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SUSTAINABLE USE OF NATURAL RESOURCES FOR INTEGRATED AQUACULTURE AND AGRICULTURE: AN INDIAN OVERVIEW

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ABSTRACT

Water is the key to development of the agricultural as well as social and economic development of the world. Considering the shortage of water, cost involved in water storage and conveyance to the users, it is necessary to adopt innovative methods of conjunctive use of water for agricultural production using water effectively and efficiently. Aquaculture is an innovative tool in the urban and also in rural agriculture to use and reuse water as well as waste water.

Aquaculture has emerged as one of the most promising industries in the world with considerable growth potential and it is expected to contribute about a quarter to the global fishery harvest in year 2000. Availability of water is a constraint in a non-irrigated agriculture system. Aquafarming has a multidimensional context in perspective agricultural growth. It is tool for utilizing land and water more economically and optimally to increase productivity, of both, land and water, through sustainable agriculture. The countries in the Asia-Pacific region have vast and varied aquafarming resources. Often these are the main source of irrigation in this region. Overuse of water causes salinity problems in many countries reducing the cultivable area resulting in reduction in agricultural production.

An attempt has been made in this paper to develop the plan for water management for agriculture, aquaculture and horticulture using innovative technologies from Indian experience. The paper also evaluates waste water quality criteria for increasing agricultural productivity. The paper also discusses the innovative small scale methods and technologies for food production using non-conventional source of water for increasing productivity especially in drought prone areas.

1. INTRODUCTION

The evidence that the people of Egypt were probably the first in the world to breed fish as far back as 2500 B.C. comes from a pictorial engraving on an ancient Egyptian tomb showing Tilapia being fished out of an artificial pond. In the beginning the practice of fish breeding in ponds was probably solely to keep fish caught in lakes, reservoirs and rivers alive for some time. Carp culture was widespread in China in 2000 BC. The Chinese brought their traditional knowledge of aquaculture to the countries they immigrated to like Malaysia, Taiwan, Thailand, Indonesia etc.

Fish farming in the Indian subcontinent is hundreds of years old. Kautilya's Arthashastra, written between 321 and 300 BC. mentions secret means of rendering fish in reservoirs poisonous in time of war (Hora, Pillay, 1962). This indicates that fish farming flourished at that time even in ponds and reservoirs. Another document, which describes methods of fattening fish in ponds is the encyclopedia of King Someswara, Manasoltara, compiled in 1927 AD (Hora, 1951). Warm water fish farming in India involving collection and transport of fish spawn from rivers and stocking ponds adopting empirically developed traditional methods of pond management was mainly confined to Bengal, Bihar & Orissa until about the end of the 19th century after which it gradually spread to other states.

The first written account of fish farming in ponds was by Fan Lai, a Chinese fish farmer, in 475 BC. The ancient Romans introduced carp from Asia into Greece and Italy. By the 17th century, fish farming was being done all over Europe. A book written in the United Kingdom in 1600 by John Taverner gives the details of good pond management and talks about growing the common fish. Taverner also wrote about pond construction management, fertilisation and feeding. Another book written in 1865 gave the details of the stripping methods of spawning fish. The method of common fish farming has not changed very much since that time.

A notable advance in fish farming in West Bengal was construction of bundhs for carp breeding, coming down to modern times, where some of the riverine conditions are simulated. The bundhs formed a

more dependable source of fish seed of selected breeding species, though on a limited scale, than the rivers.

While the beginning of the 20th century marked the introduction of several exotic species in Indian waters, warm water fish farming were given a notable lead in Tamilnadu State in 1911 when, under the guidance of Mr. H.B. Wilson, the first big fish farm with facilities for breeding, rearing and stocking carps came into existence with the object of

- Stocking barren waters, including the newly constructed Kurnool-Cuddapah canal.
- Supplying fish to urban market.
- Distributing larvicidal fishes within the state.

Following the example of Tamil Nadu State, while many other states of the country such as West Bengal, Punjab, Andhrapradesh, Gujrath, Karnatka and Maharashtra conducted surveys for the development of aquaculture, little head-way was made in piscicultureal development and empirical and traditional knowledge of the art of aquaculture remained mostly confined to the fish farmers of Bengal. Artificial induction of spawning through environmental stimulation, so common in the dry bundhs of West Bengal State has been modified and adopted on a large scale in Madhya Pradesh State and Rajstan State leading to introduce spawn, fry and fingerling production of Indian major carps, namely catla, roha and mrigal in the public sector (Dubey, 1969). The techniques have undergone a tremendous change in West Bengal where the industry exists in the private sector.

