Chapter 2

LITERATURE SURVEY

2.1. SUBJECT COVERAGE

In the context of the present work, a literature survey on the characteristics of wetlands in the global context together with such of those information related to the Indian wetlands and Kuttanad wetlands represented by three panchayat units (baseline local administration sectors), namely, Kainakari, Edathuva and Alappuzha. Considering the panchayat alone there is no specific literature, and therefore the survey made here is a comprehensive one, covering the most salient information on wetland in general and Kuttanad wetlands in particular. Apart from the literature referred in the survey, there are also unpublished information in the form of dissertation and reports which have also been taken into consideration.

2.2. WETLAND DEFINITION

There is no single, formal definition of wetlands among ecologists, managers or government regulators (Dennison and Berry, 1993; Mitsch and Gosselink, 1986). Due to the complex nature of wetlands, ecologists, managers, and government agencies have struggled to identify a formal regulatory definition of wetlands. The National Research Council (NRC, 1992) simply identifies wetlands as transitional areas between terrestrial and open water systems, whereas the NRC defines them as “an ecosystem that depends on constant or recurrent, shallow inundation or saturation at or near the surface of the substrate” (NRC, 1995). Asian Wetland Bureau (1991)
broadly defines the wetlands to cover estuaries and deltas, salt marshes, mangroves and mud flats, coastal lagoons, fresh water lakes and marshes, oasis, seasonal flood plain wetlands, swamp forests, rivers and streams, man-managed systems such as rice fields, fish ponds and reservoirs (James, 2007). Other wetland scientists define a wetland as an ecosystem that “arises when inundation by water produces soils dominated by aerobic processes and forces, the biota, particularly rooted plants, to exhibit adaptations to tolerate flooding” (Keddy, 2000). It is clear that wetlands occur in the landscape because of the combination of water, soils, and plants forming unique biotic communities, and that the definitions and delineations reported in the literature are scientifically sound even though they were specifically developed for regulatory purposes (NRC, 2001).

2.3. WETLAND CLASSIFICATION

Because of wetland functions such as flood control, groundwater recharge, water quality enhancement, and their importance to a wide array of plants and wildlife, the colloquial terms describing wetlands were incorporated and formalized by scientists into a standardized, widely accepted scientific terminology with specific ecological, regulatory, and legal usage. Common colloquial names for wetlands are ponds, bogs, fens, marshes, wet meadows, shrub swamps, and wooded swamps, each with its own unique set of attributes. Wetlands are also known and classified by specific ecological technical terms depending on their geomorphic, hydrologic, water quality and biological characteristics. There are many kinds of wetlands, from those dominated by open water, to forested areas in which standing water is rarely present at the surface for an extended length of time (Mitsch and Gosselink, 2000).

Therefore, classification of wetlands is often fraught with controversy and problems, because of the enormous variety of wetland types and their highly dynamic character on the one hand and the difficulty in defining their boundaries with any precision on the other. Nevertheless, classification of wetlands have been attempted world over by various schools (Cowardin et
al., 1979; Maltby and Turner, 1983), and the one put forth by Harris et al. (1996) stands noteworthy for its ecosystem-based approach. Their attempt provided a framework for classifying wetlands in Northwestern Ontario using vegetation and environmental features, and the system largely assisted resource managers to make informed decision on wetland management and conservation.

2.4. WETLAND STATUS

The status of wetlands of the world was reported by Maltby and Turner (1983), who observed that about 6.4% of the total land area in the world could be estimated as wetland area. Biotic control of wetland hydrology, especially by wetland vegetation was studied by Gosselink et al. (1984). The nationwide wetland inventory carried out by Garg (1998) reveals that there are 7.6 million ha of wetland units in India of which 4.0 million ha are coastal wetlands and 3.6 million ha are inland wetlands. Details of wetland area in Kerala have been provided by Nayar and Nayar (1997). From the study of coastal wetlands of Kerala, Thrivikramji et al. (2007) observed that wetlands of different origin (both of brackish water and of fresh water) are known to be spread over the three broad ecosystems, namely Lowlands, Midlands and Highlands, developed from either structural, combination of structural, fluvial or sedimentation process.

