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Agriculture-wetland Interactions: A Case Study of the Kole land Kerala

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RULNR
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Foreword

The Centre for Economic and Social Studies (CESS) was established in 1980 to undertake research in the field of economic and social development in India. The Centre recognizes that a comprehensive study of economic and social development issues requires an interdisciplinary approach and tries to involve researchers from various disciplines. The Centre's focus has been on policy relevant research through empirical investigation with sound methodology. Being a Hyderabad based think tank, it has focused on, among other things, several distinctive features of the development process of Andhra Pradesh, though its sphere of research activities has expanded beyond the state, covering other states apart from issues at the nation level. In keeping with the interests of the faculty, CESS has developed expertise on themes such as economic growth and equity, rural development and poverty, agriculture and food security, irrigation and water management, public finance, demography, health, environment and other studies. Social science research needs to respond to the challenges posed by the shifts in the development paradigms like economic reforms and globalization as well as emerging issues such as optimal use of environmental and natural resources, role of new technology and inclusive growth.

Dissemination of research findings to fellow researchers and policy thinkers is an important dimension of policy relevant research which directly or indirectly contributes to policy formulation and evaluation. CESS has published several books, journal articles, working papers and monographs over the years. The monographs provide an opportunity for CESS faculty, visiting scholars and students to disseminate their research findings in an elaborate form.

The present monograph by Dr. Jeena T Srinivasan attempts to understand interactions between agriculture and wetlands and the major challenges to sustain rice production in small farms in the Kole land, a multiple use wetland in Kerala. Rice cultivation in the Kole land, which lies submerged under water for over six months in a year, is carried out with the receding of monsoon after dewatering the fields. Although Kole land is highly productive, it faces several anthropogenic pressures which results not only in the loss of ecosystem characteristics and its services but also pose serious challenges to sustaining rice production.

Against this background, the author analyses the status as well as trends in the Kole land uses over the years using land use data based on Indian Remote Sensing Satellite Images of the study area and analyses agriculture wetland interactions and various pressures

facing the ecosystem. The author also assesses the economic viability of rice cultivation in the Kole land using primary data collected from the farm households.

The author observes considerable decline in the area under rice and an increase in the area under mixed crops and also wastelands and waterlogged areas. Apart from this, the Kole land faces pressures of agricultural intensification. Some of the developmental interventions aimed at improved drainage and water management were found to accentuate the conversion of Kole lands to non-agricultural uses and also facilitate other activities like mining.

Analysis of the data collected from Kole land farming households' shows that cultivation of rice is highly productive despite various pressures facing the ecosystem. However, it is input intensive and therefore, economically not so viable for most farmers. The author observes that cultivation of rice in the Kole exhibits diminishing returns to scale and net returns per acre are found to be low for marginal farmers. In order to make rice cultivation in the Kole farms economically more viable and to overcome some of the constraints thrown up by the small farms, the author draws attention to the substantial benefits that can be realised through collective action by the farmers. Ensuring quality and efficiency of service delivery by various institutions involved in the Kole land management and development in a coordinated manner is of considerable importance to sustain rice cultivation.

I hope that this monograph will contribute to the debate among academicians, opinion makers and policy makers on agriculture wetland interactions to make small farms economically more viable in the country.

Manoj Panda
Director, CESS

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Executive Summary

Wetlands are complex ecosystems that provide substantial benefits to human society. The interactions between agriculture and wetlands assume considerable importance as demand for food production accentuates pressures on wetlands. This study focuses on the Kole wetland in Kerala which is part of the Vembanad Kole wetland ecosystem, an important Ramsar site in India. This wetland lies below mean sea level and remains submerged under water for over six months in a year. Various activities like rice cultivation, fish farming, mining etc are carried out in the Kole land. With the withdrawal of monsoon, cultivation is carried out after dewatering the fields. Although Kole land is highly productive, it faces several anthropogenic pressures which result not only in the loss of ecosystem and its services but also pose serious challenges to sustaining rice production.

A study has been carried out to 1) to review the ecosystem characteristics and the socio economic importance of wetlands in general and the Kole wetlands in particular; 2) to analyse the status as well as trends in the Kole wetland use over the years; 3) to identify the major ecosystem services provided by the Kole wetland and analyse important agriculture wetland interactions using a Driver Pressure, State Impact Response (DPSIR) framework; 4) to carry out an economic analysis of rice cultivation, the main activity across the Kole wetlands; 5) to identify major opportunities as well as constraints in promoting the sustainable use of the remaining Kole rice fields from the perspective of agriculture-wetlands interactions.

Data sets, sources and methodology

Based on Indian Remote Sensing Satellite Images of the study area acquired for the years 1989, 1997, 2007 from the National Remote Sensing Centre (NRSC) and Survey of India (SOI) topo sheets of 1:50000 scale surveyed during 1981, an analysis of land use dynamics in the Kole land over the years has been carried out.

Important services provided by the Kole wetlands have been classified into provisioning, regulatory, supporting and cultural services. A Driver Pressure State Impact Response Framework has been applied for understanding wetland agriculture interactions and the various pressures exerted on the ecosystem.

To work out the economics of rice cultivation in the Kole land, a detailed survey of Kole rice farming households using a structured questionnaire was carried out. Kole rice farms are organised under an institutional arrangement called padasekharam which is a collection of contiguous farms. Data collected for the crop season 2009-10 from 231 farmers comprising small and marginal has been used in the study. About 10 per cent of the farmers were selected from each stratum adopting probability based proportionate sampling method from purposively selected padasekharams after arbitrarily classifying them into small, medium and large.

The details of various inputs including material inputs, their quantities and prices, and managerial inputs apart from rice output have been collected and valued in monetary terms for examining the net returns and profitability aspects. A Cobb-Douglas production function (log linear) has been fitted for examining the input-output relationship and for estimating returns to scale. In order to examine the economic viability of Kole farming, net returns have been estimated by taking the difference between gross value of output and the total variable cost of cultivation including the imputed cost of family labour. We have also calculated the ratio of gross value of output to total costs to see the extent of profit margin and also to identify farmers who find rice cultivation viable and not viable.

Major Findings

Land use changes (1981-2007)

The Kole land covering 546.25 sq.km, is divided into Southern and Northern Kole. Areas under rice, mixed crop, built up land, water bodies, water logging and wastelands form major land use categories. In line with the general trend observed in Kerala, area under rice declined from 46 per cent to 34 per cent during 1981-2007. This period also witnessed an increase in the area under mixed crops as well as the emergence of new land use categories such as wastelands and water logged areas. The area under rice declined at 1.07 per cent per annum while the area under built up land increased at 2.45 per cent during 1989-2007. However, wastelands also sharply increased during this period at 12.9 per cent per annum. Ground verification confirms that these lands were once used for mining and later abandoned as they had been found unfit for cultivation.

Agriculture Wetland Interactions

Agriculture and fisheries are the most important provisioning services of the wetland. Important drivers identified using a DPSIR framework relates to population dynamics and government policies pertaining to agriculture and food production. Agriculture intensification has become a major pressure on the Kole land. Several engineering interventions aimed at improved drainage and water management have been carried out for facilitating double cropping. Although the construction of farm roads has helped the

movements of tillers and tractors, seeds and fertilisers at reduced costs, it has also facilitated the conversion of Kole land to non-agricultural uses apart from facilitating mining and other activities and thereby leading to the transformation of the ecosystem. Increase in the acidic content of soil, decline in soil quality, water logging due to incomplete or faulty designs of bunds and canals, presence of water hyacinth etc are some of the state changes reported. Loss of biodiversity which can undermine the ecological character and resilience of the ecosystem, is also reported. Impacts of the state of the ecosystem changes are highly diverse and also vary across different types of users. Intensified agricultural activities followed by rice farmers have adversely affected communities dependent entirely on fishery resources. Also a shift in the fisheries from subsistence oriented to commercial and contract based one when the Kole land remains flooded has affected the livelihoods of traditional fishing communities. Mining activities have given rise to competition with respect to resource exploitation and conflicts with other users because of the increased claims over the available resource. The responses to various drivers, pressures, state changes and impacts are multiple and largely focused on Kole rice cultivation.