Even rain water is not considered essential now as bundhs have been constructed by modifying the paddy fields or roadside ditches and water taken from canals ponds or wells to induce spawning. Cement cisterns filled with sand (Chatterjee farms Mogra, West Bengal) or cement ponds provided with a shower (G.B. Pant, A.U. Pantnagar, U.P.) and facilities for water from a tube well, artesian well, or pond are also found to be effective.

Sen and Chatterjee (1979) developed techniques for pond preparation and increased stocking densities. Feed quantum and feed quality play an important role. Stocked at 10 million per hectare; a survival of 66.6 percent was obtained when the spawn were four and eight times their initial body weight during the first and second five day periods.

Alikunhi (1956, 1987) obtained high survival in laboratory trials and suggested an intensive commercial rearing system. An intensive system is certainly necessary to meet the large and growing demand of standard fingerlings (50 mm) as 14mm survival from spawn to fingerling stage is hardly what the country can afford at this stage. Besides, suitable and large nursery and rearing space is not easily available for farm construction and commercial production in some parts of the country.

An intensive recirculatory filtering system was developed for the first time in the 70s in the tropics by the Indian Central Institute of Freshwater Aquaculture. With complete control over water flow and its biological purification the system facilitated high stocking densities as well as high production per unit area.

While on the one hand increasing densities resulted in higher yields, even a low density of 4000 per hectare gave yields as high as 8000 kg/ha in eight months (Shah, Rangayya, 1984) with addition of water in ponds with heavy seepage. High rates of production using varying but large quantities of water are being obtained by fish farmers in Andhra Pradesh with Indian major carps alone. The essence of high yield rates lies in heavy manuring and feeding coupled with water management.

In 1991, the Indian Central Institute of Freshwater Aquaculture emphasised the need of management of soil and water characteristics in aquaculture as it is necessary to know about these two important parameters of aquaproduction for higher growth and better yields. Further, the soil and water quality standards can be an aid to the improvement of soil and water status in fish farming ponds for effective growth. It was also suggested the Biological filtration system for water quality control in aquaculture industry. In both fisheries and aquaculture, higher production can be obtained by sustaining and maintaining water stable and of good quality. The water quality can be controlled by keeping away the pollutants from the aquatic environment, adopting different water filtration techniques and treatment practices; the fundamental concept of filtration is the process of removing undesirable impurities from a fluid by passing it through a porous material.

S.D. Tripathi (*et al.*, 1933) explained environmental improvement for aquaculture activities. Maintenance of a proper balance in the environmental quality or its improvement is an important

parameter. Studies on water and soil quality, weed management, waste water from ponds have formed a part of the overall programme of use of available resources for aquaculture and maximization of fish yields. Aquatic productivity is dependent on the environment or the soil & water quality of the pond. Recognizing the need for effective management of these valuable resources in environment it is necessary to prepare an environmental management plan for the subject under reference.

2. SELECTION OF SITES

One of the most important parts of planning is finding the right place for the pond. The past history of aquafarming projects all over the country and world has led to the conclusion that the right selection of sites is probably the most important factor that determines the feasibility of viable operations. Even though many years of painful efforts and new technology have turned some forms on poor sites into productive units, there are many that have been abandoned after considerable investment of money and effort. So there is no understating the basic importance of selection of sites which are mostly suitable for successful and profitable aquafarming activity. As it is not always possible to find out ideal sites, adjustments and compromises have often to be made regarding the site conditions and problems of land water use will have to be resolved. In many situations good quality of irrigated agricultural land may be the best site for pond farms for fish farming, but national priorities in cereal food production may make it unavailable for aquaculture, irrespective of economic or other advantages. On the other hand many countries, particularly in the Asia region, are now giving higher priority to aquaculture and farmers are increasingly utilising paddy fields for fish farming.

Although site selection will generally be based on the species to be grown and technology to be adopted, under certain conditions the order may have to be reversed. Limitations in any of the three factors, namely site Characteristics, Species and appropriate technology obviously restrict the choice of the others.