Various threats faced by wetlands of Kerala and its impact and the need for their conservation was suggested by Nair (1998). Geomorphological classifications of wetlands in Kerala were also given by Nair and Sankar (2002), who observed that the State has a total wetland area of 12,793,0.07 ha., in which 64 units are in the “inland wetlands” covering an area of 34,19,9.57 ha., where as 93 units are in the coastal wetlands covering an area of 93,73,0.5 ha., and that these wetlands offer ideal habitats for fish and wildlife species, including rare and endangered birds. Nayar et al. (2011) carried out a comprehensive investigation on the qualitative and quantitative analysis of physical, chemical, biological and socio-ecological status of Sasthamkotta fresh water wetland (Ramsar site) of Kerala, in an effort to
correlate the biological and chemical quality of lake water with the biodiversity status.

Bijoy Nandan (2007) made an analysis on the environmental and biotic status of Kayal ecosystems of Kerala, evaluating diversity of plankton, benthic fauna and its diversity, wood boring organisms, fish and shell fish resources in selected backwaters and reverine ecosystems of Kerala, particularly on Vembanad wetland ecosystems. While investigating the status of backwaters of Kerala, Gopalan (2002) concluded that it may not be possible to bring back the brackish waters to their pristine glory but it is high time to take adequate steps including legal measures to prevent further shrinkage and degradation.

From the investigations of Kokkal et al. (2008), it is known that wetland systems directly or indirectly support thousands of people providing goods and services to them. However, urbanization, developmental activities, mushrooming of residential complexes have fragmented the contiguity of the wetlands and destroyed its vegetation. The study also explained about the major issues facing the wetlands of Kerala which include pollution, eutrophication, encroachment, reclamation, mining and biodiversity loss. Primary and secondary values of wetlands have been measured by Ing Marie Gren et al. (1994). During the study, the authors established the build up and organizing capacity of the wetlands, identifying the two types of “output” values namely primary and secondary.

2.5. WETLAND HYDROLOGY

Wetlands are by definition dependent on the presence of water for all or part of a year either just below the soil/sediment surface or above it. It is vital in the transport of materials to, from and within the wetland while providing the habitat for often rich, diverse plant and animal communities; as a result most wetland research and study require at least a fundamental grasp of the site’s hydrology. The hydrological study is a pre-requisite in any aquatic ecosystem for the assessment of its potentialities and to understand the realities between its different trophic levels and food web. Therefore the
objectives of hydrological work can cross a spectrum from basic budget studies complementing other projects to self-contained research topics such as flood mitigation and water quality regulation. James (2002) carried out an excellent investigation on hydrologic consideration in the management of wetlands in Kerala and observed that primary productivity is enhanced by flowing condition and pulsing hydroperiod and is often depressed by stagnant condition. It is also observed that nutrient cycling and nutrient availability are both significantly influenced by the hydrological condition. Different species have different physiological response to flooding and large trees shows greater tolerance to flooding than do seedlings.

The overall water budget is a very useful approach to studying wetland hydrology and is described by Mitsch and Gosselink (2000). It provides an overall view of the transfer of water in a system over a year; subsequent division of the budget into smaller time periods will describe the hydrological regime, especially when coupled with knowledge of a site’s water storage capacity.

2.6. WETLAND GEOLOGY

2.6.1. Water quality

Consideration of water quality is important in wetland hydrology and habitat evaluation because a host of interacting physical and chemical factors can influence the levels of the primary productivity and thus influence trophic structure and total biomass throughout the aquatic food web (Wetzel, 1975). The water quality of resident and discharging water is intimately linked to a wetland’s hydrology. Considerable influence on local and even regional water supply quality may be exerted by a wetland receiving nutrients from run-off and groundwater sources.

A number of studies on various physico-chemical and biological aspects of wetlands were done in India and abroad, of which important contributions were made by Hutchinson (1937) Gonzalves and Joshi (1946), Sarup (1961), George (1964), Martin et al. (2008), Sujatha et al. (1999 & 2009), Seshavatharam and Chandramohan (1982), Ramalingam and Jayaraman
Bhunya and Mohanty (1990) studied various physio-chemical properties in relation to faunistic composition of Ansupa Lake, Orissa. Muduli and Panda in 2010 conducted a study on physico-chemical properties of water collected from Dhamra estuary and concluded that physico-chemical parameters affect the primary production in different seasons; the primary production varied from season to season with the load of nutrient salt in addition to phytoplankton species. Similarly, seasonal variation of physico-chemical characteristics of coastal waters of south east coast of India has been demonstrated by Damodaran et al. (2010).

