic fertilizer and supplementary feed (Yadava and Garg, 1992). Optimum ratio of Nitrogen: Phosphorus (4:1 to 8:1) should be managed in aquacultural practices. Accumulated organic matter and nitrogen fixation can serve as main source of nitrogen. Fertilizers regulate pond ecosystem, through their buffering capacity (Das and Jana, 2003). Over fertilization can lead to poor performance and high mortality rate in fish (Zoccarato *et al.*, 1995; Bhakta *et al.*, 2004). Plankton population is a crucial factor in developing pond ecosystem. It is positively correlated with fish yield (Garg and Bhatnagar, 1999). Water temperature and transparency were significantly higher as in dry season as compared to wet season, whereas a positive and significant relationship was noted among the fish yield and phytoplankton and zooplankton productivities when organic manure was used as fertilizers (Javed *et al.*, 1995; Hayat *et al.*, 1996; Hassan *et al.*, 2000).

It has also been observed that integrated farming system responds well when the number of component or enterprise involved are increased. During the present study, it has been realised that Experiment-III (IFS-II) had ducks as additional component/enterprise which increased the potentiality of the farming system resulting in highest return than Experiment-II and Experiment-I. Oribhabor and Ansa (2006) in his study agreed that manuring is widely practiced in fishponds for natural fish production. It is important for sustainable aquaculture and to minimize expenditure on artificial feeds which form more than 55 percent of the total input cost. As observed by Ansa and Jiya (2002), some carps even feed upon the undigested fraction of these manures directly, which may be low in nutrient value; but the microorganisms adhering to them are of high protein value and thereby resulting in increase in fish production. It was also studied by Fang *et al.*, (1994) that conversion efficiency of organic manure protein (chicken, duck, pig and cow manure) to a fish protein was about 40% on a dry weight basis in the fish ponds. Increased fish production was observed significantly when animal waste was utilised in Terai region of West Bengal (Banerjee and Barat, 2013).

The turmeric production and milk production in Experiment-II and III was found to be significantly higher than the Control (Experiment-I) and achieved additional income. It was also reflected in this study that feeding concentrate in IFS-I and IFS-II to the cow helped to increase the milk production by approximately 2 times than the Control (NIFS). Pond bottom soil is highly fertile and utilization of pond dyke for turmeric production using the pond bottom soil and the pond water also might have increased the turmeric production near about 5-6 t ha^{-1} yr^{-1}. In Experiment-III, due to duck raising additional income was achieved from the selling of 2939 eggs in the market. On the contrary, it was observed that when benefit cost ratio (BC ratio) was calculated, higher value of BC ratio was obtained for IFS-II (8.1) followed by NIFS (6.5) and then IFS-I (5.3). This result suggested, that small and marginal farmers of Terai region could get more benefit provided they increase the number of enterprise to be integrated under IFS.

Sharma *et al.*, (2004) also agreed that the mutual beneficial effect of combined fish cum duck culture showed increased production of both fish and duck and decreased input cost of fish culture considerably. The swimming ducks in the pond in search of food released nutrients from the soil which enhance pond productivity and increase the fish production. Woynarovich (1980), Naidu (1985), Jhingran (1986), Ganesan *et al.*, (1991) and Zheng *et al.*, (1997) also agreed that the integration of fish culture and duck farming has proven to be a profitable venture for small scale rural farmers as well as for commercial entrepreneurs. Therefore, raising ducks in fish ponds has proven viable. Fish-cum-duck culture ponds have very effective nutrient processing and retaining capacity, functioning as natural filters and depositing significant amounts of nitrogen in their bottom sediments (Olah *et al.*, 1992 and Pekar *et al.*, 1993). Therefore, the sediment utilised in this study, increased the production of the turmeric significantly.

Summary

The present thesis entitled " Investigations on the Potentialities of Crop-Livestock-Fish Integrated Farming System for the Marginal Farmers in Terai Region of West Bengal " embodies the efficiency of three farming systems analysed in the Terai region of West Bengal namely, Non Integrated Farming System (NIFS), Integrated Farming System-I(IFS-I) and Integrated Farming System-II(IFS-II). NIFS was considered to be Control. Nine ponds were selected to study the above mentioned farming systems in triplicate at Belacoba of Jalpaiguri district situated at 43 m above mean sea level having sandy loam soil with sub-tropical humid climate (latitude 26°58'N and longitude 88°58'E). The observations of the said research study are summarised as followings:

➢ Physico- chemical properties of pond water

- Application of cowdung @2600 kg/ha/10day maintained water quality favourable for fish growth.
- Manuring significantly increased the pond water temperature and also maintained optimum range.
- Cow dung and duck droppings changed the pond water towards acidic in nature.
- Manuring had a negative effect on the dissolved oxygen concentration of the pond water but, duck grazing and swimming on the pond had positive effect on the dissolved oxygen concentration of water.
- Waste fed pond water had significantly higher free carbondioxide.
- Total alkalinity was more than 20 mgl^{-1} and manuring increased significantly the Total alkalinity content of pond water.
- Manure application in the aquaculture increased the Total hardness of the pond water.

- Animal excreta increased the Chloride concentration of the pond water significantly.
- Ammonium-N, Nitrite-N and Nitrate-N was increased significantly with the application of the animal excreta in pond water.
- Duck droppings treated ponds had significantly higher Phosphate-P than the cow dung treated ponds.

➢ Pond Bottom Soil Quality

- pH of the pond bottom soil was found to be non-significantly different amongst the three farming systems maintaining productive condition of the pond.
- The % of Organic carbon was found to be significantly higher in manure treated pond than Control and maintained favourable condition for fish growth.
- The total nitrogen % of the waste fed ponds was found to be significantly higher than Control.
- The carbon to nitrogen ratio of soil was nearly 10 and non-significantly different in the three farming system which was considered to be favourable for pond productivity.

➢ Zooplankton production

- Manuring ponds with cowdung and duck droppings enhanced the zooplanktons production.
- Waste fed ponds had more diversity of zooplanktons than the Control.

- Growth and Production of The IMC and Exotic Carp
  - Manuring pond enhanced the growth rate of IMC significantly than Control.
  - Non-significant result was obtained regarding the growth rate of Grass Carp under three different farming systems.
  - The total fish yield after 150 days was found to be significantly higher in IFS-II followed by IFS-I and then the Control indicating that organic manure utilisation increased the total fish yield.
- Economic gain
  - Turmeric production from pond dykes utilising pond bottom soil and water for cultivate on was found to be increased significantly than the Control
  - Milk production achieved from the cow rearing under the semi-intensive system was significantly higher that the cow reared under extensive system indicating that concentrate feeding increased the milk production.
  - Inclusion of duck rearing under integrated farming system improved the net profit along with the B: C ratio.
  - The net profit was significantly higher in IFS-II followed by IFS-I and then NIFS.
  - B: C ratio was found to be higher in IFS-II followed by NIFS and the IFS-I.

Hence, it can be concluded that IFS-II was the most viable integrated farming system than the IFS-I and NIFS for the marginal to small farmer of the Terai region of the West Bengal.

Conclusion

It can be concluded that Integrated Farming System (IFS) had a positive effect on the economic return maintaining the environmental sustainability than the Non-Integrated Farming System (NIFS). The enterprises which were integrated, played an important role and also were found to be very much region specific. Integration of more than three enterprises always improved the Benefit Cost (BC) ratio that is, gain per unit expenditure.

In this present study, when only cattle was integrated with fish culture and pond dykes turmeric production (IFS-I) the BC ratio was found to be lesser (5.3) than NIFS (6.5) but, integration of another enterprise like duck rearing (IFS-II) enhanced the BC ratio (8.1) greater than IFS-I and NIFS. During the period of study, it was also perceived that, one must try to integrate the locally available resources in the specific area so that the input cost of the farming is reduced and also must select the output to be produced from the farming in such a way that the produce gets high local market value and thus the farming system will be more viable.

