CHAPTER 2

LITERATURE REVIEW AND SCOPE OF THE RESEARCH

A detailed review of the literature related to the scope of the thesis is presented in this section. The lack of a planning system that integrates environment and development, the lack of appreciation of the critical significance of wetlands as life supporting system among the public are the major reasons for the conversion of wetlands in Kerala. Therefore the review is categorized under three themes:

- To study about the wetlands, type, classification and major functions performed by the wetland
- To get an over view of the wetland status in India and Kerala
- To delve into the driving forces that lead to the conversion/degradation of wetlands and paddy lands in Kerala and the resulting impacts.

2.1. WHAT ARE WETLANDS?

Wetland is an ecosystem where water, energy, organisms and other materials meet and interact within the wetland over space and time and provides critical functions essential for maintaining the life on earth.

2.1.1. DEFINITIONS

Realizing the importance of wetlands in the global scenario several international agencies tried to define the wetlands as a part of their attempt to introduce this ecosystem to the public. Some important and universally accepted definitions are as follows.

Shaw and Fredine (1956) referred wetlands... ‘As lowlands covered with shallow and sometimes temporary or intermittent waters. They are referred to by such names as marshes,
swamps, bogs, wet meadows, potholes, sloughs, fens and river overflow lands. Shallow lakes and ponds, usually with emergent vegetation as a conspicuous feature, are included in the definition, but the permanent waters of streams, reservoirs, and portions of lakes too deep for emergent vegetation are not included. Neither are water areas that are so temporary as to have little or no effect on the development of moist-soil vegetation’.

Cowardin et al. (1979) in the Classification of Wetlands and Deepwater Habitats of the United States, defined “Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water... wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soil; and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during, the growing season of each year”.

According to U.S. Army Corps of Engineers (1987) Wetlands Delineation Manual, ‘wetlands means those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas’.

EPA Regulations at 40 CFR 230.3(t) listed “Wetlands are those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas.”

Ramsar Convention definition of wetlands gained wide spread acceptance and according to it “the wetlands are areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed 6 meters.”
Kerala Conservation of Paddy Land and Wetland Act 2008 defined wetland as “land lying between terrestrial and aquatic systems, where the water table is usually at or near the surface or which is covered by shallow water or characterized by the presence of sluggishly moving or standing water, saturating the soil with water and include backwaters, estuary, fens, fresh water lakes, lagoon mangroves, marshes, salt marsh and swamp forest, but does not include paddy lands and rivers”.

Definition of paddy field according to Kerala Conservation of Paddy Land and Wetland Act 2008, “Paddy field includes, all types of land situated in constant, midland or high range regions of the state and where paddy is cultivated at least once in a year or suitable for paddy cultivation and uncultivated and left fallow, and its related structures like drainage channels, ponds, lakes, wells etc”.

2.1.2. RAMSAR CLASSIFICATION SYSTEM FOR WETLAND TYPE

Though there are several classification systems for wetlands, the most approved was the classification systems coined by Ramsar Bureau. The importance and usefulness of wetlands was first brought to the world through a Convention on wetlands held at the Iranian city of Ramsar, in the year 1971. The Ramsar Convention was an international treaty that provided the frame work for national action and international cooperation for the conservation and wise use of wetlands and their resources. As of the 9th March 2007 Conference, there are 154 Contracting Parties to the Convention, with 1650 wetland sites, totaling 149.6 million hectares, designated for inclusion in the Ramsar list of wetlands of International Importance. The codes used are based upon the Ramsar Classification System for Wetland Type as approved by Recommendation 4.7 and amended by Resolution VI.5 of the Conference of the Contracting Parties. The categories listed herein are intended to provide only a very broad framework to aid rapid identification of the main wetland habitats represented at each site.
1. MARINE/COASTAL WETLANDS

A — Permanent shallow marine waters in most cases less than six metres deep at low tide; includes sea bays and straits.

B — Marine sub tidal aquatic beds; includes kelp beds, sea-grass beds, tropical marine meadows.

C — Coral reefs.

D — Rocky marine shores; includes rocky offshore islands, sea cliffs.

E — Sand, shingle or pebble shores; includes sand bars, spits and sandy islets; includes dune systems and humid dune slacks.

F — Estuarine waters; permanent water of estuaries and estuarine systems of deltas.

G — Intertidal mud, sand or salt flats.

H — Intertidal marshes; includes salt marshes, salt meadows, saltings, raised salt marshes; includes tidal brackish and freshwater marshes.

I — Intertidal forested wetlands; includes mangrove swamps and tidal freshwater swamp forests.

J — Coastal brackish/saline lagoons; brackish to saline lagoons with at least one relatively narrow connection to the sea.

K — Coastal freshwater lagoons; includes freshwater delta lagoons.

Zk(a) — Karst and other subterranean hydrological systems, marine/coastal

2. INLAND WETLANDS

L — Permanent in land deltas.

M — Permanent rivers/streams/creeks; includes waterfalls.

N — Seasonal/intermittent/irregular rivers/streams/creeks.

O — Permanent freshwater lakes (over 8 ha); includes large oxbow lakes.

P — Seasonal/intermittent freshwater lakes (over 8 ha); includes floodplain lakes.
Q — Permanent saline/brackish/alkaline lakes.
R — Seasonal/intermittent saline/brackish/alkaline lakes and flats.
Sp — Permanent saline/brackish/alkaline marshes/pools.
Ss — Seasonal/intermittent saline/brackish/alkaline marshes/pools.
Tp — Permanent freshwater marshes/pools; ponds (below 8 ha), marshes and swamps on inorganic soils; with emergent vegetation water-logged for at least most of the growing season.
Ts — Seasonal/intermittent freshwater marshes/pools on inorganic soils; includes sloughs, potholes, seasonally flooded meadows, sedge marshes.
U — Non-forested peat lands; includes shrub or open bogs, swamps, fens.
Va — Alpine wetlands; includes alpine meadows, temporary waters from snowmelt.
Vt — Tundra wetlands; includes tundra pools, temporary waters from snowmelt.
W — Shrub-dominated wetlands; shrub swamps, shrub-dominated freshwater marshes, shrub on inorganic soils.
Xf — Freshwater, tree-dominated wetlands; includes freshwater swamp forests, seasonally flooded forests, wooded swamps on inorganic soils.
Xp — Forested peat lands; peat swamp forests.
Y — Freshwater springs; oases.
Zg — Geothermal wetlands
Zk(b) — Karst and other subterranean hydrological systems, inland

Note: “floodplain” is a broad term used to refer to one or more wetland types, which may include examples from the R, Ss, Ts, W, Xf, Xp, or other wetland types. Some examples of floodplain wetlands are seasonally inundated grassland (including natural wet meadows), shrublands, wood lands and forests. Floodplain wetlands are not listed as a specific wetland type herein.
3. HUMAN-MADE WETLANDS

1 — Aquaculture (e.g., fish/shrimp) ponds

2 — Ponds; includes farm ponds, stock ponds, small tanks; (generally below 8 ha).