Economics of rice cultivation

An analysis of the data collected from Kole land farming households shows that cultivation of rice in the Kole land is highly productive. However, it is also input intensive and, therefore, economically not so viable for farmers in the small padasekharams and which are marginal in nature.

Kole rice farms are small farms having an average area of 0.36 ha. The average yield of rice per hectare works out to 5162 kgs where as it was 3705 kg/ha for Kerala as a whole during 2006-07. Dewatering of fields, an energy intensive activity, is carried out with the help of free electricity supplied by the state to *padasekharams*. Labour and other costs for dewatering, bunding etc are incurred by *padasekharams* and shared by individual farmers according to the size of their land holdings. As Kole soil is acidic in nature, farmers on an average, apply 267 kg lime per ha at the time of land preparation. It is estimated that about 150 kgs of seeds are used for cultivating a hectare of rice. High seed rates are prevalent because of the uncertainty surrounding seed germination and survival of plants due to acidity and other toxicities present in the soils. The use of transplanting, harvesting and threshing machines is very less in the study sample where as the use of chemical fertilisers and pesticides are found very high. The quantity of fertilisers used per hectare of rice (282 kg) is almost two times more than that of all Kerala average of 123 kg per hectare as reported by the Commission of Agricultural Costs and Prices, Government of India. Insecticides worth Rs 1820 per hectare are found applied by farmers. It is estimated that almost 176 human days which include females and males

hired as well as family labour are required per hectare of rice whereas it was 98 human days during 2006-07 for all Kerala. Highest amount of labour use has been reported by small padasekharams. Accounting for 32 per cent of the total labour use, land preparation and construction of bunds constitute the most labour absorbing activity. Weed control is the next major labour absorbing (21 per cent) activity followed by transplanting of rice saplings (17 per cent) and harvesting and threshing operations (15 per cent).

The estimated Cob-Douglas production function indicates that the quantity of seeds used, quantities of fertilisers applied, human labour and tilling hours significantly influence the yield levels of rice. It is seen that cultivation of rice in the Kole is operating at diminishing returns to scale as is evident from the returns to scale of 0.69.

Per hectare cost of cultivation of rice works out to Rs 45588 excluding energy costs and subsidies. While the marginal farmers (<1ha) have incurred Rs 46503, it is only Rs 27983 per hectare for small holders (1-2 ha). This difference is found statistically significant. Similarly, small padasekharams are also found to have incurred higher cost of cultivation. Labour cost constitutes about 65 per cent of the total cost of production. It is found that small farmers incur approximately 10 per cent less cost on labour and comparatively a higher cost on fertilisers when compared to marginal farmers. After valuing output at the price received by farmers, it is evident that irrespective of the size of holdings or padasekahrams, the farmers have realised a gross return of Rs 56730 per hectare. The average net benefit amounts to Rs 11142 per hectare. However, the net returns are found to be low for marginal cultivators and those belonging to small padasekharams. The ratio of gross value of output to total cost comes 1.54 for all categories of farmers and for about 32 per cent of the farmers it is found to be less than one. Average ratio for such groups of farmers is found to be 0.74 indicating that rice cultivation is not economically viable for them. It is also important to note that the level of margin or profitability improves with the size of holding. The correlation between size of landholding and level of margin works out to 0.34 and is statistically significant.

Sustaining Rice Cultivation: Actions for Short Term and Long Term

The biggest opportunity for undertaking rice cultivation in the Kole land is the fact that it is a flood plain area and therefore, a highly fertile area. In spite of decades of investment in basic infrastructure for broad based agricultural growth, inadequate and in some places incomplete construction of bunds and canals and their inadequate maintenance are posing major problems resulting in poor drainage and waterlogging of Kole land leading to faster weed growth and euotrophication of wetlands. Therefore, proper maintenance of canal networks needs to be ensured. Any infrastructural development project should consider the ecosystem characteristics so as to prevent further subdivision and fragmentation of the farms as marginal farms and small padasekharams are found to be economically unviable.

Activities which tend to alter ecosystem and its services and those that are conflicting in nature like mining need to be banned or controlled. Better coordination between rice cultivation and fish farming activities which are carried out in alternate seasons needs to be ensured.

As far as rice cultivation is concerned, labour is a major input contributing about 65 per cent of the total cost of production. However, substituting labour with machinery in activities like land preparation, transplanting, weeding, harvesting etc leads to high transaction costs because of small farm size and lack of timely availability of machines that are suitable to Kole farms. In order to overcome some of the constraints imposed by the small size farms one must emphasise the fact that substantial benefits can be realised through collective effort particularly through *padasekharams*. This may necessitate an expansion in the sphere of activities of *padasekharams* and possibly encourage collective action right from the first to last stage which would allow farmers to reap some economies of scale that are generally associated with large farms. Also there is a need to develop machines that are suitable for Kole farms which are small in size and ensure their timely availability.

Use of chemical fertilisers and pesticides is very high in Kole land. There is a need to have a relook into the subsidies given for these inputs as well as to promote environment friendly farming practices taking into account both health and food safety aspects. Towards this end, there is a need to encourage farmers to go in for more organic way of farming and replenish the soils. This is important as rice cultivation is already witnessing diminishing returns to scale. Measures may be taken to improve supply of organic inputs at reasonable prices to encourage its use as it might improve soil quality and resilience of the ecosystem.

The small scale nature of the Kole farms leads to high unit transaction costs in almost all input transactions. Therefore, quality and efficiency of service delivery by various institutions involved in Kole land management and development in a coordinated manner is of considerable importance for sustaining rice cultivation.

As a long term objective, there is a need to look for alternative farming practices considering the seasonally inundated nature of the ecosystem in which input costs including labour and energy are minimised. Review of different farming practices in similar seasonally inundated wetlands within the state and elsewhere and their suitability in the present study context needs to be explored and researched.

Chapter 1
Introduction

1.1. The Background

Wetlands, facing several threats are highly fragile complex ecosystems that provide varied services to the society. As the absence of a uniform (standard) definition of wetlands makes their global accounting very difficult, near to accurate estimates about their loss are also not available. It is generally believed that approximately 6 per cent of the world's area is covered by wetlands, however in 1900 the global wetland area might have been twice as much of what exists at present (Bateman *et al* 1992). According to the World Conservation Monitoring Centre (WCMC 1992) approximately 5.3 to 5.7 million km^2 of freshwater wetlands exist in the world with Canada thought to be containing the most around a quarter of the global total. Matthews and Fung (1987, cited in Adger and Luttrell 2000) observes that the global area of wetlands has decreased at an ever-increasing rate during the course of the century. Of the total wetland area lost, 87 per cent accounts for the diversion to agricultural development, 8 per cent to urban development, and 5 per cent to other conversions (Barbier 1997).

According to National Wetlands Conservation Programme, India has a wealth of wetland ecosystems distributed across various eco-geographical regions that range from Himalayas to Deccan Plateau. It is estimated to have 4.1m ha of wetlands excluding irrigated agricultural lands, rivers, and streams, of which 1.5 m ha are natural, while 2.6 m ha are manmade. It has also an estimated 6750 sq km of coastal wetlands largely dominated by mangrove vegetation (NWCP, 2009). According to the Directory of Asian Wetlands (1989), India has a total of 27,403 wetlands, of which 23,444 are inland and 3,959 are coastal wetlands. India has about 25 Ramsar wetlands[1] and 115 wetlands under National Wetlands Conservation Programme. The following table gives a brief description of Ramsar wetlands in India.