The dykes were utilised in this study only for turmeric production (April – December) under integrated farming system but, in future different scopes are open for researcher to find out the optimum model of pond dykes utilization along with the fish culture round the year in this rain fed Terai region of West Bengal so that maximum profit can be achieved by the small and marginal farmers. Again, there is also further research scope to study the optimum composite fish farming suitable for this regional market to get maximum profit from this integrated farming.

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List of Publications

1. Banerjee, S. & Barat, S. 2012. Effect of cow dung and stocking density on growth and production of Indian Major Carp and Ctenopharyngodon idella (Grass Carp) under integrated farming system in terrai region of West Bengal. *J. Interacad.*16 (2a):541-549.

2. Banerjee, S., Nur, R. & Barat, S. 2013. Effect of different organic manures on live weight gain of Indian Major Carp and Grass Carp *(Ctenopharyngodon idella,* Hamilton) under Integrated Fish Farming System in Terai region of West Bengal. *Environment and Ecology.* 31(2): 938-942

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EFFECT OF COW DUNG AND STOCKING DENSITY ON GROWTH AND PRODUCTION OF INDIAN MAJOR CARPS AND CTENOPHARYNGODON IDELLA (GRASS CARP) UNDER INTEGRATED FARMING SYSTEM IN TERAI REGION OF WEST BENGAL

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ABSTRACT

A study of six months duration from April to September was executed during the year 2010 and 2011 to observe the effect of different stocking density on fish growth rate and its production under integrated farming system in Jalpaiguri District of West Bengal, India. Three treatments namely, T_1 (Control), stocked with Indian Major Carps and Ctenopharyngodon idella (@10,000 fingerling per hectare following traditional farming system) without any integration; T_2 (T_1+ cow dung @2600kg/ha/ 10days interval) integrated with cow dung manure; T_3 (T_2+ increased stocking density @20,000 fingerling/ha) were considered. For all the treatments feed were given (rice bran and mustard cake @ 1:1) @2% of the body weights of the fishes and the size of the pond were average 0.01ha. The result indicated significant positive effect (P=0.05) of regular cow-dung application on the growth rate of fishes, Catla catla (41.91±35.80 g/month, 93.08±47.85 g/month and 70.83±47.23 g/month for T_1,T_2 and T_3 respectively), Labeo rohita (30.33±20.39 g/month, 67.83±43.79 g/month and 57.41±37.99 g/month for T_1,T_2 and T_3 respectively), Cirrhina mrigala (11.50±10.31g/month, 28.17±21.66 g/month and 21.50±22.12 g/month for T_1,T_2 and T_3 respectively) and Ctenopharyngodon idella (31.50±24.16 g/month, 73.25±35.73 g/month and 62.41±44.46 g/month for T_1,T_2 and T_3 respectively) maintaining the optimum water quality. However the increased stocking density from @10,000 fingerling per hectare to @20,000 fingerling per hectare has no significant effect on growth rate of the fishes under integrated farming system and the mortality percent was also found to be significantly lower (P=0.05) in T_3 . Overall production was achieved significantly higher (P=0.05) in T_3 (36.9±2.5 kg) followed by T_2 (25.15±3.88 kg) and then T_1(9.15±1.2kg). It can be concluded that optimum production can be achieved under integrated farming system with the stocking density @20,000 fingerling per hectare when the feeding is @2% of the body weight of the fishes and can be the best treatment in respect of economic return fetched by the farmer within six month.

Key words : **Integrated farming system, Indian major carp, Production, Grass carp, Growth rate, Cow-dung, Stoking density**

INTRODUCTION

The integration of livestock-fish-crop has received considerable attention during past thouree decade with emphasis on the incorporation of animal manures as fertilizer and nutrient for promotion of natural feed in fish ponds (Wohlfarth and Schroeder, 1979; Delmendo, 1980). It stimulates the natural primary food production in ponds and its maximum utilisation by the fish (Little and Muir, 1987) thus indicating that animal waste in aquaculture plays an important role. Integrated farming system seems to be the possible solution to meet the increased demand for food, stability of income and sustainable management of the limited natural resources and thereby improving the nutrition of the small and marginal farmers. According to Schroeder (1980) and Dhawan and Toor (1989) more than 50% of the total input cost in fish culture may be contributed by recycling the animal waste. Studies of Afzal, *et al.* (2007), Sarkar, *et al.*(2011) and Bhakta, *et al.* (2004) on animal wastes revealed that fish yield in ponds fertilised with animal excreta was 5-7 times higher than normal fish pond. Again, higher fish production was recorded when the fish were stocked more densely as 32.7 kg/ha/day of fish when 18000 fish/ha were stocked compared to 31.5 kg/ha/day when only 9000 fish/ha were stocked (Little and Muir, 1987). The pond system's capacity to absorb waste is high in tropical region resulting as higher fish yields. Monthly yield of cow dung was observed to be 510 kg with moisture content 81%, nitrogen 3.86%, phosphate 0.5% and potassium 1.62% (Ravisankar and Pramanik, 2007).

The ponds in the study area are generally seasonal and water in the ponds is available mostly during April to October of every year hence the present experiment is for six months (April to September) of each year. The Ctenopharyngodon idella (Grass Carp) are considered along with IMC in this study as the excreta of herbivorous fish can be utilised to fertilise the water and produce plankton for filter-feeding fish to consume(Martin, *et al*. 2005) .The present study is to observe the effect of cow-dung and increased stocking density on the monthly growth rate of Catla catla ,Labeo rohita, Cirrhina mrigala and Ctenopharyngodon idella and overall pond production within six months in terrai region (Jalpaiguri District) of West Bengal.

MATERIALS AND METHODS

As experiment was carried out during April to September period of each year 2010 and 2011 at village Belacoba of Jalpaguri district, situated in the Terai region of West Bengal having a sub- tropical humid climate at 26?58'N latitude and 88?58'E longitude and 43 m above msl. The soil of the research field was sandy and loamy in texture. Nine ponds of same size (0.01 ha) were selected to carry out the three treatments T_1, T_2 and T_3 (three ponds for one treatment). The treatments were selected following the procedure mentioned by Jena, *et al.*(2007) in carp farming and Srivastava (2009) in training manual on breeding, rearing and management of Indian Major Carps (IMC), air breathing fishes and fresh water prawns. Treatment 1(T_1) (Control), was stocked with Indian Major Carps and Ctenopharyngodon idella ,an exotic carp @10,000 fingerling per hectare following traditional farming system without any integration. Treatment 2 (T_2) was integration of cow dung @2600kg/ha/ 10days interval with the aquaculture stocked with Indian Major Carps and Ctenopharyngodon idella, an exotic carp, @10,000 fingerling per hectare. Treatment

3 (T_3) was integration of cow dung @2600kg/ha/10days interval with the aquaculture stocked with Indian Major Carps and Ctenopharyngodon idella , an exotic carp ,with stocking density @20,000 fingerling/ha.Table-1 shows the details of the three treatments. The stocking ratio followed was. 1:1:1 with IMC and 10% Ctenopharyngodon idella (Srivastava, 2009) considering the market preferences of fishes with average weight 14.0-15.0 g.