3 — Irrigated land; includes irrigation channels and rice fields.

4 — Seasonally flooded agricultural land (including intensively managed or grazed wet meadow or pasture).

5 — Salt exploitation sites; salt pans, salines, etc.

6 — Water storage areas; reservoirs/barrages/dams/impoundments (generally over 8 ha).

7 — Excavations; gravel/brick/clay pits; borrow pits, mining pools.

8 — Wastewater treatment areas; sewage farms, settling ponds, oxidation basins, etc.

9 — Canals and drainage channels, ditches.

Zk(c) – Karst and other subterranean hydrological systems, human-made

2.1.3 USE OF DEFINITIONS AND CLASSIFICATION IN THE RESEARCH WORK

The definitions and classifications discussed above justify the selection of definition adopted for the research work. It can be seen that many definitions and classifications included paddy fields as a part of the wetland but The Kerala Conservation of Paddy and Wetland Act 2008 considered wetland and paddy land separately. That is why the wetland and paddy lands are mentioned separately in this research work.

2.2 WETLAND FUNCTIONS

Wetlands perform a variety of unique functions and provide values and services which are essential for the existence of life on earth and the combination of functions and values make this ecosystem an integral part of the environment. The aggregate value of the ecological services generated by wetlands, on a global basis, has been estimated to be $4.9 trillion/year (Costanza et al 1997). But the conversion or alteration of the wetlands will result in the loss of these services. The following section will describe in detail the common functions and explain how these functions provide values and services to the society.
2.2.1 WATER STORAGE

Wetlands act as water reservoirs by storing precipitation and surface runoff during rain and then slowly release the water into associated water resources, ground water, and the atmosphere. Wetlands provide clean and reliable sources of water for human consumption, agriculture and industry because it is able to purify and retain large quantities of water.

The storage capacity of wetlands depends on a number of physical and biological characteristics such as landscape position, soil saturation, type of soil, vegetation density and type (Taylor et al. 1995). This process of water storage will reduce the velocity of surface runoff and erosive potential, avoids floods, and allows ground water recharge.

2.2.2 GROUND WATER RECHARGE AND DISCHARGE

Ground water recharge and discharge are important hydrologic processes that occur through the wetlands playing a vital role in maintaining water supply. O'Brien and Winter (1988) reported that some wetlands help to maintain water levels by recharging ground water, while other wetlands serve as discharge points for ground water and thus provide a water source for adjacent wetlands and maintain base flow discharge to streams. Thus they help to maintain the level of the water table and exert control on the hydraulic head.

When water levels are low, wetlands slowly release the stored water recharging the ground water. The water may simply leak through the base of the wetlands or percolate to the saturated zone within the aquifer. The water recharging capacity of the wetland depends on the source and amount of water in the wetland, surface area, type of soil (Carter and Novitzki, 1988). Olewiler (2004) reported that wetlands overlying permeable soil may release up to 100,000 gallons/acre/day into the ground water. If the average water level in a paddy field is one foot, an acre of field will be holding 1200 cu ms or 1200000 litres of water. Conversion of recharge wetland lowers the ground water level and the water resources in the area will receive less inflow, potentially changing the hydrology of the watershed (Brinson, 1993; Winter, 1988).
The ground water recharge and discharge function may be of very important for people relying on ground water as the source of their water. Many rivers flow throughout the year due to the presence of wetlands in their watersheds which released their stored water, thus making them perennial.

2.2.3 MAINTENANCE OF WATER QUALITY

Maintenance of water quality through pollutant removal is one of the primary functions provided by the wetlands. Wetlands remove the impurities in the surface water and ground water and keep them from migrating into the open water bodies thus maintain and improve the water quality. Ground water and surface water transport sediments, nutrients, trace metals, and organic materials. Wetlands can intercept the surface runoff, precipitate, transform, recycle, and export many of sediments, nutrients, pesticides, metals and other pollutants, through various biological and chemical processes and water leaving the wetland can differ markedly from that entering (Mitsch and Gosselink, 2007). Wetlands act as sinks (where materials is trapped and held) for some materials like sediments and nutrients; and sources (from which material is removed) of others like bacteria.

Attempts were done by several researchers to quantify the value of wetlands in water purification.

Stutheit, R., et al. (2004) reported that wetlands are more effective at removing suspended solids, phosphorus, and ammonia during high-flow periods and more effective at removing nitrates at low-flow periods. In another study Carter (1997), found that watersheds with more wetlands tend to have water with lower specific conductance and lower concentrations of chloride, lead, phosphorus, inorganic nitrogen, suspended solids, total and dissolved solids than basins with fewer wetlands. Novitzki (1979) reported that streams in a Wisconsin basin, which contained 40 percent wetland and lake area, had sediment loads that were 90 percent lower than in a comparable basin with no wetlands. Scientists have estimated that wetlands can reduce nitrogen concentrations in runoff and floodwater by up to 90 percent and phosphate concentrations by 50 percent (Gilliam, 1994). As much as 90 percent of the sediments and
other pollutants that are present in runoff or in stream flow may be removed if the water passes through wetlands (Gilliam, 1994).

Wetlands remove BOD from surface water through decomposition of organic matter or oxidation of inorganics (Hemond, H.F., and Benoit, J. (1988). BOD removal by wetlands may approach 100 percent. Pathogens, fecal coli form bacteria and protozoan etc may enter the wetlands through municipal sewage, urban storm water, leaking septic tanks, and agricultural runoff. In wetlands these bacteria get attached to the suspended solids that are then trapped by wetland vegetation. Several studies have documented the ability of wetlands to improve the quality of ground water. Fernandez (1996) found that a marsh wetland was effective in assimilating land fill leachate near Pembroke, Ontario. Richard and Connel (2001) reported reduction in dissolved chlorinated compounds in ground water for a wetland adjacent to a Minnesota manufacturing site. Schueler, (2001) found that wetlands with highly organic substrates and high densities of submerged aquatic plants appear to able to remove pesticides.