3. GENERAL CONSIDERATIONS

Although many of the factors to be investigated in the selection of the most suitable sites will depend on the farming system to be adopted, there are some factors which affect all systems, such as agro climatic zone conditions, access to markets, suitable communications, protection from natural disasters, availability of skilled and unskilled labour; public utilities and securities etc. It may be possible to find solutions when these factors are unfavourable and present problems, but it would involve increased investment and operation and maintenance costs, which would affect overall profitability of the entire project. In cases of small scale aquaculture, it is necessary to see that the selected site has easy access to materials that cannot be produced on the farm and that the necessary extension services are available.

All available meteorological and hydrological information about the area, generally available from meteorological and irrigation authorities, such as range and mean monthly air temperature, rain fall, evaporation, sunshine, velocity and direction of winds, flood frequency and intensity, ground water level etc. have to be examined to assess their suitability.

In land-based aquaculture, the most commonly used installations are pond farms and hatcheries. Since most of such farms have earthen ponds, soil characteristics, the quality and quantity of water and the ease of filling and drainage, especially by gravity, are basic considerations. Land elevation and flood levels have to be ascertained. The maximum flood level in the last ten years or the highest astronomical tide should not be higher than the normal height of dikes that will be constructed for the farm. It will be advantageous to select land with slopes not steeper than 2 percent. The area should be sufficiently extensive to allow future expansion and preferably of regularly shape to facilitate farm design and construction.

The nature of the vegetation indicates the soil type and elevation indicates water table. Obviously dense vegetation, particularly tall trees, make clearing more difficult and expensive. Land under grass or low shrubs is much better suited in this respect. However, in areas exposed to strong winds and cyclonic or similar weather conditions, sufficiently tall vegetative cover around the farm can serve as effective wind breakers. High ground water level may create problems in farm operation of mechanical equipment for pond construction and so will also become inconvenient.

Among the other important general factors to be considered are the existing and future sources of pollution and the nature of pollutants. In this connection, information and development plans for the neighbourhood areas will be necessary. It will be useful to ascertain the past use of site, if any. Croplands

that have been treated for long periods with pesticides may have residues that are harmful to fish. If the site is located adjacent to croplands that are sprayed from air or land, there is risk of contamination occurring directly or through run-off water. Similarly the possible effects of discharges from the pond farms into the waterways and irrigation systems in the neighbouring area should be considered. This can greatly influence the attitudes of the neighbourhood communities to the proposed farming.

The choice of sites for integrated aquaculture - such as fish farming combined with crop and livestock farming - is governed by factors other than their mere suitability for aquaculture. Land available for integrated aquaculture is generally agricultural land, even if it is somewhat less productive. A satisfactory irrigation system is likely to have been developed for agriculture, in which case water and soil management can be expected to be easier. Since integrated farming is based on the recycling and utilization of farm wastes, problems of pollution can be expected to be minimum or to some extent reduced.

4. SOIL CHARACTERISTICS

The quality of soil is important in pond farms, not only because of its influence on productivity and quality of the overlying water, but also because of its suitability for dike construction; the ability of ponds to retain the required water level is also greatly affected by the characteristics of the soil. It is therefore essential to carry out appropriate soil investigations when selecting sites. Such investigations may vary from simple visual and tactile inspection to detailed subsurface exploration and laboratory tests. Because of the importance of soil qualities, detailed investigations are advisable particularly when large scale farms are proposed.

Sandy clay to clayey loam soils are considered suitable for pond construction. To determine nature of the soil, it is necessary to examine the soil profile and either test pits will have to be dug or soil samples collected by a soil auger at regular intervals on site. To obtain samples, rectangular pits of size 1.0 to 2.0 m. deep, 1.5 m long and 0.8 m wide, are recommended. If available a standard core sample or soil auger of known capacity eg. 100 cu.cm. can be used for collecting samples of soil from each soil horizon.

Texture and porosity are the two most important physical properties to be examined. Soil texture depends on the relative properties of particles of sand, silt and clay.

By touch and feel one can roughly determine the texture. A sample of the soil should be kneaded in the hand (to make it somewhat drier, if it is wet and sticky; if the sample is dry add some water to make it moist but not sticky). If the kneaded sample can be rolled into a bar (about 6 mm thick) and bent to form a ring around the thumb, without any cracks, the soil must be clayey. If it cannot be made into a bar and remains separate with visible grains when dry, the sample is sandy. If the sample does not fall into either of these categories it can be classified as silty or loamy. Sand grains can be felt distinctly, even when not readily visible in loamy soils. Silty soils feel like flour or dough between the fingers. There are, of course, intermediate categories depending on the proportions of the constituents.