All the ponds under the experiment were seasonal with an average size of 0.01 ha and depth of 1.5 to 2 m. During March, ponds were dried and the bottom soil along with aquatic weeds was removed. Raw cow-dung at the rate of 3 tonnes per ha was applied as the basal dose 15 days prior to stocking. Lime was applied @250 kg per ha three to four days prior to stocking (Jena, *et al.* 2007). The fingerlings of IMC and Grass Carp were stocked in the month of April @ 10,000 fingerlings/ha in the pond

Table 1. Detail of the three treatments followed in the experiment

Treatments	T1(control)	T_2	T_3
Farming system	Non integrated	Integrated	Integrated
No. of ponds	3	3	3
Period of study	Six month (April to September)	Six month (April to September)	Six month (April to September)
Year of study	2010 and 2011	2010 and 2011	2010 and 2011
Size of ponds	0.01ha	0.01ha	0.01ha
Stocking density	10,000/ha	10,000/ha	20,000/ha
Stocking ratio (C:R:M:GC)	3:3:3:1	3:3:3:1	3:3:3:1
Aquaculture	Composite aquaculture (IMC+GrassCarp)	Composite aquaculture (IMC+GrassCarp)	Composite aquaculture (IMC+GrassCarp)
Avg fingerling size(g)	14-15	14-15	14-15
Cow dung application	No manuring	Manuring @2600kg/ha/10days	Manuring @2600kg/ha/10days
Fish feed (Rice Bran: Mustard oil cake, 1:1)	@2% of the total fish weight	@2% of the total fish weight	@2% of the total fish weight

C= Catla catla ,
R=Labeo rohita,
M=Cirrhina mrigala
GC= Ctenopharyngodon idella

under T_1, T_2 and @ 20,000 fingerlings/ha for T_3. Application of cow dung @ 2600kg per ha once in ten days (Jha, *et al.* 2004) was followed for the ponds under T_1 and T_3. The cow-dung was collected everyday and stored for application in the pond after each 10 days. The cow-dung were spread equally covering the whole pond. Starting application was 10days after stocking of fish fingerlings.

Optional application of lime @ 200kg per ha was done when the pH of pond water was found to be slightly acidic during the experiment. Supplementary feed (Mustard Oil Cake and Rice Bran @1:1) was given from the day of stocking @ 2% of total body weight once daily (R.C. Srivastava, 2009). The feeds were supplied in the pond in powdered form at the beginning and then in a dough form after 2 months of stocking.

Samples of water were collected bimonthly at a fixed hour of the day (9:00 am), using the standard water samplers. Samples were collected from different sites of each pond then pooled into one for each pond before final analysis. Water quality parameters were examined following the standard methods described by APHA (2005). Samples of zooplankton were collected from each ponds using plankton net made of standard bolting silk cloth (60ìm) and the samples were concentrated to a suitable volume for quantitative determinations following the methods described in APHA (2005).

Before sampling of fish, fishes were starved for 24 hr to avoid stressful effect of netting and handling, 0.5% of the fishes were netted from each of the pond at monthly (Goddard, 1996) and data relating to fish absolute growth rate were collected. The absolute fish growth rate was observed monthly during the study period and calculated according to Wootton (1989) as follows:

Absolute growth rate(g) = (W1-W0)/ (t1-t0)

Where

W0=mean body weight at time t0 and W1=mean body weight at time t1

Overall production of fishes and their survival were recorded at the time of harvest after the end of study period (September).

Cost – benefit analysis :

On the basis of current market prices for the procurement of advanced fry of fish and returns of fish species,the cost-benefit analysis of data was carried out following the simple procedure as (Jolly and Clonts 1993):

Profit= Gross output- Total cost.

Statistical analysis:

One –way ANOVA (Gomez and Gomez 1984) was used for the analysis of data. If the main effect was found significant, the ANOVA was followed by least significant difference (LSD) test. Statistical analysis was made by using SPSS (Version 18) software. All statistical tests were performed at a 5% probability level.

RESULTS AND DISCUSSION

During the study period the mean±SD of pond water quality of the three treatments were observed and summarized in Table 2 which shows that within T_1, T_2 and T_3 the Dissolved oxygen (mg l^{-1}) (5.39±0.42 , 5.12±0.36 and 5.02±0.49 respectively), Free carbon dioxide (mg l^{-1}) (11.38±0.93, 11.70±0.68 and 14.00±0.85

Table 2. Mean±SD of the Water Quality of pond under different Treatment (N=36) during the experiment

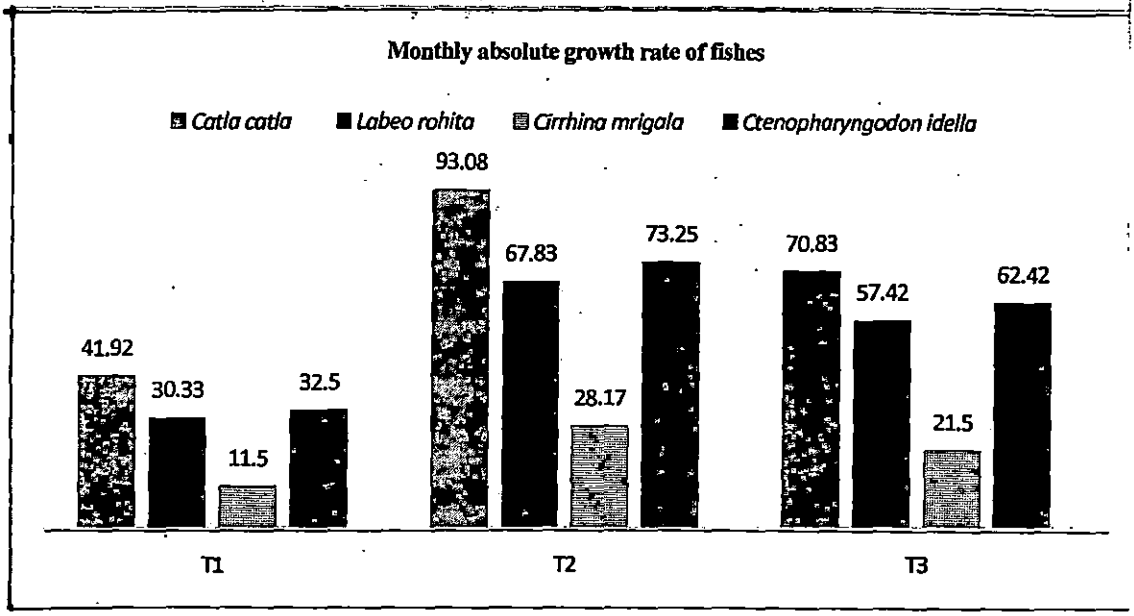
Water parameters	Treatment - 1	Treatment - 2	Treatment - 3
Temperature (°C)	29.12 ± 1.64^a	26.08 ± 1.88^a	28.81 ± 1.36^a
pH	7.94 ± 0.60^a	7.96 ± 0.44^a	7.65 ± 0.57^a
Dissolved oxygen (mg l^{-1})	5.39 ± 0.42^b	5.12 ± 0.36^{ab}	5.02 ± 0.49^a
Free carbondioxide (mg l^{-1})	11.38 ± 0.93^a	11.70 ± 0.68^a	14.00 ± 0.85^b
Total alkalinity (mg l^{-1})	23.81 ± 2.09^a	26.61 ± 1.47^b	27.46 ± 1.40^b
Total hardness (mg l^{-1})	43.67 ± 5.02^a	44.58 ± 5.52^a	45.00 ± 5.54^a
Chloride (mg l^{-1})	18.08 ± 4.12^a	22.92 ± 3.75^b	24.58 ± 2.94^b
Ammonium-N (mg l^{-1})	0.04 ± 0.03^a	0.06 ± 0.02^b	0.07 ± 0.02^b
Nitrite-N (mg l^{-1})	0.06 ± 0.03^a	0.32 ± 0.10^b	0.46 ± 0.26^c
Nitrate-N (mg l^{-1})	0.23 ± 0.14^a	0.38 ± 0.31^{ab}	0.53 ± 0.21^b
Phosphate (mg l^{-1})	0.03 ± 0.02^a	0.29 ± 0.10^b	0.33 ± 0.14^b
Zooplankton (no. l^{-1})	42.08 ± 29.61^a	146.67 ± 104.37^b	130.08 ± 82.07^b