2.2.4 FLOOD CONTROL

Wetlands have the ability to collect, store and slowly release runoff and flood waters, thus to protect the surrounding properties from flooding by acting as a sponge. This temporary storage of water decreases runoff velocity, reduces flood peaks, and distributes storm flows over longer time periods, causing tributary and main channels to peak at different times. Several studies conducted in United States revealed that there exists a strong correlation between the size of flood peaks and basin storage (percentage of basin area occupied by lakes and wetlands) in many drainage basins throughout the United States. The effectiveness of the wetland for flood control may vary depending upon the wetland area, slope and location of the wetland, type and condition of vegetation, saturation of wetland soil before flooding, amount of flooding (Mitsch and Gosselink, 2007).

Novitzki (1989) found that basins with 30 percent or more areal coverage by lakes and wetlands have flood peaks that are 60 to 80 percent lower than the peaks in basins with no lake
or wetland area. In drainage basins with flat terrain that contains many depressions, lakes and wetlands store large volumes of snowmelt and runoff. These wetlands have no natural outlets, and therefore this water is retained and does not contribute to local or regional flooding (Hayashi et al. 2003).

Filling and encroachment of wetlands can reduce their capacity to attenuate flooding in a watershed. Gosselink et al. (1993) reported that the loss of floodplain forested wetland and confinement by the levees has reduced the flood storage capacity of the Mississippi River by 80 percent.

Wetlands within and downstream of urban areas are particularly valuable for flood protection. It is estimated that a one-acre wetland can typically store about three-acre feet of water, or one million gallons. Wetlands in coastal areas play an important role in flood protection. Preserving and reconstructing coastal marshes can help to reduce storm damage. The importance of wetlands was clearly demonstrated by 2004 Indian Ocean Tsunami. Wetlands have provided a green barrier to protect coastlines and coastal communities that lived there. There were localized and anecdotal reports from around the Indian Ocean region how the damaging impact of the tsunami was reduced behind the mangroves stands and coral reefs.

2.2.5 EROSION CONTROL

Wetlands reduce shoreline erosion by stabilizing sediments and absorbing and dissipating wave energy (Hammer, 1992). Vegetated wetlands along the shores of lakes or rivers can protect against erosion caused by waves along the shorelines during floods and storms. Coastal wetlands buffer shorelines against the wave action produced by hurricanes and tropical storms (Mitsch and Gosselink 2007). The ability of wetlands to control erosion is so valuable that some states and landowners are restoring wetlands to control shoreline erosion in coastal areas. The erosion control of wetlands depends on their capacity to reduce the erosive forces of wind and waves which in turn depends upon vegetative density and root structure, soil type, frequency and intensity that waves meet the shore or runoff cuts the bank. Wetland vegetation decreases water
velocities through friction and causes sedimentation in shallow water areas and flood-plain wetlands, thus decreasing the erosive power of the water and building up natural levees. Wetland trees are excellent riverbank stabilizers and have been planted to reduce erosion along United States shorelines.

2.2.6 CLIMATE CONTROL

Wetlands can influence local or regional weather and climate in several ways. Wetlands tend to moderate seasonal temperature fluctuations. During the summer, wetlands maintain lower temperatures because evapotranspiration from the wetland converts latent heat and releases water vapor to the atmosphere. In the winter, the warmer water of the wetland prevents rapid cooling at night; warm breezes from the wetland surface may prevent freezing in nearby uplands. Wetlands also modify local atmospheric circulation and thus affect moisture convection, cloud formation, thunderstorms, and precipitation patterns. Therefore, when wetlands are drained or replaced by impermeable materials, significant changes in weather systems can occur. Many wetlands return over two-thirds of their annual water inputs to the atmosphere through evapotranspiration (Richardson, 1994). This fall as rain in the surrounding area and helps to maintain stable climatic conditions.

Wetlands act as carbon sinks and store as much as 40 percent of global terrestrial carbon the removal of carbon dioxide from the atmosphere into plant matter and its burial as peat (sequestration) the most valuable function of wetlands (OTA 1993). Carbon sequestration is thought to be an important process in reducing the greenhouse effect and the threat of global warming.

2.2.7 HABITAT FOR FISH AND WILDLIFE

Wetlands are one of the most productive ecosystems in the world with a rich and varied flora and fauna. Corner et al. (2005) reported that wetlands provide habitat for more aquatic, terrestrial, and avian species on an area basis than any other habitat type, making them one of the most ecologically and economically important ecosystems on earth. The very high rate of plant productivity exhibited by the wetland often supports a varied and complex food web both within and outside of the wetland. Many endangered and threatened species rely directly or
indirectly on wetlands for survival. Every wetland type offers a unique mix of habitat elements such as cover, food, water, nesting and other life sustaining features.

2.2.8 RECREATION AND SCIENCE
Wetlands provide tremendous opportunities for popular recreational activities, such as hiking, boating, hunting, fishing, trapping and bird watching. Wetlands can provide opportunities for education and research particularly due to the role of wetlands in the global cycles of carbon, nitrogen and water.

2.2.9 COMMERCIAL BENEFITS
Wetlands provide a wide variety of commercially important products including fish, shellfish, cranberries, timber, and wild rice, as well as some medicines derived from wetland soils and plants. Many mammals and reptiles are harvested for their skins.

2.3 STATUS OF WETLANDS IN INDIA
Due to varied topographical and climatic conditions, India supports and sustains diverse and unique wetland ecosystems distributed in different geographical regions ranging from Himalayas to Deccan plateau. Indian wetlands include almost all types of wetland ecosystems found in the world except bogs, fens and typical salt marshes. The variability in climatic conditions and changing topography is responsible for significant diversity.

A serious and systematic inventory of Indian wetlands have been conducted by Space Application Centre and Ministry of Environment & Forest on the basis of visual interpretation of Satellite Data in 1989 and they mapped wetlands which are 50 ha or above in size as in Table 2.1.