2.6.2. Soil quality

Soils often provide important clues to wetland processes, character and history. Waterlogged soils have classic morphological features, such as the presence of a surface peaty layer and distinct mottling in the mineral horizons. The latter is caused by variations in the oxidation/reduction state of the soil, which affects the chemical status of particular elements resulting in distinct colour changes. It has been reported that tillage practices influence the physical and chemical properties of soil, soil moisture, temperature, root growth, nutrient uptake, population of weeds and insects (Chatterjee et al., 1999). Premachandran et al. (2002) studied various kinds of toxicity and their adverse effects in agricultural lands, and noted that problems and toxicities can be tackled by adopting appropriate alternate technologies and soil management strategies without any harm to the ecology.

Through a detailed investigation on wetland soils of Kerala, Premachandran and Roshni (2007) explains that the duration of the period that the soil must be saturated to have an aquatic regime is not known. The authors made an attempt to study the characteristics and occurrence of various kinds of soils of Kerala. They classified the wetland soils of Kerala into 4 categories viz. wetland soils of coastal area, wetland soils of depressional land in and around the river mouth, wetland soils of broad valleys and plain and wetland soils of narrow valleys. A similar study conducted by Usha and Alice
(1989), which provide detailed information about the productivity of paddy soils of Kerala. The study revealed the net changes in fertility level due to submergence of some of the important rice growing soils of the State viz. the alluvial, acid sulphate and acid saline soil. In general, physical and microbial processes are more important than vegetative uptake in controlling sediment and nutrient retention (Johnston, 1991).

2.7. WETLAND BIORESOURCES

Wetlands potentially perform a number of different and often critical environmental and ecological functions benefiting humans. These include flood storage and retention, groundwater discharge/recharge, maintaining and protecting water quality and providing abundant and clean potable water. Some maintain base flow, and may enhance the water quality within streams and lakes with important fish and wildlife species. Correspondingly, some provide habitat for federally and State threatened and endangered species, as well as for a wide diversity of important micro level organisms, invertebrates, fishes, amphibians, birds and small mammals (Kusler and Opheim, 1996; NRC, 1992; 2001). Wetlands perform functions as a result of the interactions among soil, water, plant and animal species. Livelihood such as fisheries, wildlife and forest resources may be generated and attributes conferred such as biodiversity and cultural uniqueness. Functions, products and attributes are all valuable to society but the extent of this varies from wetland to wetland (Dugan, 1990). Brown (1985) and Adamus (2001) provide meaningful information on wetland resources. According to Brown (1985) a large number of fishes and wildlife are heavily dependent on wetland habitat for their life’s needs, whereas Adamus (2001) suggest that a large number of plants and animals are endemic to wetlands and even to specific wetland types.

2.7.1. Wetland flora

The composition of species in wetlands varies both in time and between wetland sites. Aquatic macrophytes in wetlands have attracted the attention of botanists since early 20th century. A wide variety of macrophytic
plants occur naturally in wetland environments. Considerable work has been carried out on various aquatic macrophytes. The diversity and abundance of plant and animal species in wetland ecosystems were discussed by Mitsch and Gosselink (1986), and Ewel (1991). The investigators emphasized the structural, genetic and physiological adaptation of species toward abiotic stress and species relation to flooding, turnover rate of water and quality of inflow water. Ralph W. Tiner (1991) made a detailed investigation on the distribution and production of macrophyte vegetation of wetlands in order to make a concept of a hydrophyte for wetland identification.

Through the studies conducted in the United States to the better understandings of ecological relationship, the ecologists have described certain plant species and communities as characteristic to the wetland (Ralph W. Tiner, 1991). In this study author made a detailed investigation on the concept of hydrophytes for wetland identification with the explanation that various hydrological regime associated with wetland create a diverse set of environmental conditions that require plants to tolerate different degrees of wetness.