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[1] The Convention on Wetlands of International Importance especially as Waterfowl Habitat- commonly referred to as the Ramsar Convention named after its place of adoption in Iran in 1971- was the first of the modern global intergovernmental treaties on conservation and wise use of natural resources (Barbier et al 1997).

Table 1. Ramsar wetlands in India

Name of site	Year of Declaration	Brief Description
Chilika Lake (Orissa)	1981	This brackish lake is an important area for breeding, wintering and staging for 33 species of waterbirds. It also supports 118 species of fish, including commercially important species. Significant numbers of people are dependent upon the lake's resources.
Keoladeo National Park (Rajasthan)	1981	This is a World Heritage Site; National Park; Bird Sanctuary and provides habitat for breeding, wintering and staging migratory birds. Also supported are five species of ungulates, four species of cats, and two species of primates, as well as diverse plants, fish and reptiles.
Wular Lake (Jammu and Kasmir)	1990	The largest freshwater lake in India with extensive marshes of emergent and floating vegetation, particularly water chestnut, that provide an important source of revenue for the State Government and fodder for domestic livestock and supports fishing.
Harike Lake (Punajb)	1990	An important site for breeding, wintering and staging birds, supporting over 200,000 Anatidae (ducks, geese, swans, etc.) during migration.
Loktak Lake (Manipur)	1990	A large, but shrinking freshwater lake and associated swamplands supplied by several streams. The lake is used extensively by local people as a source of water for irrigation and domestic use and is an important wintering and staging area for waterbirds, particularly ducks.
Sambhar Lake (Rajasthan)	1990	A large saline lake surrounded by sand flats and dry thorn scrub and fed by seasonal rivers and streams. The site is important for a variety of wintering waterbirds, including large numbers of flamingos. Human activities consist of salt production and livestock grazing.
Kanjli (Punjab)	2002	A permanent stream, the Kali Bein, converted by construction of a small barrage in 1870 into a water storage area for irrigation purposes. The site fulfils Criteria 3 because of its importance in supporting a considerable diversity of aquatic, mesophytic, and terrestrial flora and fauna in the biogeographical region.
Ropar (Punajb)	2002	A humanmade wetland of lake and river formed by the 1952 construction of a barrage for diversion of water from the Sutlej River for drinking and irrigation supplies. The site is an important breeding place for the nationally protected Smooth Indian Otter, Hog Deer, Sambar, and several reptiles, and the endangered Indian Pangolin (Manis crassicaudata) is thought to be present.

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Ashtamudi Wetland (Kerala)	2002	An extensive estuarine system, the second largest in Kerala State, which is of extraordinary importance for its hydrological functions, its biodiversity, and its support for fish. The site supports a number of mangrove species as well as over 40 associated plant species, and 57 species of birds have been observed, including six that are migratory.
Bhitarkanika Mangroves (Orissa)	2002	One of the finest remaining patches of mangrove forests along the Indian coast. The site's Gahirmatha beach is said to host the largest known Olive Ridley sea turtle nesting beach in the world, and the site has the highest density of saltwater crocodile in the country, with nearly 700 Crocodylus porosus. Also a breeding and wintering place for many resident and migratory waterbirds, and has 55 of Indian India's 58 recorded species of mangroves.
Bhoj Wetland (Madhya Pradesh)	2002	Two contiguous human-made reservoirs - the lakes are very rich in biodiversity, particularly for macrophytes, phytoplankton, zooplankton, both natural and cultured fish species, both resident and migratory birds, insects, and reptiles and amphibians.
Deepor Beel (Assam)	2002	A permanent freshwater lake in a former channel of the Brahmaputra river, of great biological importance and also essential as the only major storm water storage basin for the city of Guwahati. Some globally threatened birds are supported, including Spotbilled Pelican (Pelicanus philippensis), Lesser and Greater Adjutant Stork (Leptoptilos javanicus and dubius), and Baer's Pochard (Aythya baeri).
East Calcutta Wetlands (West Bengal)	2002	World-renowned as a model of a multiple use wetland, the site's resource recovery systems, developed by local people through the ages, have saved the city of Calcutta from the costs of constructing and maintaining waste water treatment plants. The wetland forms an urban facility for treating the city's waste water and utilizing the treated water for pisciculture and agriculture, through the recovery of nutrients in an efficient manner.
Kolleru Lake (Andhra Pradesh)	2002	A natural eutrophic lake, situated between the two major river basins of the Godavari and the Krishna, fed by two seasonal rivers and a number of drains and channels, which functions as a natural flood balancing reservoir between the deltas of the two rivers. It provides habitat for a number of resident and migratory birds, and sustains both culture and capture fisheries, agriculture and related occupations of the people in the area.

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Point Calimere Wildlife and Bird Sanctuary (Tamil Nadu)	2002	A coastal area consisting of shallow waters, shores, and long sand bars, intertidal flats and intertidal forests, chiefly mangrove, and seasonal, often-saline lagoons, as well as human-made salt exploitation sites. Some 257 species of birds have been recorded, and the site serves as the breeding ground or nursery for many commercially important species of fish, as well as for prawns and crabs.
Pong Dam Lake (Himachal Pradesh)	2002	A water storage reservoir created in 1975 on the Beas River in the low foothills of the Himalaya on the northern edge of the Indo-Gangetic plain. Given the site's location on the trans-Himalayan flyway, more than 220 bird species have been identified, with 54 species of waterfowl
Sasthamkotta Lake (Kerala)	2002	The largest freshwater lake in Kerala state in the southwest of the country, spring-fed and the source of drinking water for half a million people in the Kollam district. Some 27 freshwater fish species are present. The water contains no common salts or other minerals and supports no water plants; a larva called "cavaborus" abounds and eliminates bacteria in the water, thus contributing to its exceptional purity.
Tsomoriri (Jammu and Kashmir)	2002	A freshwater to brackish lake lying at 4,595m above sea level. The site is said to represent the only breeding ground outside of China for one of the most endangered cranes, the Black-necked crane (Grus nigricollis), and the only breeding ground for Bar-headed geese in India. The barley fields at Korzok have been described as the highest cultivated land in the world.
Vembanad-Kol Wetland (Kerala)	2002	The largest brackish, humid tropical wetland ecosystem on the southwest coast of India, fed by 10 rivers and typical of large estuarine systems on the western coast, renowned for its clams and supporting the third largest waterfowl population in India during the winter months. Over 90 species of resident birds and 50 species of migratory birds are found in the Kol area. Flood protection for thickly-populated coastal areas of three districts of Kerala is considered a major benefit, groundwater recharge helps to supply well water for the region, and the value of the system for the local transport of people and trade is considerable.

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Chandertal Wetland (Himachal Pradesh)	2005	A high altitude lake on the upper Chandra valley flowing to the Chandra river of the Western Himalayas (4,337m asl.) near the Kunzam pass joining the Himalayan and Pir Panchal ranges. It supports CITES and IUCN Redlisted Snow Leopard and is a refuge for many species like Snow Cock, Chukor, Black Ring Stilt, Kestrel, Golden Eagle, Chough, Red Fox, Himalayan Ibex, and Blue Sheep.
Hokera Wetland (Jammu and Kashmir)	2005	A natural perennial wetland contiguous to the Jhelum basin, it is the only site with remaining reedbeds of Kashmir and pathway of 68 waterfowl species like Large Egret, Great Crested Grebe, Little Cormorant, Common Shelduck, Tufted Duck and endangered White-eyed Pochard, coming from Siberia, China, Central Asia, and Northern Europe. It is an important source of food, spawning ground and nursery for fishes, besides offering feeding and breeding ground to a variety of water birds.
Renuka Wetland (Himachal Pradesh)	2005	A natural wetland with freshwater springs and inland subterranean karst formations, fed by a small stream flowing from the lower Himalayan out to the Giri river. The lake is home to at least 443 species of fauna and 19 species of ichthyofauna representative of lacustrine ecosystems like Puntius, Labeo, Rasbora, Channa. Prominent vegetation ranges from dry deciduous like Shorea Robusta, Terminalia tomentosa, Dalbergia sissoo to hydrophytes. There are 103 species of birds of which 66 are residents.
Rudrasagar Lake (Tripura)	2005	A lowland sedimentation reservoir in the northeast hills, fed by three perennial streams discharging to the River Gomti. The lake is abundant in commercially important freshwater fishes like Botia spp, Notopterus Chitala, Mystus spp., Ompok pabda, Labeo bata, and freshwater scampi, with annual production of 26 metric-tons, and an ideal habitat for IUCN Redlisted Three-striped Roof Turtle Kachuga dhongka.
Surinsar-Mansar Lakes (Jammu and Kashmir)	2005	Freshwater composite lake in semi-arid Punjab Plains, adjoining the Jhelum Basin with catchment of sandy conglomeratic soil, boulders and pebbles. Surinsar is rain-fed without permanent discharge, and Mansar is primarily fed by surface run-off and partially by mineralised water through paddy fields, with inflow increasing in rainy season. The lake supports CITES and IUCN Redlisted Lissemys punctata, Aspideretes gangeticus, and Mansariella lacustris, is a habitat, breeding and nursery ground for migratory waterfowls.