According to their estimate wetlands in India occupy 58.2 million hectares, including areas under wet paddy cultivation and excluding rivers, canals and irrigation channels. This constitutes about 18.40% of the total land area and among the wetland area the majority area (70%) is under wet paddy field. Using space borne remotely sensed data from IRS 1A/1B, Space Application Centre (ISRO), Ahmedabad (1998) estimated total Indian wetland areas to be about 7.6 million ha excluding paddy fields, rivers and canals, out of which 4.1 million ha
are inland and the remaining are coastal wetlands. In India out of the total 27,403 wetlands 23,444 are inland wetlands and 3,959 are coastal wetlands. Inland natural wetlands include lakes, ponds, oxbow lakes, cut off meanders, seasonally waterlogged areas, palayas, marsh and man made wetlands consist of reservoirs, tanks, waterlogged areas, abandoned quarries, ash ponds. Out of the estimated 4.1 m ha inland wetlands (excluding irrigated agricultural lands, rivers, and streams), 1.5 mha are natural, while 2.6 mha are manmade. The coastal wetlands occupy an estimated 6,750 sq km. Coastal natural wetlands include the vast inter tidal areas, backwater (Kayal), coral reef, rocky coast, mangroves and lagoons along the 7500 kilometer long coastline. Natural coastal wetlands in India are largely dominated by mangrove vegetation and about 80 percent of the mangroves are distributed in the Sunderbans of West Bengal, Andaman and Nicobar Islands, with the rest in the coastal states of Orissa, Andhra Pradesh, Tamil Nadu, Karnataka, Kerala, Goa, Maharashtra and Gujarat. Coastal man made wetlands are salt pans and aquaculture ponds.

### Table 2.1 Extent of wetlands in India

<table>
<thead>
<tr>
<th>Wetlands in India</th>
<th>Area (million ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area under wet paddy cultivation</td>
<td>40.9</td>
</tr>
<tr>
<td>Area suitable for fish culture</td>
<td>3.6</td>
</tr>
<tr>
<td>Area under capture fisheries</td>
<td>2.9</td>
</tr>
<tr>
<td>Mangroves</td>
<td>0.4</td>
</tr>
<tr>
<td>Estuaries</td>
<td>3.9</td>
</tr>
<tr>
<td>Backwaters</td>
<td>3.5</td>
</tr>
<tr>
<td>Impoundments</td>
<td>3</td>
</tr>
<tr>
<td>Total area</td>
<td>58.2</td>
</tr>
</tbody>
</table>

*Source: Ministry of Environment & Forests, (1989)*
2.3.1 RAMSAR WETLAND SITES IN INDIA

Twenty-five sites from India have been designated as Ramsar sites of international importance (Appendix-I&II) and six are under process of designation. During the next triennium, it is proposed to include at least ten sites under the list which will include mosaic of habitats such as high altitude wetlands, corals, mangroves, creeks, alpine wetlands in the list from India.

In addition the National Committee on Wetlands, Mangroves and Coral Reefs, constituted for advising the Government on appropriate policies and measures to be taken for conservation and management of the wetlands, has identified 94 wetlands for conservation and management on priority basis. These wetlands are under great threat due to various land use practices and natural causes. Point Calimere in Tamilnadu, Ashtamudi, Sasthamkotta and Vembanad Kol lakes in Kerala, and Kolleru Lake in Andhra Pradesh are some of the natural wetland sites in South India.

2.3.2 WETLANDS OF KERALA

The state of Kerala, the Gods Own Country, situated along a narrow strip of land between the Western Ghats and Arabian Sea is picturesque and unrivalled in beauty. The undulating topography, sloppy terrain, high rain fall, criss crossing rivers and their deltaic formations, resulted in a variety of heterogeneous wetland ecosystems. But the land use classification of the state has not included wetlands as a separate unit of land (Table 2.2).

Geomorphologically, the wetlands in Kerala may be divided among the five major systems at the broadest level as marine, estuarine, riverine, lacustrine and palustrine. Due to the unique physical characteristics of Kerala and a diverse terrain of high land, midland and low land within a thin strip of land mass of about 38864 sq.km, there exists much ambiguity in the classification of wetlands. Thus major classes and types of wetlands are defined keeping the MoEF classification system as the standard. However all these do not include the paddy wetland ecosystems in the state.
Table 2.2. Land use pattern in Kerala

<table>
<thead>
<tr>
<th>Land use type</th>
<th>Area in ha</th>
<th>% Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total geographic area</td>
<td>3886287</td>
<td></td>
</tr>
<tr>
<td>Forests</td>
<td>1081509</td>
<td>27.83</td>
</tr>
<tr>
<td>Land put to non agricultural uses</td>
<td>462678</td>
<td>11.63</td>
</tr>
<tr>
<td>Barren and uncultivable land</td>
<td>25527</td>
<td>0.58</td>
</tr>
<tr>
<td>Permanent Pastures and Grazing land</td>
<td>216</td>
<td>0.01</td>
</tr>
<tr>
<td>Land under miscellaneous tree crops</td>
<td>6397</td>
<td>0.14</td>
</tr>
<tr>
<td>Cultivable waste</td>
<td>92764</td>
<td>2.36</td>
</tr>
<tr>
<td>Fallow other than current fallow</td>
<td>45214</td>
<td>1.16</td>
</tr>
<tr>
<td>Current Fallow</td>
<td>82953</td>
<td>1.84</td>
</tr>
<tr>
<td>Net area sown</td>
<td>2089029</td>
<td>54.46</td>
</tr>
<tr>
<td>Area sown more than once</td>
<td>672065</td>
<td>15.07</td>
</tr>
<tr>
<td>Total cropped area</td>
<td>2761094</td>
<td>69.53</td>
</tr>
</tbody>
</table>

*Economic Review (2009)*

2.3.2.1 STATUS OF WETLANDS IN KERALA

Several attempts have been made by different agencies to map the wetlands of Kerala. The SAC (1998) has mapped the wetlands of Kerala using the satellite imageries of 1988-1990 at 1:2,50,000 scale. The wetlands of the size 56.25 ha and above and excluding paddy wetlands were estimated at 64, covering an area of 342 sq km. It includes 29 reservoirs, 16 waterlogged areas, and the remaining ponds/lakes.

2.3.2.2. WETLANDS OF INTERNATIONAL IMPORTANCE IN KERALA

Sasthamcotta, Vembanad and Ashtamudi are the notified wetlands under Ramsar Convention for conservation and management. In addition to this Ministry of Environment and Forests, Government of India, under the National wetland Conservation Programme identified two more wetlands as sites
of national importance—Kottuli in Kozhikode District and Kadalundi in Kozhikode and Malappuram District.