Different superscript (a, b and c) bears significant difference (P=0.05) in the mean value

respectively), Total alkalinity (mg l^{-1}) (23.81±2.09, 26.61±1.47 and 27.46±1.40 respectively), Chloride (mg l^{-1}) (18.08±4.12, 22.92±3.75 and 24.58±2.94 respectively), Ammonium-N (mg l^{-1}) (0.04±0.03, 0.06±0.02 and 0.07±0.02 respectively), Nitrite-N (mg l^{-1}) (0.06±0.03, 0.32±0.10 and 0.46±0.26 respectively), Nitrate-N (mg l^{-1}) (0.23±0.14, 0.38±0.31and 0.53±0.21 respectively), Phosphate (mg l^{-1}) (0.03±0.02 , 0.29±0.10 and 0.33±0.14 respectively) are significantly different (p=0.05) whereas the Temperature (°C) (29.12±1.64, 26.08± 1.88 and 28.81±1.36 respectively), pH (7.94±0.60, 7.96±0.44 and 7.65±0.57 respectively) and Total hardness (mg l^{-1})(43.67±5.02, 44.58±5.52 and 45.00±5.54 respectively) are none significantly different.

It has been observed that though in T3 the Free carbon dioxide (mg l^{-1}),Total alkalinity (mg l^{-1}),Chloride (mg l^{-1}), Ammonium-N (mg l^{-1}), Nitrite-N (mg l^{-1}), Nitrate-N (mg l^{-1}) and Phosphate (mg l^{-1}) were found to be significantly higher than control(T_1) but the pH and temperature were within the moderate range maintaining the favourable condition for fish growth (Jana, *et al.* 2012) . Lloyd and Herbert (1960) showed that the toxicity of ammonia decreases with increasing carbon dioxide concentration. In the present study the Free carbon dioxide (mg l^{-1}) in T_3 was highest (14.00±0.85) which may have managed the toxicity of ammonia.

T_1 has significantly higher Dissolved oxygen (mg l^{-1}) followed by T2 then T3 indicating that manuring and increasing stocking density decreases the Dissolved oxygen. No significant difference were observed in T_2 and T_3 regarding Total alkalinity (mg l^{-1}), Chloride (mg l^{-1}), Ammonium-N (mg l^{-1}), and Phosphate (mg l^{-1}) however Nitrite-N (mg l^{-1}) and Nitrate-N (mg



l^{-1}) were found to be significantly different. Boyd (1982) observed that regardless of the source, ponds occasionally contain nitrite concentrations of 0.5 to 5.0mgl^{-1} of $NO2^{-}$-N. Again concentrations of $NO2^{-}$ as low as 0.5mgl^{-1} were found to be toxic to certain cold water fish (Crawford and Allen, 1977). While examining the interactions of stocking density of common carp and ambient ammonium concentrations, Biswas, *et al.* (2006) expressed the values at three different concentration levels of ammonium (a) favourable concentration range – 0.262 to 0.294 mg l^{-1}, (b)growth-inhibiting concentration range – 0.313 to 0.322 mg l^{-1} and (c) lethal concentration range - 0.323 to o.422 mg l^{-1}. In the present study, all the values of ambient ammonium concentration in T_1, T_2 and T_3 remained lower than the threshold concentration of 0.313 mg l^{-1} and, therefore, perhaps favourable for fish culture.

Primary productivity in respect to zooplankton (no.l^{-1}) was found to be significantly higher ($p=0.05$) in T_2 (146.67±104.37) and T3 (130.08±82.07) than T_1 (42.08±29.61) indicating that cow dung application facilitates zooplankton production in pond (Wohlfarth and Schroeder, 1979; Delmendo, 1980; Little and Muir, 1987).). Jha, *et al.* (2004) also found that application of both cow dung and poultry manure at the rate of 0.26kg per m^2 every 10 days is most suitable for better growth in Koi Carp tanks through maintenance of better water quality and greater abundance of plankton in the system. Rahman, *et al.*(2006) indicated that common carp naturally ingests mainly zooplankton and benthic macro invertebrate and small quantities of phytoplankton but when offered formulated feed, the latter becomes the preferred food item; hence feed administration enhanced growth of the common carp.

The monthly growth rate of IMC was found to be significantly higher (p=0.05) in T2 followed by T_3 then T_1 (Figure 1). The mean±SD of monthly growth rate of Catla catla; Labeo rohita; Cirrhina mrigala; Ctenopharyngodon idella in T_2, T_3 and T_1 were 93.08±47.85, 70.83±47.23 and 41.92±35.81; 67.83±43.79, 57.42±37.99 and 30.33±20.40; 28.17±21.66, 21.50±22.12 and 11.50±10.32; 73.25±35.74, 62.42±44.46 and 32.50±24.16 respectively. In case of Ctenopharyngodon idella (Grass Carp) the monthly growth rate in T2 and T3 were none significantly different but found to be significantly higher than T1(control). As evident by workers in Israel (Moav ,*et al.*1977) the high fish yields are obtainable using cattle slurry and the cattle waste inputs into the pond that were gradually increased over the period, from the equivalent of 57 dairy cows to nearly 400/ ha of fish pond. Hepher (1975) has also correlated yields in manure ponds with the stocking density of the fish and found linear relationship up to 9300 fish/ha although these yields are only likely with optimum management. Throughout the study period, it was again observed that the average monthly growth rate pattern is highest in Catla catla followed by Ctenopharyngodon idella, then by Labeo rohita and lastly by Cirrhina mrigala indicating quick and high return in Catla catla followed by Ctenopharyngodon idella, Labeo rohita and Cirrhina mrigala production under village condition.

Total mean±SD of half yearly production during the study period was significantly (p=0.05) higher in T3 (36.90± 2.54 kg) followed by, T_2(25.15± 3.89kg) and then T_1 (9.15± 1.20 kg) as depicted in Table 3. Therefore, it is evident that, though T3 has a significantly lower monthly growth rate of all the fishes but it fetches the overall highest production and there by higher economic return. Little and Muir, 1987 also opined for higher stocking density to obtain higher production. It was also reported by Schroeder (1978) that manures could achieve75% of the yields attained by using supplementary feeding of grains and 60% of the yields possible with protein-rich pellets. Schroeder(1974) observed fish yields in Israel around 14600 kg/ha/yr, and these yields correspond with those found in Brazil (Carvalho et.al.,1979) where the wastes from calves (aged between 1-180 days) are used in fish culture yields 3977 kg/ha over 130days with a tilapia hybrid. . The mean±SD fish survival (table 4) at the time of harvesting was observed to be significantly highest in T2 (70±7.07%) followed by T_3 (61±5.66%) and T_1 (50±2.83%).

Cost benefit analysis was done considering the expenditure incurred on the fingerling (@250/kg) and feed (@14/ kg).The mean ±SD of profit/half yearly in rupees are given in Table 4. It has been observed that T3 has achieved significantly (p=0.05) highest profit (Rs 2287±216) than T2 (Rs 1406±359) and T1 (Rs 141±163), indicating that the undigested fraction in animal waste is eaten by fish which may reduces the feeding cost of aquaculture (Delmendo, 1980) along with the higher zooplankton production which further facilitates the fish growth rate resulting the maximum profit inT3.Hence, in the terai region of West-Bengal Treatment 3 can be the solution for income generation among the small and marginal farmers.