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Upper Ganga River (Brijghat to Narora Stretch) (Uttar Pradesh)	2005	A shallow river stretch of the great Ganges with intermittent small stretches of deep-water pools and reservoirs upstream from barrages. The river provides habitat for IUCN Red listed Ganges River Dolphin, Gharial, Crocodile, 6 species of turtles, otters, 82 species of fish and more than hundred species of birds. Major plant species, some of which have high medicinal values, include Dalbergia sissoo, Saraca indica, Eucalyptus globulus, Ficus bengalensis, Dendrocalamus strictus, Tectona grandis, Azadirachta indica and aquatic Eichhorina.

Source: www.ramsar.org accessed on 14 June 2011

It has been noted that the conversion of wetlands to agriculture, urban and other uses tends to have profound ecological impacts, especially at local levels. Moreover, as growing demand for food production accentuates pressures on wetlands the interactions between agriculture practices and wetlands assume greater importance. Although the Millennium Ecosystem Assessment identifies agriculture as a major driver of wetland degradation and loss, agricultural development considerably increases some of the provisioning services of wetlands, though some other regulating and supporting services may get reduced in the process. In a recent Comprehensive Assessment of Water Management in Agriculture (CA), it has been concluded that the pressures on wetlands will probably increase, with the prospect of a serious loss of wetlands and their ecosystem services. This is pointed out as a major challenge as the regulating and supporting ecosystem services that wetlands provide are essential for the functioning of river basins, the maintenance of ecological flows, and the sustainability of agricultural production (FAO, 2008). Here it needs to be noted that the conversion of wetlands to agriculture and other uses is irreversible and that it imposes external costs on renewable resource production. The irreversibility places wetlands in non-renewable resource sector (Krutilla 1967, Swallow 1994). In fact, the lack of sufficient information on the goods and services provided by wetlands and their linkages has been a major factor for the loss of wetlands all over the world. In this present study, we have tried to explore the case of Kole land[2], a Ramsar wetland in Thrissur, Kerala (Figure 1.1), with a particular emphasis on agricultural activities being undertaken on it in relation to their potential impacts on the fragile ecosystem.

[2] In this study, we use 'Kole wetland' and 'Kole land' as interchangeable terms. In several reports Kole rice fields are referred to as Kole land. However, Kole rice fields are part of larger ecosystem comprising permanent water bodies in and around rice fields, and land put to other uses like for growing mixed crops etc. These lands are believed to have been reclaimed from *kayal* or backwaters. Refer Chapter 3 for a classification and an analysis of land uses of Kole wetland.

1.2. The Kole wetland

The Kole land, one of the rice granaries of Kerala is of a unique wetland ecosystem down South. It is part of Vembanad-Kole wetland system spread across 151250 ha and is the largest wetland system from India included as a Ramsar site in 2002. The very inclusion of this as a Ramsar site shows this wetland is of considerable national as well as international importance. The following table 1.2 summarises some of the key characteristics of the Vembanad Kole wetland as per the Ramsar Information sheet.

Table 1.2. Some of the key characteristics of the Vembanad-Kole wetland

Item	Details
Geographical coordinates	09^0 00' – 10^0 40' N Latitude and 76^0 00' -77^0 30' E Longitude South West Coast of India
Elevation:	0.6 – 2.2 m below MSL
Area: (in hectares	151250 ha
Ramsar Citeria	1,2,4,5 and 8
Criterion 1:	Vembanad Kol wetland system fed by 10 rivers, covering an area of 1512 km2, forms a typical and one of the largest estuarine systems of the western coastal wetland systems. It is renowned for its live clam resources and Sub-Fossil deposits.
Criterion 2:	The wetland supports vulnerable species Spot-billed pelican *(Pelicanus philippensis*
Criterion 4:	The Vembanad supports the third largest population of waterfowl in India during the winter months. 91 species of resident/locally migratory and 50 species of migratory birds are found in the Kol area. The birds came here from different regions they stay here for breeding and feeding.
Criterion 5	The Vembanad supports the third largest population of waterfowl more than 20,000 in India. According to the Asian Waterfowl Census 1994-96, Vembanad Lake supported 27 species 29,991 waterbirds in 1994; 33 species 21,416 waterbirds in 1995 and 35 species 21,724 waterbirds in 1996.
Criterion 8:	Vembanad serves as a habitat for variety of finfish, shellfish, a nursery of several species of aquatic life, and a transitional ecotone between sea and land. Many fish species depend on the wetland for food, spawning and nursery.
General location:	Alappuzha, Kochi and Thrissur towns which falls within Alappuzha, Ernakulam, and Thrissur districts of Kerala State respectively.

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Physical features	The drainage basins may be divided physiographically into three near-parallel north-south zones, viz. the highland (above 75 m above sea level), the middle reaches (7.5 m – 75 m above sea level) and the lowland (below 7.5 m above sea level). Vembanad Kol wetland system fed by 10 rivers, all these rivers originate from the Western Ghats, flow westwards through the wetland system and join the Lakshadweep / Arabian Sea. The wetland is typically divided into two distinct segments viz. The freshwater dominant southern zone and the salt water dominant northern zone.
Hydrological values:	These canals offer immense navigational facilities to the local people. Besides continuous flow in the river, the area is also exposed to diurnal tidal cycles. The system has several functions and values. This water body contains the flood waters and saves about 3500 sq km thickly populated coastal area of 3 districts of Kerala from flood damages.
Ecological features	Ecosystem serves as a habitat for variety of fin fish, shell fish, a nursery of several species of aquatic life, and a transitional ecotone between sea and land. Prawn culture is also popular in several areas of the wetland. The wetland along with the lower reaches of the rivers draining into it serves the purpose of inland navigation. This wetland system also serves as a sink and transformer for the agricultural and municipal wastes discharged into it. Agriculture and fisheries in the wetland are considered to be conflicting values Rice cultivation is practiced in the polders covering a total area of 100 sq km in the Kuttanad belt - the rice bowl of Kerala – of the Vembanad and most of the area of the Kol; the yield of rice from the wetland is 4-6 times more than the uplands.

Source: Ramsar Information Sheet (2002)

Within the Vembanad Kole ecosystem, geologically Kole is a low lying area with rich alluvium deposits brought along by Kechery and Karuvannur rivers. It is a basin with a saucer shape flanked by laterite hills in the western and eastern margins. A portion of Kole area exhibits a lacustrine environment, containing black carbonaceous clay with luxuriant plant growth, and in some places withered tree trunks (Johnkutty and Venugopal, 1993). As per the earlier official estimates, the Kole rice fields are low lying tracts located at 0.5 to 1 m below mean sea level extending to an area of 13632 ha, spread over Thrissur and Malappuram districts of Kerala. The southern boundary is marked by Chalakudy river while northern boundary by Bharathapuzha river. The area is located between 10°20' and 10°40'N latitude and 75°58' to 76°11'E longitude. The Kole land in Thrissur district is located in Mukundapuram, Thrissur and Chavakkad *thaluks,* where as Ponnani Kole is located in Chavakkad and Thalapilly *thaluks* of Thrissur district and Ponnani taluk of Malappuram district. (Refer figure 1.1 for the location map of Kole wetlands).