Because of their cohesive properties, fine-textured soils (clay, silty clay, clay loam, silty clay loam and sandy clay) are more suitable for pond farms. They have a greater surface area and can therefore absorb more nutrients and retain and release them for organic production in ponds; they are also less subject to erosion and other damage. The soil structure or the arrangement of soil particles is of special importance in determining compactness, and therefore porosity, of the soil. Light textured soils, particularly in close proximity to open drains can cause high seepage and percolation. Pond farms built on such soils may, however, improve in the course of time due to the blocking of interstitial pores by organic sediments produced in the pond, or introduced with the water supply or derived from manuring. Puddling is an efficient means of sealing ponds. In this process, fine particles clog the most permeable parts and in due course the bottom of the pond may be completely sealed. Compaction of soil by mechanical means during pond construction can also assist in reducing seepage. Suitable linings like polyethylene sheets have been used on pond bottoms and water supply channels to prevent seepage with some success. But it is difficult to prevent damage to the lining and it often turns out to be too expensive for practical use. It may also greatly reduce the contribution of the pond bottom to natural productivity in the pond, even if the initial and continuing costs of the lining are acceptable.

5. WATER QUANTITY AND QUALITY

The availability of appropriate quality water is important for all systems of aquaculture but the quantity

is particularly important for land based systems. It is therefore necessary to investigate as thoroughly as possible, the extent and seasonality of water sources as well as liability to pollution. Since predictions have to be made on long term water conditions, it is desirable to have data for a reasonably long period of time. In areas with controlled irrigation, reliability of supplies can generally be expected. Together with the availability of cheap electricity, this has made water management fairly easy for fish farmers in Southern China, in spite of dense stocks of fish and heavy loading of manures in pond farms. On the other hand, when rain-fed or ground water ponds are used, as in Eastern India, water levels in the ponds become dangerously low due to seepage and evaporation in summer months, when the ponds have generally the maximum biomass of fish. Access to other reliable sources of water, such as rivers, streams, lakes and reservoirs or even tube wells, which can yield enough water are essential for the enterprises to succeed. Loss of water due to seepage and evaporation varies considerably. For example, the average loss in Europe is reported to be about 0.4-0.8 cm per day, whereas in tropical regions it may be as much as 2.5 cm per day. When ground water is the major source of water supply, the effect of pumping on the water table and possible land subsidence have to be considered.

The need to investigate the elevation and ranges of tides for coastal aquaculture has to be considered. This is most important when tidal movements have to be depended on for filling and draining of the ponds. The constant flushing of newly constructed ponds to leach out toxic elements from the soil has also been mentioned. It is believed that if pumping were to be used for water management, the costs of construction of dikes and sluice gates would be minimized and the ponds could be constructed and operated without disturbing the acid soils, allowing a non-acidic layer of sediment to deposit on the bottom. In the long run, this may be more economical, despite increased energy costs. However, it will be necessary to make rough calculations of the comparative costs before finally selecting the site and deciding on the system of management to be adopted.

The temperature of the water will be an important criterion as to whether the species selected can be farmed on the site. Although the temperature can be controlled in hatcheries and in systems with a recirculating water supply, it is extremely difficult, if not impossible, to do so at affordable costs in large pond farms. Industrial waste heat can to a certain extent be used to raise temperatures in aquaculture areas, but very often practical problems of quality of heated water or irregularity in availability limits their use, except in well controlled environments or where the fish can stand considerable variations in temperature.

Salinity and variations thereof are also important environmental factors, which have to be taken into account. Some species have wide salinity tolerance limits and it has been noted that some fresh-water fish grow faster in slightly saline water and some brackish - water fish faster in fresh water. However, they still have their limits of tolerance. Even if they survive, their growth and reproduction may be affected. For example, the common carp (*Cyprinus Carpio*) can grow well in salinities up to 5 ppt, but at 11.5 ppt the salinity becomes lethal.

Salinity and water temperature are important considerations in deciding on the sites for hatcheries. Not only do these require higher water quality but the levels of salinity and water temperature required for spawning and larval rearing may differ from those needed for grow-out to market size. This may make it sometimes necessary to select separate sites for hatcheries and grow out farms for certain species.