Weaver and Clement (1929) broadly divided vascular hydrophytes into floating, submerged and amphibious type. Penfound (1952) recognized two types of hydrophytes, aquatic types and wetland types, of which aquatic types are distinguished into emergent, floating and submerged types. Daubenmire (1947) classified into floating, suspended, submerged-anchored and emergent-anchored. Joseph (2002) enumerates the wetland flora in terms of plants growing in running water, plants growing in stagnant water and marshy plants. The documentation on the aquatic flora of Kerala was carried out by Schelpyl (1961) and Cook (1996). Manilal and Sivarajan (1975) published a check list of hydrophytes of some districts in Northern Kerala (Malabar). A general survey of the flora of Alappuzha district was recently carried out by Sunil and Sivadasan (2009).

2.7.2. Invasive alien species

Jamil (1991) observed that aquatic plants could change the quality of water by lowering temperature, pH and dissolved oxygen content. The thick
mat of floating weeds such as *Eichhornia crassipes* and *Salvinia molesta* prevent sunlight from reaching the submerged flora and fauna cutting off their energy source (Pieterse and Murphy, 1990). It is also noted that after habitat loss, invasive alien species (IAS) are considered the most serious threat to biodiversity (IUCN, 2000) while for some aquatic ecosystems such as lakes they are the principal threat because of frequent intentional introductions (Sala et al., 2000).

However, there are many studies emphasizing the need for the conservation of wetland macrophytes for the management of bird habitat. Weller (1994) noted that waterfowl species richness was greatly influenced by water level and vegetation characteristics. Bhupathy (1991) and Urfi (1993) correlated the biomass of aquatic vegetation with increased numbers of herbivorous bird species such as moorhen and coot. Ramachandran and Vijayan (1995) reported that Bronze Winged Jacana and Pheasent Tailed Jacana preferred areas where *Eichhornia crassipes* and *Ipomoea aquatica* were abundant.

2.7.3. **Planktons**

The phytoplankton and zooplankton form a vital part of the aquatic food web and therefore information of their population is important to wetland management. Phytoplankton forms one of the major producers of the wetland ecosystems, and thus contributes substantially to the gross productivity of the area. From the ecological point of view, investigation on both phytoplankton and zooplankton composition and community structure are very important (Sinha and Sinha, 1993; Kumar, 1995). There are many international reports regarding planktonic population and water quality of wetlands. Gabellone et al. (2001) in Argentina reported that limnological characteristics of Floodplain Lake in different seasons are related to hydrological condition, which influence the planktonic community. Garcia et al. (1997) in Argentina, Oliveira et al. (2000) in Brazil also reported higher density of phytoplankton in a Floodplain Lakes. Ogbeibu et al. (2007) observed the severe impact of drudging on water quality and rotifer diversity in a river of Nigeria.
Many Indian investigators pointed out similar types of observation from various parts of India. While studying the hydrobiological study of Vembanad Lake, Kunjukrishna Pillai et al. (1975) reported that the positive loading of NH$_3$ and BOD supports decomposition of organic material by microbial organisms within the ecosystem. Senthilkumar and Sivakumar (2008) and Singhal et al. (1986) reported a decrease of phytoplankton population with increase in electrical conductivity of a lake in Tamil Nadu. Alexander et al. (2010) reported 67 species of phytoplanktons and 7 species of zooplanktons from various water bodies of Kainakari panchayat under the Kuttanad wetland systems.

2.7.4. Wetland fauna

Wetlands are known to be an indispensable habitat to a variety of biologically and economically important resident and migratory fauna, which include birds, fish, skinks, geckos, frogs and invertebrates—both terrestrial and aquatic. Despite the limited area covered by remnant wetlands in New Zealand, it is home to 22% of native bird species and 30% of native freshwater fish (Corrine Watts et al., 2010). Kerala is blessed with an array of water bodies referred to as wetlands providing a very unique and endemic faunal biodiversity. Bijoy Nandan (2007) carried out a detailed investigation on the faunal biodiversity of wetlands of Kerala. The author reported 13 species of polychaetes, 8 species of boring organisms, 94 species of fishes and several species of clams and oysters from various backwater wetlands of Kerala. A systematic account of freshwater fishes in Kerala is available from Day’s (1865) book ‘Fishes of Malabar’. After Day’s monumental work, the next fish fauna study in Kerala was made by Pillay (1929), in which he listed 369 species from Travancore region. While studying the fishery resource, Nair et al. (1983) recorded 97 species of fishes from Ashtamudi wetland. Based on the above studies Hora (1941) published a comprehensive list of 76 species of typical freshwater fishes of Travancore. In 1994, Pethiyagoda and Kottelat described three new species from the Chalakudy River in central Kerala. Studies by Mary John (1958) reported 117 fishes and 12 prawns from the Kayamkulam backwaters.
2.7.5. **Wetland avifauna**