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Effect of Different Organic Manures on Live Weight Gain of Indian Major Carp and Grass Carp (*Ctenopharyngodon idella*, Hamilton) under Integrated Fish Farming System in Terai Region of West Bengal

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Abstract An experiment was carried out from May to September, 2011 (150 days) to observe the effect of different manures on live weight gain of Indian major carps and grass carp (*Ctenopharyngodon idella*). Three ponds were treated namely, T_1 (no manuring), T_2 (cow dung manuring) and T_3 (pig dung manuring). The results revealed significant increase in live weight gain (g) of *Catla catla* (439.00±5.85, 560.00±5.77, 669.67±1.12), *Labeo rohita* (365±8.66, 434±7.21, 474.67±4.84), *Cirrhina mrigala* (39.66±2.33, 136.33±3.17, 128.33±4.4) and *Ctenopharyngodon idella* (455.33±5.84, 485.67±3.48, 485±3.21) in T_1, T_2 and T_3, respectively. It was concluded that application of organic manure increases the live weight while pig dung showed positive influence on *Catla catla* and *Labeo rohita*.

Keywords Integrated fish farming, Water quality, Sustainability, Indian major carp, Grass carp (*Ctenopharyngodon idella*).

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Introduction

Integrated farming system (IFS) is a sequential linkage between two or more farming activities (1). The integration of livestock with fish has received considerable attention during past three decade with emphasis on the incorporation of animal manures as fertilizer and nutrient for promotion of natural feed in fish ponds. It stimulates the natural primary food production in ponds and its maximum utilization by the fish and thereby indicating that animal waste in aquaculture plays an important role. Among the different culture systems, "Integrated fish farming" refers to a combination of practices. It incorporates the recycling of the wastes and recources from one farming system to the other and optimizing the production efficiencies in order to achieve maximal biomass harvest from a unit area with due environmental considerations (2). In the IFS, wastes, leftovers and by-product from other farm activities are used to raise fish. This practice results into the production of highly valued fish protein. IFS seems to be the possible solution to meet the increased demand for food, stabilise the income and manage the limited natural resources in a sustainable manner and thereby improve the nutrition of the small and marginal farmers. Studies of Afzal et al. (3) and Sarkar et al. (4) on animal wastes revealed that fish yield in ponds fertilized with animal

Table 1. Summary of the experimental designs under different integrated farming systems.

Treatments	T_1 (control)	T_2	T_3
Components of farming	Fish	Fish cum cow	Fish cum pig
Type of farming	Non-integrated (traditional)	Integrated	Integrated
No. of ponds	1	1	1
Average size of pond (ha)	0.01	0.01	0.01
Manuring	No manuring	Manuring 2600 kg/ha/ ten days with cowdung	Manuring 2600 kg/ha/ ten days with pigdung
Stocking density of fingerlings/ha	10,000	10,000	10,000
Types of fish stocked	IMC+Grass carp	IMC+Grass carp	IMC+Grass carp
Stocking ratio	3:3:3:1	3:3:3:1	3:3:3:1
Fish feeding schedule (on daily basis)	2% of total body weight with mustard oil cake and rice bran (1:1)	2% of total body weight with mustard oil cake and rice bran (1:1)	2% of total body weight with mustard oil cake and rice bran (1:1)
Duration of study	2011 (150 days)	2011 (150 days)	2011 (150 days)

excreta was 5—7 times higher than that of normal fish pond. IFS, involving aquaculture, have usually been classified according to the combination of farm enterprises being practised, viz. rice-cum-fish, pig-cum-fish, poultry-cum-fish and multi component systems with three or more enterprises, usually crop-livestock-fish farming system. The integration of duck and chicken with fish poly culture system is amongst the most popular in Asian countries followed by pig-fish and ruminants (cattles)-fish production systems (5). The best way to reduce the cost of fish production is to minimize the use of supplemental food; and this can be best achieved by exploiting the synergetic interaction between natural food and supplemental feed (6). Thus, utilization of resources through IFS increases production per unit area, helps achieve efficient recycling of farm wastes, generates more employment, reduces the risk and ensures environmental safety and sustainability.

Terai region of northern region of West Bengal is situated between 25°57′ and 27°N latitude and 88°25′ and 89°54′ E longitude with an altitude of 360 ft above mean sea level (MSL). The ponds in the study area are generally seasonal and water in the ponds is available mostly during April to October of every year. Accordingly the present experiment was for six months (April to September) of a year. Since as the excreta of herbivorous fish can be utilized to fertilize the water and produce plankton for filter-feeding fish to consume (7), the *Ctenopharyngodon idella* (grass carp) are considered along with IMC in this study. The present study is to observe the effect of cowdung and pig dung on the monthly growth rate of *Catla catla, Labeo rohita, Cirrhina mrigala* and *Ctenopharyngodon idella* and to find the overall pond production within six months in terai region (Jalpaiguri district) of West Bengal.

Materials and Methods

The experiment was carried out during May to September (150 days) period of 2011 in a village Belacoba of Jalpaiguri district, situated in the Terai region of West Bengal having a sub-tropical humid climate at 26°58′ N latitude and 88°58′ E longitude and 43 m above msl. The soil of the research field was sandy and loamy in texture. Three ponds of same size (0.01 ha) were selected to carry out the three treatments T_1, T_2 and T_3 (one ponds for one treatment). The treatments were selected following the procedure mentioned by Jena et al. (8) in carp farming and Srivastava (9) in training manual on breeding, rearing and management of Indian major carps (IMC), air breathing fishes and fresh water prawns. Treatment 1 (T_1) (con-

Table 2. Mean ± SE of water quality parameters and Zooplankton under different Treatments. Different superscripts (a, b and c) denotes significant difference and similar superscripts denote non-significant difference between treatments at 5% level. N=6 for all the parameters.

Parameters (mg/l)	T_1	T_2	T_3
Temperature (°C)	29±0.84[a]	28.73±0.64[a]	29.13±0.73[a]
pH	8.5±0.20[b]	7.9±0.24[ab]	7.7±0.9[a]
Dissolved oxygen	7.7±0.09[b]	6.42±0.17[a]	6.38±0.13[a]
Free carbon dioxide	10.87±0.08[a]	10.95±0.16[a]	11.67±0.15[b]
Total alkalinity	22.87±0.65[a]	26.52±0.76[b]	27.23±0.63[b]
Total hardness	42.83±1.87[a]	43.17±1.64[a]	42.17±2.77[a]
Chloride	18.0±2.11[a]	24.33±3.75[a]	27.16±4.86[a]
Ammonium-N	0.02±0.005[a]	0.03±0.001[a]	0.04±0.002[a]
Nitrite-N	0.28±0.027[a]	0.30±0.017[a]	0.35±0.04[a]
Nitrate-N	0.24±0.017[a]	0.34±0.023[b]	0.32±0.02[b]
Phosphate	0.25±0.075[a]	0.45±0.08[a]	0.48±0.70[a]
Zooplankton (no/l)	23.14±1.5[a]	126.33±4.6[b]	135.85±3.0[b]

trol), was stocked with Indian major carps and *Ctenopharyngodon idella*, an exotic carp at 10,000 fingerling per hectare following traditional farming system without any integration. Treatment 2 (T_2) was integration of cow dung at 2,600 kg/ha per 10 day interval with the aquaculture stocked with Indian major carps and *Ctenopharyngodon idella*, an exotic carp, at 10,000 fingerling per hectare. Treatment 3 (T_3) was integration of pig dung at 2,600 kg/ha per 10 days interval with the aquaculture stocked with Indian major carps and *Ctenopharyngodon idella*, an exotic carp, with stocking density at 10,000 fingerling/ha. Table 1 shows the details of the three treatments. The stocking ratio followed was 1:1:1 with IMC and 10% *Ctenopharyngodon idella* (9) considering the market preferences of fishes with average weight 14.0—15.0 g.