High turbidity of water caused by suspended solids can affect productivity and fish life. It will decrease light penetration into the water and thus reduce primary production into the water and thus reduce primary production. This would naturally also affect secondary production. In certain cases, oxygen deficiency has also been reported as a result of a sudden increase in turbidity. The suspended solids may clog the filter - feeding apparatus and digestive organs of planktonic organisms. The gills of fish may be injured by turbid water. Although the effect will depend on the species and the nature of the suspended matter, pronounced effects are seen when the water contains about 4 per cent for volume of solids. The use of turbid water in hatcheries should be avoided, as it can greatly affect the hatching and rearing of larvae.

If it becomes necessary to select sites with highly turbid water, which the candidate species cannot tolerate, suitable methods of reducing turbidity have to be adopted. The use of settling tanks, different types of filters and repeated application on gypsum (initially 200 kg per 1000 m, followed, if necessary, by an additional application of 50 g per 1000 m) have been recommended. All of these will involve higher capital or operational costs, but in cases where there are no alternatives the possibility of absorbing the costs will have to be examined in feasibility studies. Improvements in drainage from catchment areas, often the cause of high turbidity, may also be considered.

Among other water quality criteria of importance in site selection are acidity and alkalinity. The most

suitable p^H of water for aquaculture farms is considered to lie in the range of 6.7-8.6 and values above or below this inhibit growth and production, although the extent of their effect will depend on the species concerned and environmental conditions such as the concentration of carbon dioxide or the presence of heavy metals like iron.

The prevalence of low p^H in brackish-water areas and the problems of improving soil and water quality in farm built in such areas have been described earlier. Water of low p^H is also common in fresh-water areas with soils low in calcium and rich in humic acids. Acid water with a p^H range of 5.0-5.5 can be harmful to the eggs and fry of most fish and the adults of many species. Acidity reduces the rate of decomposition of organic matter and inhibits nitrogen fixation, thereby affecting overall productivity.

The most common method of correcting low p^H is by liming to neutralize acidity. The dose will depend on the p^H value and the chemical composition of the water, especially the concentration of calcium bicarbonate [$Ca (HCO_3)_2$]. It will also depend on the type of lime used. The relative quantities of quick lime (calcium oxide, CaO), slaked lime or agricultural lime (calcium hydroxide, $Ca (OH)_2$) and limestone (calcium carbonate, $CaCO_3$) required will be in proportions of 1;1.5;2 respectively. The actual dosage has to be determined by titrating the water to neutrality and calculating the equivalent amount of lime to be added. Additional costs involved will have to be taken into account before selecting sites with acid water.

High p^H , indicating excessive alkalinity, can also be harmful. However, it should be noted that in productive water p^H may reach higher values of 9 to 10 due to the uptake of carbon dioxide during photosynthesis in the daily p^H cycle. This is why it is better to take p^H measurements before daybreak to determine their suitability for aquaculture. A p^H level of 11 may be lethal to fish.

6. RESULTS AND DISCUSSION

Experimental ponds were constructed at the site and observations were recorded for different conditions and stages of aquafarming activities. For optimum growth of fish, soil and water analysis are essential for proper decision making for achieving required profit.

One of the most important parts of planning is finding the right place i.e. selection of site for the pond. If the site for the pond is well chosen, the pond can be more productive than the land by reducing environmental deterioration itself.

Development of soil salinity is a challenge to the permanence of aquafarming. Lack of drainage facilities and poor water management are the main causes of water logging and salt accumulation in the surrounding area of aquafarming. An accumulation of salts in soil leads to unfavourable soil-water-air relationships and decreases overall productivity of land. Saline soil with p^H 6 to 8 is favourable for aquafarming activity.

Water supply, soil, and topography are all important but water supply is the most important factor in selecting a site. Fish depend upon water for all their needs. If a site has water available all year round, that site meets its first test easily. If water is not available always but there is some way to store water in large tanks, ponds, drums etc, for use when the natural water supply is low, then additional costs for water storage should be considered and feasibility should be checked.

A series of observations were carried out in an experiment regarding the levels of oxygen dropped during different times of the day, seasons and various atmospheric factors like sunshine, wind, velocity etc. The average wind velocity of the experiment site was found between 6 to 12 km per hour and average sunshine hours were between 6 to 8 hours.

Oxygen troubles arise in a pond when the supply of oxygen is used up faster than oxygen is put into the pond. The level of oxygen depends on the fish population in the pond. For Indian carp the stocking density i.e. density range from 4000 to 11000 per hectare. If fish are stocked so that there is enough oxygen, and no temperature difference between the stocking water and the pond water, they are not touched, and the fish will not be stressed and will survive the stocking.