Wetlands are known for their migratory bird species, the composition of species in wetlands vary both in time and between wetland sites. The diversity and abundance of birds in wetland ecosystems are discussed in the publications of Mitsch and Gosselink (1986), Williams (1990) and Ewel (1991). In fact, the diversity of birds (Richter and Azous 2000a) and small mammals (Richter and Azous 2000b) in wetlands may exceed that found in upland habitats, because of the unique mix of water and biodiversity. In India, Inspired by the pioneer studies on Ali (1999), many efforts were made to describe the birds of wetlands of Kerala. Neelakantan extensively explored the water bodies in the State over a period of four decades and reported many aspects of wetland birds of the state (Neelakantan, 1969, 1981 and 1982). Recently a couple of detailed ecological studies on birds of wetlands of the State and their conservation were carried out by Jayson (2002) and Nameer (2007) particularly in the Vembanad Lake. Narayanan et al. (2011) reported 225 species of birds from the Kuttanad wetland systems. Sivaperuman and Jayson (2000) made a detailed analysis on the birds of Kol wetlands of Thrissur district, Kerala and reported 167 species of birds belonging 39 families.

2.8. **WETLAND CONSERVATION AND SUSTAINABLE DEVELOPMENT**

It is noteworthy that even a small country like UK could designate 161 wetlands as Ramsar sites, India being a mega-diversity Country, so far managed to delineate a mere six site till date. There is obviously much ground to be covered in our conservation effort of wetlands (Prasad et al. 2002). If conservation of wetland biodiversity is a goal of wetland protection programmes, regulations used in nationwide wetlands protection should be redesignated accordingly (James, 1999). Baskaran et al. (2007) suggested that major factors of wetland management include the buffering of wetlands from direct human pressures and maintaining natural processes in surrounding lands so as not to disrupt the natural activities in that specific piece of land. During the course of an investigation on wetland conservation, Nayar et al.,
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(2011) reported a variety of problems faced by Sasthamkotta fresh water wetland system are encroachment, sedimentation of the lake due to agricultural activities, land filling, pollution due to urban sanitary discharge and destruction of vegetation around the lake. The authors proposed an array of conservation action plan for protection of the threatened wetland ecosystem of Sasthakotta Lake.

2.9. KUTTANAD/VEMBANAD WETLAND

2.9.1. Status

The present investigation gives a serious thrust on the vegetation faunal composition, physico-chemical and geomorphological features of Pamba River basin with special emphasis on sustainable development of ecology, economy and bioresources of Kuttanad wetland system. In this background the most recent scientific investigation has been conducted by Alexander et al. (2010). During the study authors documented the various environmental resources and made some suggestions for their sustainable development in the Kuttanad wetland with special reference to Kainakari Panchayat. In another study Nair et al. (2010) made an attempt to evaluate the status of climate change in wetlands and suggest the possibilities of climate change control of Kuttanad wetland through eco-development activities.

Kuttanad wetland ecosystem particularly the Vembanad Lake is now receiving global attention because nature is at the peak of its beauty in this Ramsar site (Swaminathan, 2007). In this background several scientific investigations have been carried out with reference to the eco-biological, socio-economical, cultural and toxicological aspects of both Kuttanad wetland and Vembanad Lake particularly in the Pamba River Basins. Although historical notes on the land and people of the State of Kerala are recorded in various Govt. documents, a review of the Kuttanad area in the lowland ecosystem by the Sasthra Sahithya Parishath (Babu Ambat, 1992) provide a glimpse into the problems and promises of the environmental resources and sustainable development theme as a direction for better livelihood and the application of science and technology in the planning and development of policies and its implementation.
2.9.2. Resources