Figure 1.1 Location map of the Kole wetland in Thrissur, Kerala

A major portion of the Kole land remains submerged under water for about six months in a year lending it both terrestrial and water related properties. A network of canal connects different regions of the Kole to the rivers besides acting as good drainage systems. The Kole lands reclaimed from the Kayal area by putting up temporary earthen bunds are used for the cultivation of rice by dewatering them. Studies conducted in the Kole area reveal wide variations in morphological and physico-chemical characteristics of soil systems which are mainly the product of weathering of river alluvial deposits and colluvium. Based on the physiographic position, soils can be grouped into (1) soils of the flood plain, comprising of *Perumpuzha, Anthikkad* and *Konchira* series and (2) soils of a slightly higher elevation occupying the outer fringes that consist of *Manalur, Edathuruthy, Ayyanthole and Kizhipallikkara* series (Johnkutty and Venugopal, 1993).

It is known that soil systems in the Kole area especially in the flood plain are heavy clay in texture and acidic in reaction. The presence of organic peat layer in the sub-surface of the soil profile makes soils extremely acidic with pH level ranging from 2.6 to 6.3. Besides, in the Kole land adjacent to the coast, sea water inundation causes high salinity levels that can have toxic effects on crops. On the whole, the Kole land is a unique wetland ecosystem whose characteristics are determined by the volume and duration of flooding along with the silt brought in.

However, this ecosystem is subjected to various kinds of anthropogenic pressures such as the conversion of vast areas to non-agricultural purposes in addition to the unsustainable cultivation practices being adopted. Further the subsurface exploration of Kole land shows fine sandy deposits due to which mining has become an important activity in certain parts of the Kole lands recently. All such developments tend to adversely affect the flow of ecosystem services and thereby the very sustainability of the ecosystem. In this context, there is a need for further exploring the complex interface between agricultural practices and the fragile wetland and ecosystems like the Kole land, so that appropriate measures for their wise use are taken up. The present study is an attempt in this direction.

1.3. Objectives

The specific objectives of the study are stated as follows:

1) To review the ecosystem characteristics and the socio economic importance of wetlands in general and the Kole wetlands in particular.

2) To analyse the status as well as trends in the Kole wetland use over the years.

3) To identify the major ecosystem services provided by the Kole wetland and analyse important agriculture wetland interactions using a Driver Pressure, State Impact Response (DPSIR) framework.

4) To carry out an economic analysis of rice cultivation, the main activity across the Kole wetlands.

5) To identify major opportunities as well as constraints in promoting the sustainable use of the remaining Kole rice fields from the perspective of agriculture-wetlands interactions.

1.4. Data sets, sources and methodology

To begin with, a detailed review of the characteristic features of wetlands was carried out followed by an analysis of the land use dynamics in the Kole lands over the years. For this, Indian Remote Sensing Satellite Images of the study area were acquired for three years: 1989, 1997 and 2007 from the National Remote Sensing Centre (NRSC). In addition to this, Survey of India (SOI) topo sheets of 1:50000 scale surveyed during 1981 were used for accessing land use details of the relevant period. All data sets were geo-referenced using control points collected through field survey inputs and brought into Geographic co-ordinate system with WGS 84 datum[3].

Table 1.3. Type of Data used for land cover analysis

Data type	Date of production	Scale	Source
IRS LIS III image	2007-11-03	23.5m	NRSC
IRS LIS III image	1997-11-15	23.5	NRSC
IRS LIS II Image	1986-11-07	36m	NRSC
Toposheets	1981	1:50000	Survey of India

The areas lying below the mean sea level in the region have been classified as Kole wetlands. The land use/land cover categories used in this study relate to mixed crops, rice, built up lands, water bodies, water logged areas and wastelands. The definition of wasteland as used in this study refers to land without scrubs, sandy areas, dry grasses, rocky areas and other human induced barren lands. Mixed crop area comprises coconut, areca nut, plantain, and seasonal vegetables, while water logged area is the unused land inundated almost all the time.

After analysing land use changes, attempts have been made to classify important goods and services provided by the Kole wetland into provisioning, regulating, cultural and supporting services following the concept of ecosystem services. The concept of ecosystem services describes the flows of value to human societies as a result of the state and quantity of natural capital. From an economic point of view the flows of ecosystem services can

[3] Satellite data have been processed and analyzed by SBL Cochin.

be seen as the 'dividend' that society receives from natural capital. This implies that maintaining stocks of natural capital allow sustained provision of future flows of ecosystem services and thereby help to ensure enduring human well being (TEEB, 2010).

A Driver Pressure State Impact Response Framework has been applied for understanding wetland agriculture interactions and the various pressures exerted on the ecosystem. In this framework, the ***drivers***d arethe rious pr

Wetlands perform a number of functions which can be summarised into hydrological, chemical, biological and socio-economic functions (Williams, 1990). The hydrological functions are important in that they prevent flooding and erosion of shorelines apart from facilitating recharging and discharging of aquifers across wetlands.

Table 2.1. Functions, Products and Attributes of Wetlands

	Wetland types							
	Estuaries	**Mangroves**	**Open coasts**	**Flood plains**	**Freshwater marshes**	**Lakes**	**Peat lands**	**Swamp forests**
				Functions				
1.Groundwater recharge	×	×	×	✱	✱	✱	•	•
2. Groundwater discharge	•	•	•	•	✱	•	•	✱
3. Flood control	•	✱	×	✱	✱	✱	•	✱
4. Shoreline stabilisation, erosion control	•	✱	•	•	✱	×	×	×
5. Sediment / toxicant retention	•	✱	•	✱	✱	✱	✱	✱
6. Nutrient retention	•	✱	•	✱	✱	•	✱	✱
7. Biomass export	•	✱	•	✱	•	•	×	✱
8. Storm protection / windbreak	•	✱	•	×	×	×	×	•
9. Micro-climate stabilisation	×	•	×	•	•	•	×	•
10. Water transport	•	•	×	•	×	•	×	×
11. Recreation, tourism	•	•	✱	•	•	•	•	•
				Products				
1. Forest resources	×	✱	×	•	×	×	×	✱
2. Wildlife resources	✱	•	•	✱	✱	•	•	•
3. Fisheries	✱	✱	•	✱	✱	✱	×	•
4. Forage resources	•	•	×	✱	✱	×	×	×
5. Agricultural resources	×	×	×	✱	•	•	•	×
6. Water supply	×	×	×	•	•	✱	•	•
				Attributes				
1. Biological diversity	✱	•	•	✱	•	✱	•	•
2. Uniqueness to culture / heritage	•	•	•	•	•	•	•	•

Key: × = absent or exceptional; • = present; ✱ = common and important value of that wetland type

Source: Dugan (1990) adapted from Dixon and Lal (1997)