All the ponds under the experiment were seasonal with an average size of 0.01 ha and depth of 1.5 to 2 m. During March, ponds were dried and the bottom soil along with aquatic weeds was removed. Raw cow-dung at the rate of 3 tonnes per ha was applied as the basal dose 15 days prior to stocking. Lime was applied at 250 kg per ha three to four days prior to stocking (8). The fingerlings of IMC and grass carp were stocked in the month of April at 10,000 fingerlings/ha in the pond under T_1, T_2 and T_3. Application of cow dung at 2,600 kg per ha once in ten days (10)

Table 3. Mean ± SD of absolute monthly growth rate of different species of fish under different treatments (N=6).

Treatments	*Catla catla* (g/month)	*Labeo rohita* (g/month)	*Cirrhina mrigala* (g/month)	*Ctenopharyngodon idella* (g/month)
T_1	69.16±4.16	61.16±3.54	4.56±7.86	71.50±3.89
T_2	90.83±6.96	67.8±4.15	21.5±2.69	78.66±4.62
T_3	109.17±5.86	75.33±5.85	19.83±2.29	77.66±3.93

was followed for the ponds under T_2 and in the same way application of pig dung was followed at 2,600 kg per ha once in ten days for the ponds under T_3 in this study. The cow-dung and the pig dung were collected everyday and stored for application in the pond after every 10 days. The cow-dung and the pig dung were spread equally covering the whole pond. Application was started after 10 days from the stocking of fish fingerlings.

Optional application of lime at 200 kg per ha was done when the pH of pond water was found to be slightly acidic during the experiment. Supplementary feed (mustard oil cake and rice bran at 1:1) was given once daily starting from the day of stocking at 2% of total body weight (9). The feeds were supplied in the pond in powdered form at the beginning and then in a dough form after 2 months of stocking.

Samples of water were collected bimonthly at a fixed hour of the day (9:00 am), using the standard water samples. Samples were collected from different sites of each pond then pooled into one for each pond before final analysis. Water quality parameters were examined following the standard methods described by APHA (2005). Samples of zooplankton were collected from each pond using plankton net made of standard bolting silk cloth (60 μm) and the samples were concentrated to a suitable volume for quantitative determinations following the methods described in APHA (11).

Before sampling of fish, fishes were starved for 24 h to avoid stressful effect of netting and handling and 0.5% of the fishes were netted from each of the pond on a monthly basis (12) and data relating to absolute growth rate of fish were collected. The absolute fish growth rate was observed monthly during the study period and calculated as follows:

$$\text{Absolute growth rate (g)} = (W_1-W_0)/(t_1-t_0)$$

Table 4. Mean ± SE of different live weight gain of fish under different treatments. Different superscripts (a, b and c) denotes significant difference and similar superscripts denote non-significant difference between treatments at 5% level. N=6 for all the parameters.

Treat-ments	*Catla catla*	*Labeo rohita*	*Cirrhina mrigala*	*Ctenopha-ryngodon idella*
T_1	439.00 ± 5.85^a	365 ± 8.66^a	39.66 ± 2.33^a	455.33 ± 5.84^a
T_2	560.00 ± 5.77^b	434 ± 7.21^b	136.33 ± 3.17^b	485.67 ± 3.48^b
T_3	669.67 ± 1.12^c	474.67 ± 4.84^c	128.33 ± 4.4^b	485 ± 3.21^b

Where W_0=mean body weight at time t_0 and W_1=mean body weight at time t_1

One-way ANOVA (13) was used for the analysis of data. If the main effect was found significant, the ANOVA was followed by least significant difference (LSD) test. Statistical analysis was made by using SPSS (Version 18) software. All statistical tests were performed at a 5% probability level.

Results and Discussion

Water quality

During the study period the mean±SE of pond water quality of the three treatments observed are summarized in Table 2. It shows that within the treatments T_1, T_2 and T_3 the values of all physico-chemical parameters except, temperature, total hardness, chloride, ammonium-N, nitrite-N and phosphate-p are significantly different ($p \leq 0.05$).

The pH and temperature were found to be within the moderate range maintaining the favorable condition for fish growth (14). T_3 and T_2 had significantly lower dissolved oxygen than T_1 indicating that manuring decreases the dissolved oxygen. Ammonia is more toxic when dissolved oxygen concentration is low (15). Free carbon dioxide was observed to be significantly higher in T_3 than T_2 and T_1. The concentrations of total alkalinity and nitrate-N are found to be significantly higher ($p \leq 0.05$) in T_2 and T_3 than the control (T_1).

Biswas et al. (16) expressed the values at three different concentration levels of ammonium (a) favorable concentration range : 0.262 to 0.294 mg/l, (b) growth-inhibiting concentration range : 0.313 to 0.322 mg/l and (c) lethal concentration range : 0.323 to 0.422 mg/l. In the present strudy, all the values of ambient ammonium concentration in T_1, T_2 and T_3 remained lower than the threshold concentration of 0.313 mg/l and, therefore, perhaps favorable for fish culture under waste fed condition though the dissolve oxygen was low in T_2 and T_3. Murad and Boyd (17) stated that ponds should have at least 20 mg/l total alkalinity for good fish production. In the present study, the total alkalinity was found to be more than 20 mg/l in T_2 and T_3 throughout the experiment. Hence, the use of organic inputs may keep total alkalinity at higher levels.

Zooplankton production

Quantitative study of zooplankton was found to be significantly higher ($p \leq 0.05$) in T_2 (126.33 ± 4.6 no./l) and T_3 (135.85 ± 3.0 no./l) than T_1 (23.14 ± 1.5 no./l) indicating that cow dung application facilitates zooplankton production in pond. Jha et al. (10) also found that application of both cowdung at the rate of 0.26 kg/m^2 per 10 days is most suitable for better growth of koi carp in tanks through maintenance of better water quality and greater abundance of plankton in the system. Rahman et al. (18) too indicated that common carp naturally ingests zooplankton and benthic macro invertebrate and small quantities of phytoplankton but when offered formulated feed, the latter becomes the preferred food item; hence feed administration enhanced growth of the common carp.

Growth rate and live weight gain of different fishes

The mean±SD of monthly growth rates (g/month) of *Catla catla; Labeo rohita;* and *Cirrhina mrigala;* in T_1, T_2 and T_3 are shown in Table 3. However, the monthly growth rate was found to be non-significantly different ($p \geq 0.05$) among the three treatment but throughout the study period, it was again observed that the average live weight gain after 150 days was significantly higher ($p \leq 0.05$) in T_2 and T_3 for all the fishes (Table 4) namely *Catla catla, Labeo rohita, Cirrhina mrigala* and *Ctenopharyngodon idella* indicating quick and high return from aquaculture when applied organic manure under village condition. Pig dung was found to be significantly ($p \leq 0.05$) influencing the weight gain in *Catla catla* and *Labeo rohita*. Singh and Sharma (19) determined the efficiency of cow dung and pig dung and conclude that ponds treated with pig dung has higher production (2,219 kg per ha per year) of fishes than cow dung (789 kg per ha per year). Zoccarato et al. (20) also obtained high fish production (3,369.0 kg per ha per 4 months) when feed supplementation along with fertilization with pig dung were done. Thus, it was observed that application of organic manure increases the live weight of fishes while pig dung showed positive influence on *Catla catla* and *Labeo rohita*.

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Economics of Different Livestock-Carp Integrated Farming Systems over Traditional Non Integrated Farming System in Terai Region of West Bengal

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ABSTRACT

Economics of different integrated farming systems in Terai region of West Bengal were studied by observing three treatments as T1 (Control): Traditional farming system, T2: Integrated cattle farming with aquaculture and T3: Integrated cattle and ducks farming with aquaculture. The fish and milk production was significantly higher (Pd"0.05) in T3 as 27.8±0.5 kg and 441.3±81.4 l., respectively followed by T2 as 20.6±0.3kg and 405.4±27.8 l., respectively and T1 as 10.7±0.3kg and 219±5.6 l. with addition of 2,939±32.0 numbers of eggs in T3. Hence, the profit was significantly higher in T3 (Rs 25,126.8±394.0) than T2 (Rs 9,566.8±185.7) and T1 (Rs 4,982.2±206.1).