Central Ground Water Board, Govt. of India conducted a survey and analysis on ground water status and characteristics of Alappuzha district, which provide a comprehensive idea on geomorphology and ground characteristics along with the management strategies of soil and water of Alappuzha district particularly Kuttanad wetland system (Vinayachandran, 2005). Similarly the environmental status and physico-chemical characteristics of Pamba River Basin has been studied by Koshy and Nair (1999) and Mathew et al. (2007) and reported enhanced pollution in the downstream due to urbanization as well as anthropogenic activities. Elizabeth (2009) conducted a study on physico - chemical properties of Pamba River with special reference to the distribution of giant prawn. The study revealed that Pamba River holds good amount of oxygen which provide favorable condition for the growth and survival of prawns. Money (1961) and Thampath and Jose (1997a) carried out an investigation about the characterization and classification of the Kuttanad wetland soils, and also made an attempt to evaluate the heavy metal accumulation of Thanneermukkam regulator of Vembanad Lake (Thampath and Jose 1997b). During the course of a study about the reactive fluoride sediments in Kuttanad waters, Geetha et al. (2007) classified the sedimentary fluoride of Kuttanad into three categories namely, acid extractable fluoride, NaCl extractable fluoride and NaHCO$_3$ extractable fluorides. Christina Tang (2009) carried out a detailed study and analysis on water quality and cost-benefit of rainwater harvesting in Kuttanad wetland. The study developed a recommendation that domestic rainwater harvesting system in a rural setting, which is the most appropriate system in the Kuttanad region to mitigate the water shortage problems. Biju Vikram and Jha (2004) reported that the deteriorating water quality condition of Pamba River marked with low transparency, pH and alkalinity and high carbon dioxide apparently influenced the distribution of phytoplankton.

Aquatic weeds of Kuttanad particularly Vembanad Lake cause severe threat in terms of environmental damage through pollution and agriculture disasters. Aquatic weed species, their environmental impacts in agriculture
especially in rice cultivation and their management measures were studied by Abraham et al. (1990), Sasidharan et al. (1990) and Elizabeth et al. (1993). In a recent study about aquatic macrophytes, Sylas (2010) reported that, in Kuttanad the aquatic macrophytes are efficient in purifying polluted waters and periodic removal of these macrophytes during cultivation enables restoration of the system to a great extent. These macrophytes are a boon in disguise to the maintenance of the Kuttanad wetland ecosystem from further deterioration. John (2011) observed 130 species of aquatic macrophytes from the Kuttanad wetland system, and also noted that there was a considerable increase in the area occupied by aquatic macrophytes in the Kuttanad wetlands.

Padmakumar et al. (1990, 2002b) carried out an analysis on open water fishery interventions in Kuttanad wetland, and is yet another work of the author on the fish faunal status of Thanneermukkam bund of Vembanad Lake. From the studies it has been observed that salt water barrage built at Thanneermukkam appears to have played a significant role in fluctuation of physico-chemical parameters as well as the reduction in fish population in the southern portion of the lake. During the studies on faunal biodiversity Narayanan et al. (2005) reported 37 species of fishes from Kuttanad wetlands of Kerala. Nair (1994) also carried out similar work in fish fauna of Vembanad Lake. George and Andrews (1995) made an attempt to study amphibian resources of Vembanad wetlands. Babukutty (1997) made a detailed survey on ecology of wetland birds and reported pond herons and little egrets from the Vembanad Lake. John and John (2004) reported for the first time a fish species Bunaka gyrinoides from Kerala during the course of an investigation in Pamba River at Perumthennisery region.

2.9.3. Sustainable Development

By virtue of the occurrence of expansive paddy fields it is understood that agriculture especially paddy cultivation is the major livelihood occupation and income generation of the Kuttanad people. Several scientific studies have been carried out by various investigators on the status of rice cultivation and its stress apart from the integrated approaches of
income generation associated with rice farming and other agriculture practices. Krishnakumary et al. (1993) suggested that the lack of improved technologies affect the yield loss in Kuttanad agriculture apart from soil fertility, rain fall, etc. Through the studies on agricultural mechanization in Kerala, Febi Varghese (1994) suggested that the State cannot abstain from utilizing the service of agricultural engineers to enhance agricultural mechanization and thus achieve increased crop production. Rema Bhai et al. (1994) studied about improved practice of rice farming such as application of mutant varieties of rice species in Kuttanad. The study concluded that rice mutants of red kernelled bold grains are promising for cultivation under Kuttanad condition.