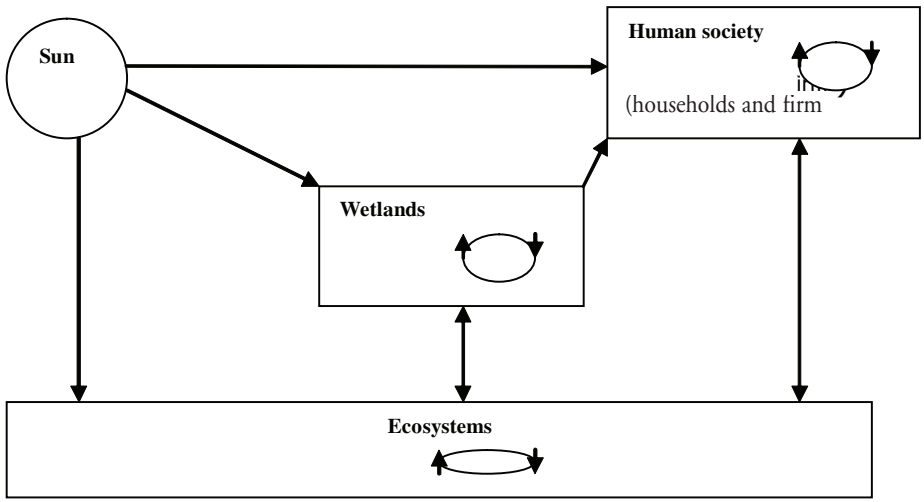
The chemical functions include water quality improvement, sediment trapping and wastewater treatment. It is a sink or a natural cleaning centre for pollution, especially, with nutrients. Williams (1990) divides biological functions into productivity and biodiversity. The socio-economic functions include productive agricultural areas, production of drinking water, firewood and the stock of fish, *etc*. The non-consumptive elements of socio-economic functions include recreational, educational, aesthetic, archaeological and gene pool benefits. With the increased scientific understanding, wetlands have come to be described both as 'the kidneys of the landscape' and 'biological supermarkets'. This is not only because of the functions they perform in terms of hydrological and chemical cycles but also the extensive food webs and the rich biodiversity that they support (Mitsch and Gosselink 1993 cited in Barbier *et al* 1997). (Table 2.1 explains the functions, products, and attributes of different natural wetlands).

2.2. Ecosystem Linkages, Functions and Values of Wetlands

A unique feature of wetlands is that they are often located between dry terrestrial systems and permanent deep water systems like rivers, lakes, or oceans. Because of their occupying a unique niche across landscapes, wetlands are considered important exporters or importers of organic and inorganic nutrients in addition to being regarded as one of the most productive ecosystems. Besides, wetlands help reduce the adverse effects of floods, facilitate recharging of groundwater and provide recreational opportunities. The climatic function of some wetlands is also important as it positively affects the mesoclimate of nearby lands by increasing evaporation and absorbing heat during periods of drought. It also acts as a barrier against strong winds (Vasicek 1985). In short, the services provided by wetlands are many.

According to Gren and Soderqvist (1994), wetlands are open systems which receive inputs from other ecosystems and also from the sun. The outputs or environmental services of wetlands can be exported to human society and /or to other ecosystems. Synergetic effects (represented by circles in Figure 2.1) of hydrology, chemical inputs, and climatic conditions, which affect the productivity of environmental services, take place within wetlands. The figure also shows that wetlands export services to other ecosystems, for example, water purification, which is beneficial to downstream stretches of the river and its tributaries.

Figure 2.1. Flows Between Wetlands, Human Society, and Other Ecosystems



Source: Gren and Soderqvist (1994)

Human society receives benefits directly from wetlands and indirectly through other ecosystems. Other important services include recreational opportunities provided by wetlands. The creation of wetlands for certain purposes, say for example, nitrogen purification, provides an example of impact of human society on wetlands. Therefore, a negative impact of conversions on wetland may imply feedbacks, such as, decreased supply of services from the wetland and from other ecosystems. In other words, a change caused by human society on other ecosystems may improve or hamper the production of environmental services by wetlands. Thus, it is important to note that although fluctuations are a part of the wetland ecosystem, human interventions can result in the improvement or degradation of the services provided by the wetlands.

The linkages of wetlands with other systems are explained in a simple manner in Table 2.2 using an input-output matrix developed by Gren and Soderqvist (1994). In the table, the exporters and importers of services are presented in the first column and the first row respectively. For example, the SàW element of the matrix indicates that the energy output of the sun serves as an input for wetlands; wetlands, in turn, produce a wide range of environmental services.

Apart from the services used by wetlands themselves for their own development and maintenance (W→W), there is also export of services to other ecosystems (W→OE), and human society (W→HF, W→HH). An example of the W→OE export is the nursery

that wetlands provide for migratory animals. Similarly, an example of a good that wetlands export to firms (W→HF) is peat[6] which, in turn, can be used for the production of electricity consumed by other firms or by households (HF→HF, HF→HH). It is important to observe from Figure 2.1 and Table 2.2 that the environmental services that wetlands export are used partly directly by human society and partly indirectly through wetland transport to other ecosystems. However, some of the recent studies clearly bring out the complexities involved in modelling wetlands. For example, the study by Kadekodi (2000) on Chilika lake ecosystem provides a more realistic picture of the complexities involved and the challenges in modelling wetlands.

Table 2.2. An Input-Output Matrix Showing, Inter Alia, Deliveries of Environmental Services

To ↑↓		**Sun (S)**	**Wetlands (W)**	**Other Ecosystems (OE)**	**Human Society**	
					Firms (HF)	**Households**
(HH) From↓						
Sun (S)		S→S	S→W	S→OE	S→HF	S→HH
Wetlands (W)			W→W	W→ OE	W→HF	W→HH
Other Ecosystems (OE)			OE→W	OE→OE	OE→HF	OE→HH
Human	Firms (HF)		HF→W	HF→OE	HF→HF	HF→HH
Society	Households (HH)		HH→W	HH→OE	HH→HF	HH→HF

Source: Gren and Soderqvist (1994)

The multi-level model of wetlands as developed by Turner *et al* (2000) helps one understand the complexities involved in the modelling of wetlands. Here, the foundations of the model are provided by natural science in terms of defining characteristics of the wetland ecosystem, its processes and functions. It can be noted that the characteristics relate to biological, chemical and physical aspects that describe wetland areas in the simplest and most objective terms. The ecosystem processes refer to the dynamics of transformation of matter or energy[7] . The processes are subsequently responsible for the

[6] Partly decayed, moisture absorbing plant matter found in swamps.

[7] Of the basic constituents of matter and energy of our biotic and abiotic environment, energy has an unidirectional flow, while, material moves in circular pattern passing back and forth between organisms and their abiotic environment and such material cycles are termed as bio-geo-chemical. There are three types of cycles- hydrological, gaseous and sedimentary. The hydrological cycle is concerned with the movement of a compound H_2O, the other two types of cycles, gaseous and sedimentary are concerned with the movement of basic chemical elements (Sengupta 2001).

services – life support services such as assimilation of pollutants, and enable the development and maintenance of the ecosystem's structure which in turn is key to the continuing provision of goods and services. From an anthropocentric view, all ecosystems can be classified in terms of their structural and functional aspects (Westman 1985). While the ecosystem structure is defined as the tangible items such as plants, animals, soil, air and water of which it is composed, the structural benefits include the direct harvest of marketable products and the use of ecosystems for recreation and aesthetic enjoyment. Ecosystem functions on the other hand are the result of interactions between structure and processes.

According to Turner *et al* (2000), it is the interactions between wetland hydrology, geomorphology, saturated soil and vegetation that constitute the functions of the wetland ecosystem. The functions performed by wetlands determine the general characteristics and significance of the processes that occur in any given wetland. Moreover, it is the processes that are responsible for the services, the life-support services, such as assimilation of pollutants, cycling of nutrients, etc. They also enable the development and maintenance of the ecosystem's structure which, in turn, is a key to the continuous flow of goods and services. In short, the ecosystem functions in terms of providing humans with goods and services are the result of interactions between the structure and processes.