2.3.2.3 MANGROVE ECOSYSTEMS

By virtue of its unique location Kerala provides a wide variety of aquatic habitats harboring unique types of vegetation of their own. The most important among them are the mangrove ecosystems which are very rich in species diversity. It was stretching for about 1,000 sq. km a century ago, but now reduced to just about 17sq.km in isolated bits at Kumaragom, Dharmadom, Chettuva, Nadakavu, Pappinisseri, Kunjimangalam, Chittari, Veli, Ashramam etc (Chand Basha, 1992).

The Ministry of Environment and Forests, Government of India in the notification (1991) declaring the coastal stretches as Coastal Regulation Zones have included mangrove areas in the CRZ 1 category where construction activities are prohibited.

2.3.2.4 PADDY WETLAND ECOSYSTEMS OF KERALA

Kerala is blessed with a wide variety of paddy wetlands due to the presence of criss crossing rivers and their deltaic formations, and saline water intrusion from the Arabian Sea. Paddy fields are typical wetland ecosystems with extraordinary stability and durability. With its peculiarities of flooding and drainage, they are very conducive for rice growing. The paddy wetland ecosystem will perform all the major function and provide values as catered by a typical wetland including maintenance of fertility and productivity, biochemical cycling, biosphere stability, primary production and biodiversity, ground water recharge and discharge, absorption and control of flood water, water purification function, habitat of plants, predators and micro organisms, production of fish, medicinal plants, grass and green leaves for live stock population.
2.3.2.5 TYPES OF PADDY WETLAND ECOSYSTEM

According to the estimate of the Ministry of Environment & Forests, in 1989 the wet paddy cultivation in India occupies about 40.9 million hectares. Kerala enjoys a special place in the agricultural front on account of its diverse and heterogeneous wetland ecosystems and rich heritage of rice diversity arising out of the combinations of the topography, climatic conditions, soils and vegetation etc. Rice is the staple food of Keralites and its cultivation had been the main occupation for generations. Rice is cultivated in paddy fields which are a few meters below sea level to 2000m above the sea level and about 600 varieties of rice are grown in the sprawling paddy fields of Kerala. The laterite midland contributes the lion’s share of the paddy wetland.

Some of the major paddy ecosystems situated in different agro ecological zones in the state are:

a) Midland and Malayarom paddy ecosystems - This includes the inter hill paddy strips of midland regions of Kerala.

b) Poonthala Padams - Paddy fields adjoining the black soils of the Chittoor taluk of Palaghat district are termed as poonthla padams.

c) Irrigated Paddy fields of Palakkad District - This includes the Palaghat plains and Periyar valley Command area in Ernakulam district.

d) Onattukara - only traditional area where the intensive multiple cropping is in practice. In Onattukara owing to low productivity, fallowing of rice lands is on the increase and thus the area under rice has come down considerably.

e) The costal saline paddy ecosystem.

Based on location, extent, intensity of salinity and crop season three types of paddy areas are recognized in Kerala. They are locally known as

1. ‘Kaippad’ fields located in Kannur, Thalasery and Thaliparambu taluks of Kannur district.
2. 'Pokkali' fields located in Kochi, Kanayannur and Paravur taluks of Ernakulam district and Kodungallur taluk of Thrissur district.

3. Orumundakan fields of Ambalapuzha and Kollam districts known after the long duration variety of rice grown and distributed mostly in Sherthalai, Ambalapuzha and Karunagappally taluks

These lands constitutes an area of about 30000 ha where rice is cultivated once in a year from June-July to October-November when the salinity level in the surface soils are brought below the critical level by monsoon showers.

f) Kole lands

Kole lands of Kerala which extend over an area of 136282 ha is distributed in Thrissur, Chavakkad and Mukundapuram thaluks of Thrissur districts and in Ponnani taluks of Malappuram districts.

g) Kuttanad Paddy ecosystem

Kuttanadan fields located in Kuttanad taluk, parts of Ampalapuzha, Mavelikara and Karthikappally taluks of Alapuzha district, parts of Tiruvalla thaluk of Pathanamthitta district and parts of Vaikom and Kottayam taluks of Kottayam district.

Kuttanad soils are grouped into three categories

(i) Kari lands: - The Kari lands formed in isolated patches in Alappuzha and Kottayam district, distinguished by their black charcoal colour with an estimated extent of 9400ha.

(ii) Karappadam soils: - Karappadam soils are occurring along the inland waterways and rivers covering an area of 33800ha. Soils are very deep, poorly drained with clay loam surface texture followed by silty clay subsoil. This extends in 1014 Padasekharoms in Alapuzha, Kottayam and Pathanamthitta districts.
(iii) *Kayal lands*: They are seen in reclaimed beds of Vembanad Lake and extend over an area of 13000 ha.

h) High range rice ecosystem.

This includes the following paddy fields spreading over an area of 27000 ha.

i) Koravakandom fields located in the Manathavadi and Sulthan Batheri taluks of Wayanad district

ii) Kolakkai fields in Kasargode and Hosedurg taluks of Kasargode district

iii) Palliyal fields located in Eranad Taluk of Malappuram district

j) Koottumundakan system

This system is found in patches to an extent of 3900 ha in Alappuzha district and this followed in sandy or sandy loam soils.

### 2.4 DRIVING FORCES LEADING TO THE CONVERSION OF WETLANDS AND PADDY LANDS IN KERALA

The degradation and conversion of wetlands and paddy fields of Kerala has been driven by various direct and indirect forces. The major driving forces of wetland degradation and paddy field conversion in Kerala are discussed below.

#### 2.4.1 POPULATION

The population growth and the consequent development of infrastructure have identified as one of the major driving forces for the conversion of paddy fields and degradation of wetlands. As the population of Kerala have doubled over five times in the last century (6 million in 1901 to 32 million in 2001), with 1.2 percent of land area of the country, the state has to accommodate about 4 percent of its total population. Because of the availability of the land at low prices and human desire to live near the water, the pressure to develop increasing amounts of paddy lands and wetlands for residential use has and will continue to grow.
2.4.2 URBANISATION

Urbanisation and urban sprawl has been identified as a significant factor for the loss of wetlands, ecosystem complexity and disruption of ecosystem structure (Taylor et al, 1995). Urbanization includes the development of land into residential, commercial, and industrial properties. Urban developments cause profound changes to natural watershed conditions by altering the terrain, modifying the vegetation and soil characteristics, introducing pavement, buildings, drainage, and flood control infrastructure all of them affecting the wetland ecosystem. The increase in urban population density and built up areas directly or indirectly affects hydrological process of the wetland through changes in water quality, quantity and flow rates, increases in pollutant inputs, and changes in species composition. Rapid urbanization and the consequent growth of infrastructure had taken a heavy toll of wetlands in Kerala. According to 2001 census 25.97 % of the population lives in urban areas whereas in 1981 it was only 18.74 %.

