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).

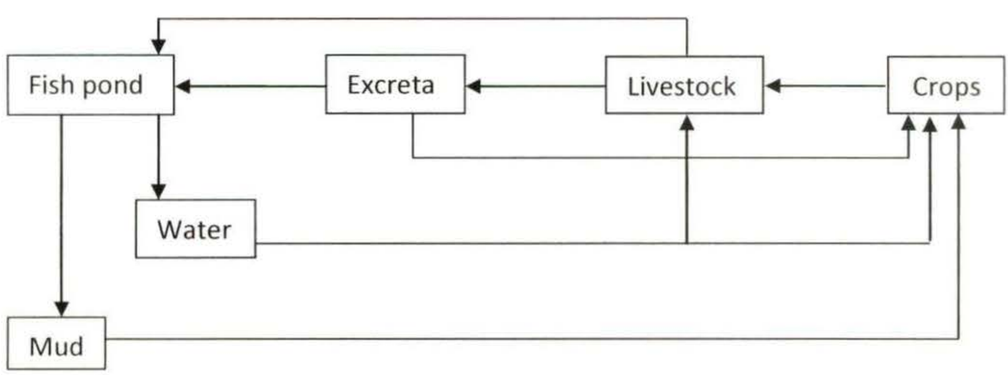

Fig-3: Schematic diagram of the major interactions between the various subsystems in a crop- livestock-fish integration farming system (Edwards, 1993).

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).

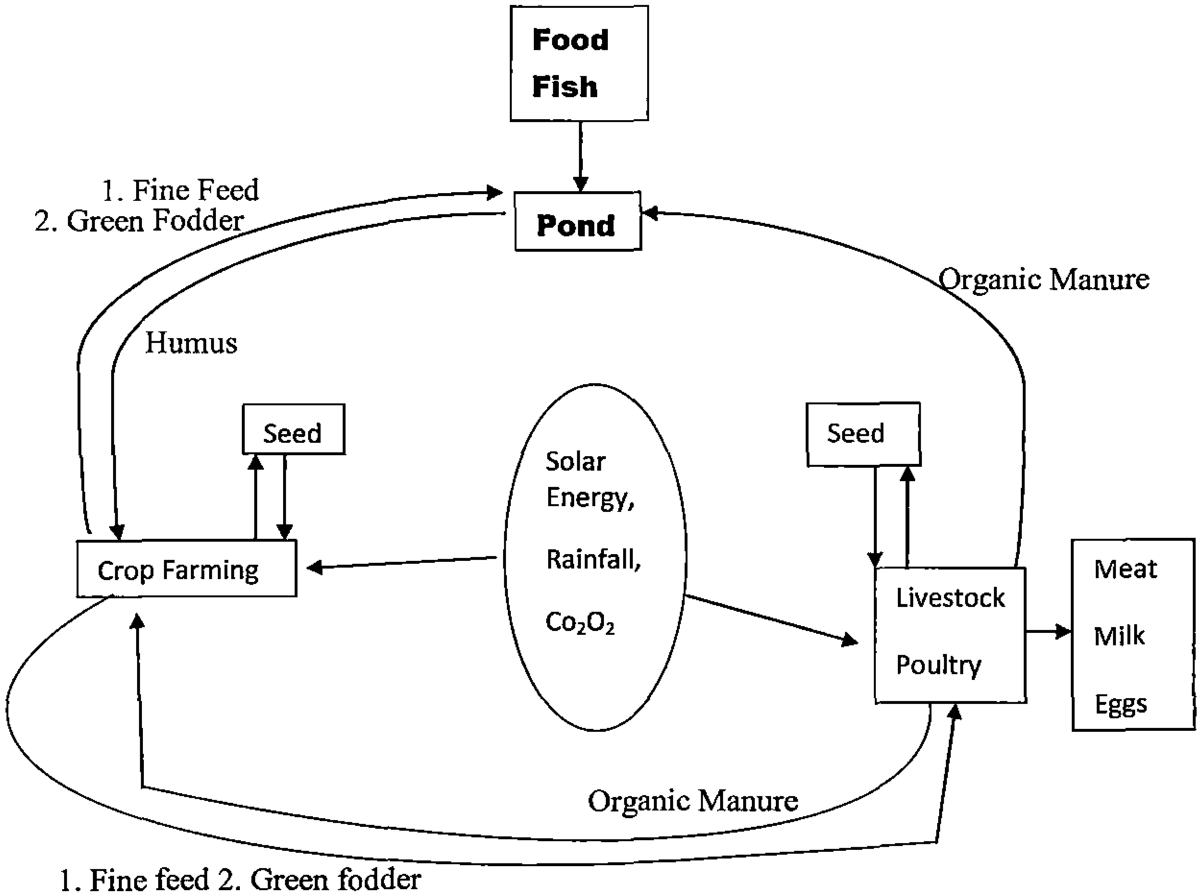

Fig- 4: Recycling of material in a well managed integrated fish farm.

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 carbon-dioxide, 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°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.