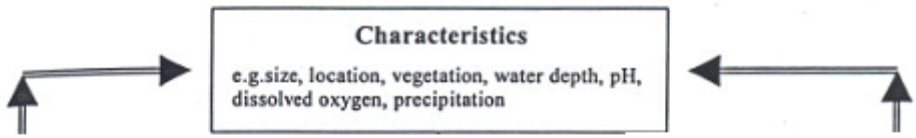
The next level of this model contains the interrelated uses (activities) that socio-economic systems derive directly and indirectly. These have been classified into various categories using the total economic value framework [for example, see Barbier (1994) and Turner *et al* (1997)]. Under this framework, a distinction is made between direct, indirect and non-use values. While direct use values are those derived from the direct use of or interaction with a wetland's resources and services, indirect use values are those arising out of the indirect support and protection provided to economic activity and property by a wetland's natural functions, or regulatory environmental services. Non-use values are those derived from neither direct nor indirect use of wetland. Option value is a special category of value which arises because an individual may be uncertain about his or her future demand for a wetland resource and /or its availability in the future. Contrary to this, there are individuals who may not be currently making use of tropical wetlands, but wish to see them preserved 'in their own right'. 'Intrinsic' value is often referred to as existence value. Thus, the total economic value of a tropical wetland ecosystem comprises of use, option and existence values.

Finally, the methods and techniques available for the economic valuation of wetland goods and services form the last level of the Turner *et al* (2000) model. A wide range of valuation techniques exist for assessing the economic value of wetlands perhaps because

many wetland functions result in goods and services which are neither traded in markets nor are they priced. Approaches to market analysis include the assessment of productivity losses attributable to structural changes in wetlands, and the incorporation of wetlands as an input in the production function of other goods and services.

The total economic value, however, does not reflect the total primary value of an ecosystem. Gren *et al* (1994) elaborate that the total output of a wetland system can be divided into three different uses: (i) for its own development; (ii) exports to other ecosystems and/or (iii) exports to human society. The first type of output refers to the build-up and organising capacity of a wetland itself and the other two to exported life-support values which the authors call as 'primary' and 'secondary' values respectively. Under this categorisation, the prior existence of primary value is necessary for the derivation of secondary values. In other words, the total primary value constitutes the total 'life-support service' of an ecosystem as an integral whole. These are essentially the existence, functional operation, and maintenance of the entire ecosystem that underlie the ecological services and resources of value to human beings. In short, the wetland and its functional relationships in their entirety are the source of total primary value, which is over and above the combined economic value of various wetland 'characteristics'. Thus, the total economic value of wetlands is, in some sense, a total 'secondary' value which is always less than the total primary value (Barbier 1995).

Figure 2.2 Wetland- Functions, Uses and Values



Mitsch and Gosselink (2000) explains that the value of wetlands occur at three levels of ecological hierarchy[8] , that is, population, ecosystem and biosphere.

Table 2.3. General Categories of Wetland Values at Three Different Ecological Scales

Ecological scale	Value
Population	Animals harvested for skin, fur, *etc*, waterfowl and other birds, fish and shellfish, timber and other vegetation harvest, endangered / threatened Species
Ecosystem	Flood mitigation, storm abatement, Aquifer recharge, water quality improvement aesthetics, subsistence Use
Biosphere	Nitrogen cycle, sulphur cycle, carbon cycle

Source: Mitsch and Gosselink (1993), cited in Mitsch and Gosselink (2000).

As per table 2.3 the wetlands provide resources like fish which are generally harvested for food or fibre at the population scale. At the ecosystem scale, wetlands provide flood control, drought prevention, water quality protection, and similar values. These are referred to as 'ecosystem values' because the ecosystem provides them most effectively when abiotic and biotic components of the ecosystem get synchronised. Then there are values of wetlands at biosphere scale. Recently there have been increased attempts to consider wetlands as an integral part of river basins as hydrology is the single most important characteristic of a wetland (James, 1997).

The concept of ecosystem services

The links between nature and the economy are often described in the recent literature using the concept of ecosystem services. The ecosystem services are flows of value to human societies as a result of the state and quantity of natural capital. The Millennium Ecosystem Assessment (MA) (2005) introduced a new classification of services provided by ecosystems such as: provisioning services (e.g. food, water, fibre and fuel); regulating services (e.g. water regulation and purification, erosion control, and climate regulation); cultural services (e.g. spiritual and recreational values); and supporting services (e.g. soil formation and nutrient recycling). The concept of 'ecosystem services' helps us recognize the many benefits that nature provides and is useful to identify the linkages and interactions between various ecosystem services, and to determine those whose services

[8] In its simplest terms, a hierarchy is an ordered ranking. Across ecological systems, hierarchy can be described as ordered ranking of biotic and *abiotic* interactions. These interactions are intrinsically interconnected by such complex patterns as food web dynamics and energy flows. Inherent in any discussion on ecological hierarchies is the concept of scale. The scale of an ecosystem refers to its spatial and temporal dimensions.

are mutually supportive or incompatible. Table 2.4 gives the important ecosystem services provided by or derived from wetlands as reported in the Millennium Ecosystem Assessment report.

Table 2.4 Ecosystem services provided by or derived from wetlands

Services	Comments and Examples
Provisioning	
Food	Production of fish, wild game, fruits and grains Fresh water Storage and retentions of water for domestic, industrial, and agricultural use Fiber and Fuel Production of logs, fuel wood, peat, fodder
Biochemical	Extraction of medicines and other materials from biota
Genetic materials	Genes for resistance to plant pathogens, ornamental species, and so on
Regulating	
Climate regulation	Source of and sink for greenhouse gases, influence local and regional temperature, precipitation and other climatic processes
Water regulation (hydrological flows)	Groundwater recharge/discharge
Water purification and waste treatment	Retention, recovery, and removal of excess nutrients and other pollutants
Erosion regulation	Retention of soils and sediments
Natural hazard regulation	Flood control, storm protection
Pollination	Habitat for pollinators
Cultural	
Spiritual and inspirational	Source of inspiration, many religions attach spiritual and religious values to aspects of wetland ecosystems
Recreational	Opportunities for recreational activities
Aesthetic	Many people find beauty or aesthetic value in aspects of wetland ecosystems
Educational	Opportunities for formal and informal education and training
Supporting	
Soil formation	Sediment retention and accumulation of organic matter
Nutrient cycling	Storage, recycling, processing, and acquisition of nutrients

It is also important to note that sustaining flows of values to human societies from nature requires a good understanding of how ecosystems function and provide services and how they are likely to be affected by various pressures.

Understanding this relationship is central to the development of wetland based sustainable agricultural systems. In their study on valuing ecosystem services flowing from wetlands restoration in Mississippi valley Jekins et al (2010), takes into account three focal services viz greenhouse gas (GHG) mitigation, nitrogen mitigation and waterfowl recreation. The study finds that the estimated social value surpasses the public expenditure or social cost of wetlands restoration in only 1 year, indicating that the return on public investment is very positive in respect of wetland restoration. Jogo and Hassan (2010) analyses the case of Limpopo wetland in Southern Africa from the perspective of balancing the use of wetlands for economic well being and ecological security. The authors develop an ecological-economic model based on the system dynamics framework for simulating the impacts of alternative policy regimes for wetland functioning and economic well being. The authors find that wetland services mainly for crop production and natural resource harvesting are inter-linked with trade-offs through competition of labour, land and water resources. It is also found that diversifying of livelihoods beyond agriculture simultaneously improves economic well-being besides enhancing wetland conservation.