From observations it is clear that as the temperature increases, the level of oxygen decreases accordingly and aeration needed to maintain the required level of oxygen in the pond. The oxygen in the pond is also used up by the process of decay. Dead organic matter, leaves, fish, other plant and animal material present in the pond, use up oxygen in the decay process called oxidation. Oxygen is also required for oxidation processes in the pond.

The phytoplankton and higher plants use carbon dioxide and sunlight to produce oxygen during a process of photosynthesis. Oxidation and respiration go on both day and night, while photosynthesis take place only during sunlight. Therefore, these are times during the day when the oxygen levels in the pond can be very low, and oxygen may have to be added to the water.

Oxygen can be added to the pond by taking out some of the old water, which is low in oxygen and adding new water. A cloudy day can sometime cause oxygen levels to drop. The new water should be sprayed or bubbled into the pond so that the water picks up oxygen from the air as it falls into the pond. The oxygen also can be added to pond water by stirring up the water already in the pond. But in this method the water bubbles are not formed in large quantity and hence limited quantity of oxygen is added to the water. To form more bubbles it is essential to run a small motor in the pond water. This is the easiest way to achieve the required oxygen level in the pond.

The level of oxygen can be increased during day time by increasing the vegetation in pond but excessive vegetation leads to decrease in oxygen level during night time.

Oxygen can be added to the pond water by taking out some of the old water which is low in oxygen and adding new water. This method is suitable where running water is available throughout the day and does not require skilled labour.

Fish begin to be stressed when the oxygen level falls below 4 mg/l. For best growth, oxygen levels should be above 5 mg/l but not more than 11 mg/l. Hence for a continuous supply of oxygen bubbling aeration is the most suitable method. It keeps the oxygen level almost constant.

The cheapest way to add oxygen to pond water is to stir the water with poles so that water picks up oxygen from the air while moving.

For effective fish growth, 6.5 to 9.5 p^H level is required. The p^H level of water is changed from acidic to alkaline condition, by adding lime to the water. During the rainy season the p^H value may change due to addition of rain water and surface runoff from surrounding areas into the pond. Sometimes the pond p^H can change quickly due to a sudden change in temperature or decrease in oxygen level. The best way to get the p^H back to neutral is to add limestone (calcium carbonate) to the water by spreading it on the pond bottom or on surface of the water.

If the p^H of pond water is between 0 and 7, the water is considered to be acid. If the p^H is at 7, the water is neutral and p^H of 7 to 14 means the water is basic. Fish grow best in a p^H of water between 6.5 and 9.0. Fish are very sensitive to low p^H , in other words, to water which is acid. Most pond fish will die, if the p^H falls below 4 for a very long period of time. The best way to get the p^H back to neutral is to add limestone (Calcium Carbonate) to the water by spreading it on the pond bottom or on the surface of the water. A fish like tilapia can tolerate p^H from 3.7 to 10.5, but below a p^H of 5, they are stressed and they will not eat.

Addition of water or replacement of water is another way but it has some limitations because large quantities of water are needed in this procedure and replacement of water is also not possible due to the requirement of large storage tanks, effective inlet and outlet arrangements and proper drainage systems, which involve additional costs.

The feasibility of the conjunctive use approach depends on operating a pond water effluent over a range of water levels; that is, there must be space to store the filtered water and in addition there must be water in storage for aquafarming activity when needed. Management by conjunctive use requires careful planning to optimize use of available surface water and ground water resources along with pond effluents. The conjunctive use can prove to be a promising technology in drought-prone areas. The conjunctive use application reduces soil salinity and water logging hazards.

Reuse or conjunctive use of water is also possible but for this filtration of water becomes essential. The conjunctive use is recommended for agricultural purposes as the water in the pond contains valuable nutrients and sludge formed due to application of fertilizers and feed for aquafarming. The application of rapid sand filters and slow sand filters removes total solid effectively from effluents of the pond. The filter media consisting in 75 cms of gravel (size 20 mm to 40 mm) and 75 cms of sand. (size 0.4 to 0.5 mm) was found suitable for the rate of 75 lit/min/sq.m. area. This combination required minimum backwashing of the filter media. The water thus filtered is found suitable for agricultural purposes and the yield of groundnuts is increased by 35% to that of sub-standard conditions.