2.4.3 SETTLEMENT PATTERN

The settlement pattern of Kerala is a major threat to the wetland ecosystem of the state. All other states in India have nucleated built up area in a settlement and their urban and rural settlements are surrounded by vast stretches of agricultural or vacant land.

The settlement pattern of Kerala is unique with dwellings constructed on individual plots and scattered all over the habitable areas almost through out the state with an urban rural continuum having a fairly uniform spread of dwelling units.

Due to the inflow of gulf money and unprecedented changes occurred in the socio-economic scenario of the state, people prefer to live in individual houses and this resulted in a rapid increase in the number of houses. Population and the number of houses (dwelling units) predictably have increased, nationally, but household numbers have increased more quickly than population in Kerala. According to 2001 census the number of house holds in Kerala grew from 55 lakhs in 1967 to 67 lakhs in 2001, an increase of 12 lakhs or 22% in about 32 years.
The average size of the household in the state has declined from 5.3 persons per household in 1997 to 4.7 persons in 2001.

2.4.4 AGRICULTURE

One of the major factors that accelerated the wetland conversion in Kerala is the radical and far-reaching changes that have taken place in the state’s agrarian economy. The most significant change in the field of agriculture is the shrinking of area under paddy and increase in the rate of filling and conversion for other purposes like cultivation of commercial crops and construction activities. The low income generated from the cultivation of food crops forced the people to shift the cropping pattern from food crops to commercial crops without considering the biophysical production potential of the land parcels. The farmers adopted improved cultivation practices, using chemical fertilizers as well as high yielding varieties. The enhanced use of chemical fertilizers to compensate for the reduction in the productive capacity of the land led to dangerous quantities of their residues in soil and water. The fertilizers and pesticides applied in the paddy fields and home gardens, ultimately reach the wetlands during rainfall and floods. Unscientific agriculture aimed at short term benefits to mankind resulted in land degradation and natural disasters such as flood, drought, landslides, soil erosion, salinity intrusion etc.

2.4.5 INDUSTRIES

Rapid industrialization is impetus to the economic development and solving unemployment problem but their unfettered proliferation near the wetlands and paddy fields are leading to severe degradation of these natural ecosystems. Due to the availability of vast stretches of land at low prices and easy access of water, industrial developments are found to take place near the wetlands.

Impacts due to industry on wetlands are reduction in wetland area, alteration of wetland hydrology due to industrial water intake and discharge, water temperature increases, point and nonpoint source pollutant inputs, pH changes as a result of discharges, and atmospheric
Deposition. The pollutants associated with industrial effluents are organic matter, inorganic dissolved solids, fertilizer materials, thermal constituents in the form of heat, suspended solids and microorganisms and pathogens. Organic pollutants decrease level of dissolved oxygen and impart bad odour and colour to the effluent.

Toxic contaminants entering the wetlands naturally concentrate in the wetland sediments and such concentrations can enter the surface water or ground water as a result of the release of water as outflow (Owen, 1992).

2.4.6 INFRASTRUCTURE DEVELOPMENT

Uncontrolled development of infrastructure related to industrialization and urbanisation without proper planning and environmental monitoring fragmented the continuity of wetlands and destroyed extensive tracts of paddy fields thereby upsetting the entire complex ecology. The activities include construction of roads, dams, bridges, railway lines, airports harbors, ports, several commercial public and semi public uses.

Even though road network plays the most vital role in the all round development of an area, it has taken a heavy toll of wetlands, paddy fields and low lying areas in the state. Since wetland has low land value, it is economical to build roads across the lands. The inadvertent impoundment due to roads alters the wetland hydrology and changes the functions of wetlands (Winter, 1988). Roads, bridges and dam construction activities can increase the sediment loading to wetlands (Mitsch & Gosselink, 2007).

2.4.7 MINING

Mining of minerals and other materials from wetlands for various uses resulted in the loss and degradation of thousands of acres of wetlands through hydrologic alterations, high metal concentrations, and decreased pH (Mitsch and Gosselink, 2007). The magnitude and intensity of degradation vary depending upon the type of mining and the environmental fragility of the location.
Even though Kerala is blessed with large deposits of minerals and other materials, indiscriminate mining activity without considering the environmental repercussions are taking place in the case of river sand, brick clay from paddy fields, lime shell etc.

If scientific method of exploitation is adopted, mining of resources will not be a major issue but there is indiscriminate mining activity in the state without considering the environmental repercussions (KSCTE report 2007).

2.4.8 DEFORESTATION

Deforestation is the process of the removal of the forest cover due to various anthropogenic activities from the forest area which are the water shed of the rivers. Deforestation has resulted in soil erosion, which has quickened the runoff, reducing the percolation of water and thus the replenishment of groundwater. Increase in surface runoff and sediment load reduces the light penetration in wetlands and results in loss of primary productivity.

2.4.9 MARINAS/BOATS /TOURISM

Marina construction and dredging activities can contribute suspended sediments into waters adjacent to wetlands. Intense boating activity can also increase turbidity and degradation of wetlands. Wetlands can be adversely affected by pollutants released from boats and marinas. Pollutants include hydrocarbons, heavy metals, toxic chemicals from paints, cleaners, and solvents (USEPA, 1993a).

2.5 IMPACTS DUE TO DEGRADATION/CONVERSION OF WETLANDS AND PADDY FIELDS

The conversion/degradation of wetlands and paddy fields will result in various impacts on hydrologic regime, disrupt the eco-system, create additional stresses to the environment and finally lead to the degradation of the environment. The major direct and indirect impacts associated with the conversion of wetlands and paddy lands are the following:
2.5.1 DEGRADATION THROUGH HYDROLOGIC ALTERATION

The conversion of wetlands in a watershed will naturally introduce hydrologic changes in the contributing drainage area of the wetland as well as changing the hydrology of the wetland itself. The critical factor, determining the type and functions of wetland and the kinds of plants that will inhibit, is the hydrology (Mitsch and Gosselink, 2007). The wetland hydrology is altered by the activities occurring inside the wetland boundary or by development activities occurring within a wetland's contributing drainage area. Changes in frequency, duration, and timing of the wetland hydro period may adversely affect spawning, migration, species composition, and thus the food web in a wetland as well as in associated ecosystems (USEPA, 1993c). The development activities occurring within a wetland's contributing drainage area increases the percentage of impervious surface and it is a strong indicator of stream quality (Schueler, 2001).