Key Words Cow-dung, Grass carp, Indian Major Carp, Livestock-Carp Integrated Farming System, Water Quality, Economics

INTRODUCTION

Integrated Farming Systems (IFS) have received considerable attention in recent years due to the reason that the resources being used under non-integrated farming system are depleting and thus the prevailing farming system is not sustainable in long run resulting threat to the environment. During past three decades great emphasis was given on the incorporation of animal manures as fertilizer and nutrients for promotion of feed and fauna in fish ponds and utilized by the fish . According to Dhawan and Toor (1989) more than 50 per cent of the total input cost in fish culture may be reduced by recycling the animal waste. Hence integrated livestock- carp farming became important to ensure waste management as well as in reducing the production cost (Nnaji *et al.*, 2011)

As the integrated farming system seems to be profitable by reducing the input cost and probable solution to meet the increased demand for food stability, the present study was therefore executed to observe the economics of two IFS models, using different existing components such as cow, ducks and fish ponds in Terai region of West Bengal.

MATERIALS AND METHODS

Study area

The experiment was carried out during the years 2010 and 2011 at a village Belacoba of Jalpaguri district, situated in the northern region of West Bengal, India having a sub- tropical humid climate at 26Ú58´N latitude and 88Ú58´E longitude (43 m above msl). The soil of the research field was sandy - loam in texture.

Experimental design

Nine ponds were selected in triplicates for each treatment of same size 0.01 hectare (ha) to carry out the three treatments T1, T2 and T3 (Table 1). Ponds were stocked with Indian Major Carp (IMC) as *Catla catla, Labeo rohita* and *Cirrhina mrigala* and Exotic Carp *Ctenopharyngodon idella*, in the stocking ratio of 3:3:3:1 as suggested by Jena *et al.*, (2007).

Pond Management under different treatments

All the ponds under experiment were seasonal (April to September) from 2010 to 2011 with an average size of 0.01 ha and depth of 1.5 to 2.0 m. During March, ponds were dried and the bottom

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soil along with aquatic weeds and unwanted fishes were removed. Raw cow-dung at 3 t/ ha was applied as the basal dose 15 days prior to stocking. Lime was applied @250 kg/ha three to four days prior to stocking. The fingerlings were stocked in the month of April @ 10,000 fingerlings/ha in the ponds under T1, T2 and T3. The average weights of the fingerlings were 14-15g. Application of cow dung @ 2600kg/ ha once in ten days was followed for the ponds under T2 and T3. Optional application of lime @ 200kg / ha was done to maintain the pH of the ponds between 6.5 to 8.5. Supplementary feed in the form of Mustard Oil Cake and Rice Bran in the ratio 1:1 was applied after stocking @ 2 per cent of total body weight once a day. The cow-dung was collected everyday and stored for application in the pond after each 10 days. The cow-dung was spread equally covering the whole pond. Starting application of manuring was 10days after stocking of fingerlings. The methology followed was as suggested by Jha *et al.*, 2004 and Jena *et al.*, 2007.

Livestock Management under different treatments

The livestock considered in this study was non descriptive (local variety with no specific breed character) cows and ducks mostly prevalent amongst small and marginal farmers of this area with the production potentiality of 500 to 800 l/ lactation and 80-120 eggs/year , respectively. In T1 the cattle was reared in extensive system of rearing where, the cow was allowed to graze whole day and at night shelter was provided along with some paddy straw and water. The cow dung was not stocked to integrate with aquaculture. Milking of the cow was done twice a day.

The cattle under T2 and T3 were reared in semi-extensive system where the cows were allowed to graze for 6 hours every day considering the climatic condition to avoid stress. In cattle house, the cows were provided concentrate feed @ 1kg /day along with some green grass and paddy straw. The cow dung was collected to integrate with aquaculture. De-worming of the cows were done routinely thrice in a year.

Additional twenty ducks were reared in extensive system in T3 along with the cattle. After one month of stocking five months old ducks were brought into use. Ducks were allowed to graze on the pond from 9.00 am to 5 pm daily and fed with kitchen left overs and agricultural by - products @75g/d. The eggs produced were collected in the morning.

Sampling of pond water

Water samples were collected from different sites of the ponds at bimonthly intervals at a fixed hour of the day (9:00 am). The water quality parameters were analysed following the standard methods as described by APHA (2005).

Cost-benefit analysis

Cost-benefit analysis of the data was carried out on the basis of current market prices for the investment made as input cost and the total returns of fish harvested , milk and egg produced as gross output from the farm and following the simple procedure as suggested by Jolly and Clonts (1993).

Profit = Gross output –Total Cost

Statistical analyses

One-way ANOVA (Gomez and Gomez, 1984) was used for the analysis of data. If the main effect was found significant, the ANOVA was followed by a least significant difference (LSD) using Duncan's Multiple Range Test (DMRT). All statistical tests were performed at a 5 per cent probability level using the statistical package SPSS-18.

RESULTS AND DISCUSSION

Water Quality

It was found that within the treatments i.e., T1, T2 and T3 the values of all physico-chemical parameters except total hardness were significantly different (pd" 0.05). Total alkalinity, concentration of chloride, ammonium-N, nitrite-N, nitrate-N and phosphate- p were found to be significantly higher (pd"0.05) in T2 and T3 than the Control (T1). T3 significantly had the higher (pd"0.05) Phosphate- p concentration indicating that duck grazing may have affected the Phosphate- p concentration in pond water. Phosphorus is commonly considered the major limiting nutrient in freshwater, and additions of phosphorus often result in increased primary production in aquaculture systems (Daina *et al.*, 1991).

Table 1. Experimental Designs under different Integrated Farming Systems.

Treatment	T1(Control)	T2	T3
Components of farming	Fish and cow	Fish cum cow	Fish cum cow cum duck
Type of farming	Non-integrated (Traditional)	Integrated	Integrated
No. of ponds	3	3	3
Average size of pond(ha)	0.01	0.01	0.01
Manuring	No manuring	Manuring @ 2600kg/ ha / ten days with cowdung	Manuring @ 2600kg/ ha / ten days with cowdung
No. of ducks per pond	nil	nil	20
Stocking density of fingerlings/ha	10,000	10,000	10,000
Types of fish stocked	IMC+Grass carp	IMC+Grass carp	IMC+Grass carp
Stocking ratio	3:3:3:1	3:3:3:1	3:3:3:1
Fish feeding schedule (on daily basis)	@ 2% of total body weight with Mustard oil cake and Rice Bran (1:1)	@ 2% of total body weight with Mustard oil cake and Rice Bran (1:1)	@ 2% of total body weight with Mustard oil cake and Rice Bran (1:1)
No of Cattle	1	1	1
System of cattle rearing	Extensive	Semi extensive	Semi extensive
Feeding schedule of cow	12 hours grazing with	6 hours grazing and Concentrate feed and green grass along with paddy straw	6 hours grazing and Concentrate feed and green grass along with paddy straw
Type of cow	Non descriptive	Non descriptive	Non descriptive
System of duck rearing	Nil	Nil	Extensive
Type of Duck	Nil	Nil	Non descriptive
Duration of Study	2008-2011(4 years)	2008-2011(4 years)	2008-2011(4 years)
Harvesting of Fish	Six months	Six months	Six months

Table-2: Mean ± SE of water quality parameters under T1, T2 and T3.