The application of slow sand filter is proves beneficial where there is shortage of water. The reuse of filter water is found suitable for the aquaculture pond. This filter remove the B.O.D. and give the rate of filtration as 100 to 120 lit/hr./sq.m and also found highly efficient in removing bacteria and other suspended solid and turbidity.

7. CONCLUSION

The fishery sector is gaining importance in Indian Economy. It contributes about 4 percent to the nation's total export earnings and provides sources of employment for about 9.5 million people. India has a great potential for fishery development both in marine and inland sectors. Though for farmers in many Asian Countries aquaculture has been a way of life for centuries its status in the context of global food production, aquatic resources management of rural areas remained until recently a matter of debate. Many present day aquaculture practices are based on biological studies with only limited involvement of other disciplines. This major handicap is now being increasingly understood and aquaculture has come to be recognized as a multidisciplinary science including engineering.

While planning aquaculture, it is necessary to conduct a comprehensive environmental impact assessment study of the system to prepare an effective Environmental Management Plan.

The first stage of the aquaculture system is to identify the proper site. The selection of the site should be done on the basis of agroclimatic conditions, access to market and availability of other inputs required.

The quality of soil is important in aquafarms, not only because of its influence on the productivity and the quality of overlying water, but also because of its suitability for dike constructions. Sandy clay to clayey loam soils are found suitable for pond constructions. Saline soils having 6 to 8 p^H are good for aquaculture and the soil p^H can be adjusted by adding lime, while constructing the pond.

The depth of water in the pond is another important criteria for an effective aquaculture system. If ponds are too shallow sunlight penetrates to the bottom, warms up the water and increases productivity. In some instances, shallow ponds may get infested with rooted aquatic micro-phytes and filamentous algae which are not desirable in aquaculture ponds. Ponds shallower than 1m. get overheated in tropical summers and *vice versa* in winter, inhibiting survival of fish and other organisms. A depth of 2.0 m is considered congenial for obtaining optimal biological productivity of ponds.

The optimum temperature range for many species of warm water fishes is 24 to 30°C. Water slight warmer than optimum provides better growth and food conversion than low temperature. Dissolved oxygen in water reduces along with increase in temperature and hence aeration becomes necessary.

It is essential that the intake water to the farming pond and the surrounding soil is free from pollution. The pond must not receive industrial effluents, sewage or pesticide runoffs from agricultural farms. Water must be free from high silt load. Silting leads to reduction in the pond depth besides other adverse water quality impacts. This can be achieved by providing silting tanks or settling tanks at inlet and outlet of pond before filtration to reduce the silt load and remove turbidity.

The turbidity of pond water has both advantages and disadvantages. The higher concentrations of suspended solids increase turbidity. If turbidity becomes too high due to suspended inorganic solids, primary productivity may be reduced because of penetration of sunlight. This can be an advantage in reducing the growth of filamentous algae and aquatic macrophytes but it can be disadvantageous if phytoplankton is required to provide food for young aquatic organisms. Turbidity caused by colloidal particles of different thermal properties is likely to influence temperature conditions of water mass by restricting penetration of sunlight.

Dissolved oxygen depletion in the aquaculture pond water is caused by less photosynthesis due to turbidity, sudden dying & decomposition of phytoplankton, increased temperatures and salinity, cloudy weather and decomposition of organic water. Bubble aeration is found most suitable for increasing oxygen levels in pond water. Other methods such as stirring of water, running small motors in the pond are also suitable for aquafarming activity. The addition of water for increasing oxygen level is not found suitable during the rainy season as the water p^H to be added is sometimes lower than the pond water and the quality of water is also greatly affected due to addition of chemical and fertilizers during the run off period.

Filtration and aeration of waste water from the pond is essential for removal of B.O.D. load, removal of suspended solids and to enhance the oxygen level, so as to minimize adverse impacts on the environment and also to reuse the pond waste water for agricultural purposes as it contains valuable nutrients and sludge formed due to application of fertilizers and food for aquafarming.

For waste water treatment of pond effluents, rapid sand filters are suitable for a conjunctive use of waste water for agricultural purposes and slow sand filters are suitable for reuse of waste water for aquaculture.

Hence there are two separate environmental management plans for aquafarming activity. They are suggested below so as to minimize adverse effects on environment given by the waste water that arises from aquaculture pond and also to reduce the infiltration of soil and thereby polluting the sources of water in the surrounding area.

A) For reuse of pond effluents.

B) For conjunctive use of pond effluent.

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