2.5.2 BIODIVERSITY LOSS

Wetlands are highly productive areas with a rich and varied flora and fauna. Many developmental activities have largely destroyed biodiversity in the wetland areas including endemic species. Destruction of habitat by human activities is the primary cause for the extinction of endangered species, without the adapted habitat the species may not survive. The industrial pollution has led to the depletion of biota, especially benthic organisms, fish mortality and presence of high ammonia in water. The large doses of heavy metals from the industrial pollution in the estuarine waters are biologically non degradable and remain in the food chain of plants and animals. Fish population is alarmingly reduced in coconut husk retting areas (Bijoy, 2004).

Reclamation of wetlands led to the destruction of mangroves, the vital components of the wetland eco- system. Due to the presence of many indirect intangible values associated with mangrove forests, their conservation is important to ameliorate the rapidly deteriorating state of the environment.
2.5.3 REDUCTION IN RECHARGE/SCARCITY OF DRINKING WATER

Wells, rivers and lakes, which are the main source of drinking water, get their water supply through the process of ground water recharge mainly from wetlands. Conversion of recharge wetland lowers the ground water level and the water resources in the area will receive less inflow, potentially changing the hydrology of a watershed (Brinson, 1993; Winter, 1988). Three processes associated with the conversion significantly affect the ground water recharge. Firstly, the rainfall interception is lowered due to the removal of vegetation and compaction of the soil during the construction process (Schueler, 2004). Secondly, the runoff volume is greatly increased due to the introduction of impervious cover when roads, buildings and parking area are constructed. As impervious cover increases, the infiltration of rainfall into the soil is proportionately reduced. Finally efficient storm water drainage systems are installed to quickly convey runoff water to downstream waters. So excess water will flow into the streams instead of infiltrating to the ground water. As a result of these changes, infiltration and ground water recharge is diminished. Ewel (1990) calculated that if 80 percent of a 5-acre wetland were drained, available ground water would be reduced by an estimated amount of 45 percent. Numerous studies have also shown that impervious cover can reduce ground water recharge (Saravanapavan et al. 2004).

2.5.4 FLOOD AND DROUGHT

The conversion and filling of wetlands and paddy lands has been leading to frequent floods and droughts in many parts of the state. The destruction of wetlands in the watershed can dramatically increase the rate and volume of storm water runoff. Schueler (2004) reported that the total runoff volume from a one-acre parking lot is about 16 times greater than that produced by an undeveloped meadow. He noted that the same sized parking lot generates 19 times more runoff than an acre of natural cover.

Wetland vegetation also slow the speed of flood waters and distributes them more slowly over the floodplain. This combined water storage and braking action lowers flood heights and
reduces erosion. Wetlands within and downstream of urban areas are particularly valuable for flood protection. It is estimated that one acre wetland can typically store about three-acre feet of water, or one million gallons (Mitsch and Gosselink, 2009).

Increased stream runoff has been strongly linked to active channel enlargement by widening of the stream banks or lowering of the streambed (Schueler, 2001). As the channel deepens, the local water table drops, often to the point where it is below the rooting depth of the plants (Schueler and Brown, 2004). This may lead to severe drought conditions in summer season.

2.5.5 WATER LOGGING
Conversion of wetlands for development alters the drainage pattern resulting in the rise of water table in the nearby area during the rainy season leading to water logging. The rise in water table is to such an extent that the topsoil gets saturated to prevent the normal circulation of air within the soil; the soil is considered to be waterlogged. Inadequate drainage due to the blocking of the natural underground drainage by the overlying consolidated earth mass also causes stagnation of surface runoff leading to water logging. It also leads to salinity. If the water table has risen up, or if the plant roots happen to come within the capillary fringe, water is continuously evaporated by capillarity. Thus a continuous upward flow of water from the water table to the land surface gets established. With this upward flow, the salts which are present in the water also rise towards the surface resulting in the deposition of salts in the root zone of the crops. The concentration of these alkali salts present in the root of the crops has a corroding effect on the root, which reduces the osmotic activity of the plants and check the plant growth and the plant ultimately fades away. Thus it is evident that water logging ultimately leads to salinity, the result of which is, reduced crop yield.

2.5.6 DECREASE IN AGRICULTURE PRODUCTION AND PRODUCTIVITY
Agricultural land has been considerably reduced during the last three decades mainly because of the conversion and reclamation of the paddy lands and other wetland area for construction and other purposes. This has also amount to reduction in food production. The productivity of
the agricultural land is reduced due to loss of soil fertility. The reduction in agriculture has automatically affected the economic conditions of the people of the area, especially the farmers and farm workers.

2.5.7 SALT WATER INTRUSION

In the coastal areas, the reduction of the input from upstream sources leads to increase intrusion of sea water into the water table. The result is change in species composition as salt sensitive species are replaced by more salt tolerant ones. Saltwater intrusion and the subsequent modification of wetlands habitat threaten the fishery industry as well as agriculture and fresh water availability in coastal area.

2.6 PROCESS INVOLVED IN CONVERSION OF PADDY LANDS

2.6.1 CHANGE IN SOIL PROPERTIES

During conversion, the native vegetation is removed and the top soil is super imposed with another type of the soil. During rains, raindrops breaks down soil crumbs and aggregates, the finer silt and clay particle penetrate into previously existing pores, clogging them, and greatly reducing infiltration. This can prevent the flow of rain water into the ground water table which further leads to greater surface runoff and consequent reduction to ground water recharge. The underlying soil gets consolidated due to the overlying fill.

In consolidation water flows out due to difference in pressure head and the direction of flow is from points of high pressure head to the points of low pressure head. Depending upon the nature of flow, flows are classified as steady state flow and transient flow. The steady state flow is also called as seepage flow, which happens under water retaining structures such as dams having relatively constant heads of water. The transient flow happens because of external pressure on soil due to the construction of structures. The duration of this flow is dependent on actors like permeability of soil, length of drainage path. The transient flow continues until the water pressure at all points reaches a steady state value. Transient flow in sandy soil is almost
instantaneous where as in clayey soils; it may happen over a period of time. The settlement of structure is the vertical, downward movement due to the consolidation of soil. The strength of soil is lowest at the time of external load application. Due to transient flow the soil undergoes time dependent deformation and its strength gradually increase to higher value. However, the utility of engineering structures built on such soils may reduce if they deform excessively during their life span. Hence in land reclamation, it is advantageous to hasten the processes of transient flow so that the soil reaches a steady state condition before the structures are built, thus minimizing the differential settlement in due course of time.