Parameters	T1	T2	T3
Temperature (°C)	29.70 ± 0.23^{b}	28.67 ± 0.20^{a}	28.86 ± 0.20^{a}
pH	8.17 ± 0.07^{b}	8.11 ± 0.05^{b}	7.74 ± 0.07^{a}
Dissolved oxygen (mg l^{-1})	7.38 ± 0.08^{b}	6.72 ± 0.05^{a}	9.25 ± 0.15^{c}
Free carbon dioxide (mg l^{-1})	11.02 ± 0.17^{c}	10.34 ± 0.13^{b}	9.45 ± 0.09^{a}
Total alkalinity (mg l^{-1})	22.64 ± 0.33^{a}	23.15 ± 0.28^{ab}	23.97 ± 0.29^{b}
Total hardness (mg l^{-1})	44.54 ± 0.62^{a}	44.17 ± 0.59^{a}	44.58 ± 0.76^{a}
Chloride (mg l^{-1})	17.14 ± 0.54^{a}	24.17 ± 0.70^{b}	29.18 ± 0.67^{c}
Ammonium-N (mg l^{-1})	0.04 ± 0.01^{a}	0.08 ± 0.02^{b}	0.08 ± 0.02^{b}
Nitrite-N (mg l^{-1})	0.40 ± 0.02^{a}	0.40 ± 0.03^{ab}	0.49 ± 0.03^{b}
Nitrate-N (mg l^{-1})	0.21 ± 0.04^{a}	0.49 ± 0.03^{b}	0.48 ± 0.03^{b}
Phosphate (mg l^{-1})	0.24 ± 0.023^{a}	0.41 ± 0.03^{b}	0.59 ± 0.02^{c}

Different superscripts (a, b and c) denotes significant difference and similar superscripts denote non-significant difference between treatments at 5% level. N=72 for all the parameters.

Table 3. Mean ± SE of different productions of fish, milk and eggs under different Treatments.

Treatments	*Catla catla*	*Labeo rohita*	*Cirrhina mrigala*	*Ctenopharyngodon idella*	Total fish production (kg/six month)	Milk (l/year/cow)	Eggs (no./year)
T1	4.93± 0.11[a]	3.65±0.22[a]	0.48±0.04[a]	1.61±0.11[a]	10.67±0.33[a]	219±5.56[a]	.0000[a]
T2	9.48± 0.19[b]	6.65±0.14[b]	1.37±0.11[b]	3.07±0.14[b]	20.57±0.33[b]	405.42±27.81[b]	.0000[a]
T3	12.59± 0.26[c]	8.84±0.17[c]	2.93±0.15[c]	3.42±0.15[b]	27.78±0.50[c]	441.25±18.42[b]	2939±32.41[b]

Different superscripts (a, b and c) denotes significant difference and similar superscripts denote non-significant difference between treatments at 5% level. N=12 for all the parameters.

Table 4. Mean ± SE of net income (profit) under different Treatments.

Treatments	Total Expenditure (Rs)	Gross income (Rs)	Net Income(profit) (RS)
T1	1175.50±50.70[a]	6157.75±212.22[a]	4982.25±206.09[a]
T2	2812.50±81.48[b]	12379.25±257.76[b]	9566.75±185.74[b]
T3	3873.00±153.03[c]	28999.75±541.07[c]	25126.75±393.99[c]

Different superscripts (a, b and c) denotes significant difference between treatments at 5% level. N=4 for all the parameters and 1$=50 Rupees.

The pH and temperature were found to be within the moderate range maintaining the favourable condition for fish growth (Jana *et al.* 2012). Biswas, *et al.* (2006) expressed the values at three different concentration levels of ammonium (a) favourable concentration range : 0.262 to 0.294 mg/ l , (b)growth-inhibiting concentration range : 0.313 to 0.322 mg/ l and (c) lethal concentration range : 0.323 to o.422 mg/ l. In the present study, all the values of ambient ammonium concentration in T1, T2 and T3 remained lower than the threshold concentration of 0.313 mg/ l and, therefore, perhaps favourable for fish culture under waste fed condition. Murad and Boyd (1991) stated that ponds should have at least 20 mg/ l total alkalinity for good fish production. In the present study, the total alkalinity was found to be more than 20 mg/ l in three treatments throughout the experiment where T3 had significantly higher total alkalinity than T2 and T1. Hence, the use of organic inputs may keep total alkalinity at higher levels.

T3 has significantly highest dissolved oxygen followed by T1 then T2 indicating that manuring decreases the dissolved oxygen and Duck grazing on pond increases the same. Ammonia is more toxic when dissolved oxygen concentration is low. No significant difference were observed in T2 and T3 regarding total alkalinity, ammonium-N, nitrite-N and nitrate-N. Free carbon dioxide is observed to be significantly higher in T1 followed by T2 and T3, respectively.

Economics Under Different Treatments:

Total Mean±SE of yearly production during the study period was significantly (pd"0.05) higher in T3 (27.8 ± 0.5 kg) followed by, T2 (20.6 ± 0.3kg) and T1 (10.7± 0.3 kg) (Table 3). High fish yield were also obtained in Israel, 30 kg/ha/d with cattle manure (Schroeder, 1975), 40 kg/ha/d with duck manure and waste feed (Wohlfarth, 1978) and 20 kg/ha/d with chicken manure (Milstein *et al.* 1995). It has also been reported that the application of 15,000 kg/ ha of cow manure resulted in an average fish yield of 300 kg/ ha while the control ponds averaged 97 kg/ ha of fish. T3 has significantly highest production of *Catla catla* (12.6±0.3 kg); *Labeo rohita* (8.8±0.2 kg); *Cirrhina mrigala* (2.93±0.2 kg) and *Ctenopharyngodon idella* (3.4± 0.2 kg) followed by T2 then T1. It was also reported by Schroeder (1975), that manures could achieve75 per cent of the yields attained by using supplementary feeding of grains and 60 per cent of the yields possible with protein-rich pellets. Fish yield in properly designed and managed manure loaded ponds can reach 5 to 10 t/ha./yr without any supplemental feeding (Schroeder, 1978). The Mean±SE of milk yield was also observed to be significantly higher in T2 (405.4 ± 27.8 lt.) and T3 (441.3±18.4 l. than T1 (219±5.6 l.). This was due to the improved feeding practice followed during the integrated farming systems. T3 had additional production of duck eggs (2939±32.41). Sharma and Olah (1986) and Sharma *et al.*, (1988) observed, that the excreta of 35 to 45 pigs, 200 to 300 ducks and 250 to 300 layer poultry birds or 150 to 200 broiler birds produced 6 to 7 t, 3 to 4 t and 4 t of fish /year, respectively when recycled in one hectare of water area under the polyculture of Indian and exotic fish.

Cost benefit analysis was done considering the expenditure incurred on the fingerling (@Rs250/kg) and feed (@Rs14/kg). It was observed, that T3 has achieved significantly (pd"0.05) higher profit (Rs 25,126±394.0) than T2 (Rs 9,566±185.7) and T1 (Rs 4,982.3±207.0), indicating that the undigested fraction in animal waste was eaten by fish which may reduce the feeding cost of aquaculture along with the higher zooplankton production which further facilitates the fish growth rate resulting in maximum profit inT2 and T3. Studies of Afzal *et al.* (2007), Sarkar *et al.*(2011) and Bhakta *et al* (2004) on animal wastes revealed that fish yield in ponds fertilised with animal excreta was 5-7 times higher than normal fish pond. Panda (2002) indicated, that the approach of integration of duck farming is profitable and acceptable to the farmers in the developing world for maximum utilization of land and water resources. The droppings of ducks act as a substitute to fish feed and pond fertilizer up to 60 per cent of total feed cost.

CONCLUSION

It was concluded that integrated farming system responds well when the number of component involved are increased. T3 had ducks as additional component which increased the potentiality of the farming system resulting in highest return (BC ratio 7.5) than T2 and T1. The BC ratio in T2 (4.4) was found to be lower than T1. Hence, in the northern part of West Bengal, integration of livestock-carp and duck can be considered the best integrated farming system model for income generation among the small and marginal farmers.

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