Sudhikumar et al. (2005) carried out detailed investigation on spider populations and its seasonal abundance in the rice agro-ecosystems of Kuttanad wetland and found a significant difference in the diversity, evenness and richness between Kharif and Rabi crop cultivated seasons. Sebastian et al. (1994) reported 27 species of predatory spiders from the rice agro-ecosystems of Kuttanad. There are also some scientific studies concerned with integrated prawn culture and its economic viability associated with rice farming in Kuttanad wetlands, in which a major contribution has been made by Kurup and Ranjeet (2002).

An attempt to integrate public participation in the creation of an Action Plan for the Pamba River was carried out by the Kerala State Pollution Control Board in 2002. A comprehensive Action Plan was developed for pollution abatement for the River Pamba. The document is an attempt towards solving water pollution issues in the River Basin but, according to Integrated Water Resources Management (IWRM) principles, this is a piecemeal approach. In order to come to an integrated management plan for the Pamba River, various factors need to be considered. Those issues in need of attention have been explored in this document. In 2010 European Union conducted project in the name of ‘Pamba Pilot Project’ with the assistance of the Government of Kerala by piloting Integrated Water Resources Management (IWRM) in the Pamba River Basin. The aim of Pamba Pilot Project was to deliver “Policy Support to Integrated River Basin
Management” and to contribute to the continuing EU-India policy dialogue in the water sector.

Kuttanad water Balance Study has also provided a notable contribution in the field of water resources and its management of Kuttanad wetland (Indo-Dutch Mission, 1980). Planning commission Govt. of India (2008) made a pilot study and recommended an array of Management action Plans for the conservation and management of Vembanad Lake. In order to generate the proper status of Kuttanad wetland Aravindakshan and Joseph (1990) made a pilot study on the Kuttanad ecosystem.

2.10. ANALYTICAL NOTE

The above review of literature provides an insight into the characteristics of wetlands - physical, biological and environmental - highlighting the importance and relevance of wetland research, in evolving sustainable development options. The literature covered the core areas, and the references cited in the research documents examined, together with unpublished Reports, based on original work, and the field observation made in the present investigation provide a comprehensive picture of the Biodiversity of the ecosystem, the environmental problems and promises for sustainable management of the area.

A significant vegetational feature is the occurrence of mangroves especially in estuaries, naturally growing coconut palms, and scarce tree wealth. Bioresources of economic value cover both agricultural crops and wild plants like Centella asiatica and an array of beneficial taxa, classified under medicinals, timber yielding, fruit plants, fiber yielding, cultivated plants, vegetables and ornamentals. The agricultural occupations, particularly of the rice plant, are both productive and even destructive in the sense of pollution from residues from plant protection measures. The fish resources constitute the major faunal resources. The environmental pollution of water and soil from various sources cause damage affecting livelihood. The weed menace in the water bodies is a cause of concern in economic activity. There is hardly any organized activity in the sustainable management of resources, least of all in
providing measures to counter the impending hazards from climate change. The need for new knowledge generation, and for imparting awareness among the people for the protection of the wetland system, particularly of Kuttanad, is therefore imperative.

The information on wetlands would not be complete without the mention of the International efforts in the conservation, protection and sustainable development of the sensitive ecosystem. Organized scientific attention by world bodies such as UN under the United Nations Environment Programme has been the key to evolve strategies, plans and funding for various efforts. As part of the convention on biological diversity, the institution of “Ramsar Convention” has identified a large number of ‘Ramsar Sites’ India and elsewhere and it is particularly important to note that Vembanad Lake in Kuttanad is one of the sites identified. The attention given to Kuttanad is promoting agro system research and development including agroforestry and associated resources, known widely as Kuttanad Package under the leadership of Dr. M. S. Swaminathan is noteworthy and which will go a long way in the sustainable development of the Kuttanad wetland system (Swaminathan 2007).