2.6.2 INCREASE IN IMPERVIOUS AREA

Conversion of paddy land is mainly for construction activities and as roads, buildings and parking lots are constructed, the amount of impervious surfaces increases. Impervious surface includes the rooftops of buildings, other built up areas such as compacted land and the transportation infrastructure of the area. Each of these prevents water from seeping into the ground, slowing the recharge of groundwater aquifers and promoting runoff during wet weather. Transportation related impervious surface generally has a greater impact on surface water because it is directly connected to a storm drain system. If the surface runoff directly enters the water bodies through roads or storm drains, the stream will produce an increased peak flow magnitude in a shorter time-period than observed in an undisturbed stream system.

Numerous studies have reported similar hydrologic impacts due to increase in impervious area and found that the key index for gauging impacts on water bodies is total impervious area (TIA). Studies have shown that when there is 10 percent or greater imperviousness in a watershed, stream flow during wet weather increases so there are larger and more frequent floods. Water quality is deteriorated as a result of imperviousness because runoff quickly washes pollutants that collect on impervious surfaces into streams rather than letting them filter out as they pass through the ground. Rainfall carries sediments, organic matter, pet wastes,
pesticides and fertilizers from lawns, heavy metals hydrocarbons road salts and debris into urban streams and wetlands (USEPA 1993a; USEPA 1993c).

On the basis of research conducted on many geographical areas, SEMCOG (1999) have arrived at the following conclusion:

1. Impervious surface in area, 0-10 percent, water bodies are with stable channels and good to excellent water quality and biodiversity,

2. When imperviousness increases to between 11 and 25 percent, water bodies have unstable channels and fair to good water quality and biodiversity,

3. Greater than 25 percent imperviousness is associated with non-life supporting water bodies that have highly unstable channels, fair to poor water quality, and poor biodiversity.

4.7 CRITICAL ASSESSMENT OF LITERATURE AND NEED FOR THE PROPOSED RESEARCH

From the literature review it becomes clear that wetlands and paddy lands perform numerous vital functions and, thus, need to be looked after and used wisely. Wetlands and paddy lands help in water storage and purification, flood control, ground water replenishment, provide shoreline stabilization, protection against nutrient and sediment retention, harbors and support biological diversity, mitigate effects of climate change and pollution, act as nurseries for freshwater and marine fish, resources for recreation, tourism, transport and other services. It also delved into the major driving forces that can lead to the conversion and degradation of wetland and paddy lands and the consequent impacts due to degradation and conversion in general.

The critical assessment of the literature revealed that the output of the activities arising from the driving forces exerts pressure to convert the wetlands and paddy lands and the impacts due to these conversions are adversely affecting the areas where the existing natural and physical
resources do not have the capacity to withstand the changes. It indicates the existence of a correlation between the driving forces and the resulting impacts.

Even though it is well known that conversion of wetlands and paddy lands result in various environmental issues, they are fast disappearing both in urban and rural screen of Kerala. The huge demand of land for housing, urban and other developmental uses had led planners and engineers to reclaim vast stretches of wetlands and paddy fields for the purpose of urbanisation. But while taking up such reclamation works, the environmental consequences are not given importance. The impacts due to these conversions are so acute that in many parts the natural and physical resources have been degraded to the point where they can no longer sustain the existing levels of development.

Therefore it is necessary to assess the various driving forces that led to the conversion of wetlands and paddy lands, to estimate the resulting impacts and develop suitable measures for limiting the conversion/mitigate the negative impacts due the reclamation of paddy lands so that the nature may yield the greatest continuous benefit to the present generation while maintaining the needs and aspirations of the future generations. While reclamation of large extent of paddy lands under increasing pressure is fast changing the landscape in many parts of the state, an attempt to save the environmentally-sensitive wetlands and paddy fields from further obliteration acquires much significance. Apart from some preliminary fragmentary survey nothing has been done so far to quantify the impacts and develop mitigation measures methodologically.

1.8 OBJECTIVES AND SCOPE OF THE PRESENT RESEARCH

Based on the critical assessment of the literature and the motivation outlined above, the objectives and scope of this thesis are as follows:
• To enumerate the driving forces that led to the conversion of paddy lands and wetlands in Kollam district and select the most critical area in the district for further studies.

• To estimate the paddy land conversion and degradation of wetlands in the critical area with ground truth verification.

• To conduct field surveys, observations and experimental investigations to assess the impacts due to the conversion of wetlands and paddy lands.

• To establish the relation between the driving forces leading to the conversion and the impacts due to the conversion.

• Recommendations for limiting the conversion/reducing the impacts and the wise use of wetlands and paddy lands.

2.9 METHODOLOGY
The aim of present research is to scientifically document, using the state of the art facilities, the causes, trends and consequences of wetland and paddy conversions and to suggest guidelines to minimize the disturbance to these ecosystems due to the development. Towards this objective, a comprehensive set of methodologies are sought to be integrated for the estimation. The methodology adopted in this research is shown in the Fig 2.1.
Fig. 2.1 The Methodology
10 ORGANISATION OF THE THESIS

The chapters of the thesis are organized in the following manner:

Chapter 1 introduces the basic concepts of research, followed by the selection of study area.

Chapter 2 covers a detailed review of the related literature. The main objectives and scope of the study are then presented.

Chapter 3 presents general profile of the Kollam district, the enumeration of the driving forces leading to the conversion of wetlands and paddy fields in Kollam district.

Chapter 4 describes the estimation of the paddy conversion and degradation of wetlands in the critical area, field surveys, observations and experimental investigations to assess the impacts due to the conversion of wetlands and paddy lands.

Chapter 5 deals with the discussion of the results obtained through the investigations and establishment of a relation between the driving forces of wetland and paddy conversion and the impacts due to the conversion.

Chapter 6 presents important recommendations for conserving the wetlands and reducing the impacts due to paddy conversions, conclusions and briefly suggests scope of further research in this area.