The above observations highlight the ecological and economic importance of wetland ecosystems. However, the divergence between private and social values of wetlands has been pointed out as one of the most important reasons for the loss of wetlands worldwide (Vuuren and Roy, 1993; Danielson and Leitch, 1986). In other words, although preservation benefits take precedence over all conversion benefits from the nation's point of view, from a private point of view conversion benefits outweigh those of preservation. This brings to the fore the importance of public policies and property right issues in the context of wetlands. Property rights are social institutions that define or delimit the range of privileges granted to individuals in respect of specific assets, such as parcels of land or water. The property right related institutions range from formal arrangements, such as constitutional provisions, statutes, and judicial rulings, to informal conventions and customs regarding allocations and use of property. Such institutions critically affect decision-making regarding resource use (Libecap 1989). These various issues emerge from certain characteristics of some wetlands such as its multiple uses, indivisibility and seasonal alternations. It may be mentioned here that these unique features are not only a result of the specific ecological characteristics that make up wetland areas but also because of the fact that the historical, social and institutional contexts are interlinked and interact with these ecological aspects. All the three characteristics pose specific management problems. This is not only because most management strategies are built

around specific geographical boundaries, but also due to the externalities and conflicts that arise out of multiple activities undertaken on wetlands and the changing property rights owing to seasonal alterations. When non-fixed resources move in and out of geographical boundaries, the issue of property rights relating to wetlands gets problematic. For example, an activity in one territory, which affects the supply of fugitive resources like fish in other areas, can create serious management problems. Often there is a lack of appreciation of the value of wetlands shown by the local people and it has been argued that the effect of ignoring the role of local resource users is particularly acute in the case of tropical wetlands which tend to be heavily utilised by subsistence users (Adger and Luttrell 2000).

2.3. Wetland studies in India

Wetlands studies are gaining considerable importance in India. For example, in one of the earlier studies, Patnaik (1992) attempted an economic assessment of Chilika lake, a Ramsar site where the benefits of the lake as functions, uses and attributes and highlights the importance of Chilika lake to the Orissa economy and to the society. It is pointed out that the lake's function as an outlet for the floodwaters of Mahanadi River, its use as a source of brackish water fisheries and its attributes making it a tourist spot are to be seen from the macroeconomic perspective. The study by Kadekodi *et al* (2000) points out that Chilika lake is also subjected to a multiplicity of pressures and impacts ranging from local to global in geographical scales. Given this situation, the author examines the socio-economic root causes of biodiversity changes in the Chilika lake. A conceptual model, which incorporates socio-economic entities, ecological dimensions and characteristics, is developed to study the socio-economic root causes of biodiversity changes in Chilika lake. One of the notable findings of the study is that the root causes of ecological changes of this wetland lie outside the ecological factors and in order of importance are population dynamics, globalisation and aquacultural technology. An important aspect that has not been dealt in this study is about the property rights, or the drawbacks in the present use and management of the Lake that has lead to the present state of affairs. However, the study highlights the need to delve into non-ecological factors also to understand the causes of wetland degradation so that viable solutions can be arrived at.

Another important study is by Chopra (1997) on the Keoladeo National Park where the author attempts an economic valuation of biodiversity in the Park using travel cost method and multi-criteria analysis. The Keoladeo National Park which is human made is one of the few surviving typical floodplain wetland systems found in the region with the characteristic annual floods and hot summers. The local people living in the village collect various products from the wetland and are important stakeholders of the Park as

the tourist. To determine the value of tourism, data have been collected from 68 Indians and 43 foreigners. The consumer's surplus estimate from the travel cost method is about Rs 18689.09 per visit for Indians and Rs 11,027.32 for foreigners. Because of the joint product nature of the services provided by the park the author also estimates the consumer surplus from local cost estimates which is about Rs 427.04 per visit by Indians and Rs 432 per visits by foreigners. The study concludes that the demand for Keoladeo National Park tourism services is insensitive to price. The study also highlights the differences in the value attached by different stakeholders of the wetland. The scores obtained from multi-criteria analysis indicate that stakeholders other than tourists value livelihood and ecological functions of the park highly.

Similarly, Verma (2001) examines the economic value of Bhoj wetlands. The study uses an ecosystem modelling approach using STELLA software and argues for the need to recognize the inter-linkages and benefits that could be obtained if the wetland is managed in an 'integrated manner' and is 'sustainably used'. It further argues that it is a very challenging task and requires actions at many levels and delicate integrity of diversity of issues and management institutions. It is also argued that such an approach must begin with involving all stakeholders in the wetland in the form of a local area institution that shall be helpful in eliciting their views for use and future management of the Bhoj Wetland.

In a study on the Cochin backwater, which is a part of the Vembanad Kole ecosystem Jeena (2002) observes that both area and depth of the backwater which provides various goods and services has been reduced over the year due to human interventions. While 63 per cent of the total area of the backwater has been reclaimed for agriculture, prawn farming, industrial and related purposes since 1834, in the course of fifty years the average depth of the ecosystem, has been reduced from 6.7 metres to 4.4. metres due to siltation. The study shows that the reduction in the area and depth of the backwater and pollution impacts the marine harvest of penaied prawns a specie which migrate between the backwater and deep sea during their life cycle from Kerala coast negatively with a lag of one year.

Another study by Chopra *et al* (2009) examines the growth of aquaculture farming, largely driven by export demand, in the Sunderbans and its impact on the ecosystem, biodiversity, land use change, and human well-being by setting up biodiversity indices for three representative sites for a ten year period. The authors integrate these indices into a cost function for aquaculture farming and examines the impact of the 'ecological crop loss' caused by increasing prawn seed collection from the wild on costs of the aquaculturist. The study points out that land intensive aquaculture is indicated if biodiversity loss is to be averted.

In one of the recent studies, Das (2009) estimates the storm protection benefits due to mangroves during the super cyclone of 1999 in Orissa. According to the study, the percentage of fully collapsed houses in the Kendrapada district of Orissa, would have increased by 23 per cent without the benefit of mangrove protection. It also points out that had the mangrove cover remained at the level that it had been in the 1950s, the area would not have suffered any fully collapsed houses at all. The study combined GIS data with census information to account for the storm protection benefits of mangroves. On the whole, various studies have attempted to value the various goods and services provided by the wetland ecosystems in India.

2.4. Conclusion

In this chapter, we have made an attempt to understand the characteristic features of wetland ecosystems besides identifying their various economic and ecological linkages. Some of the major institutional issues concerning the use and management of wetlands also have been highlighted. Select case studies on wetlands in India were also presented in this chapter. An account of the ecosystem characteristics brings out the interconnectedness of various ecosystem services in addition to the importance of conserving wetland resources. It is widely seen that the provisioning services of wetlands are often over exploited at the cost of regulating, cultural and supportive services. This in turn raises issues related to the sustainability of provisioning services. As pointed by CA (2007), a key challenge to wetland conservation and rehabilitation which is focused on regulating services is the need to appreciate the wider socio-economic importance of wetland resources for provisioning services, particularly through wetland agriculture. In other words, it stresses the need for paying more attention to how ecosystem services can contribute to sustainable agriculture and how agriculture practices should recognise the significance of contributing to balanced ecosystem functioning.

Chapter 3
Land Use Changes in the Kole Wetland

3.1. Introduction

This chapter presents the results of analysis of land use changes that have taken place in the Kole wetlands over the years using data based on satellite imageries. As pointed out earlier, the Kole wetland cover the area below mean sea level and, therefore, include the reclaimed lands which are put to various land uses and not just the present rice fields. Notwithstanding the various limitations owing largely to the paucity of comparable as well as quantitative data for assessing the magnitude of changes, the analysis has been carried out. Even though it is widely believed that the Kole rice fields have been shrinking over time reliable estimates are not available for assessing the extent of it. Recently, the government of Kerala has enacted an Act aimed at the Conservation of Paddy fields and other wetlands. The analysis has been carried out with a view to providing baseline information on which assessments for the future can also be made.

3.2. Land use changes in the Kole wetland

As mentioned earlier, land use/land cover analysis has been carried out in the Kole land between 1981 and 2007 using Remote Sensing and Geographical Information Systems based data for determining discernible changes that have taken place over the said periods. Indian Remote Sensing Satellite images for the years 1989, 1997, and 2007[9] have been acquired through National Remote Sensing Centre (NRSC), while for the year 1981 we have used Survey of India (SOI) toposheets of 1:50,000 scale for land use assessment. These data sets have been geo referenced using control points collected through field surveys and brought into geographic co-ordinate system with WGS 84 datum[10]. ArcMap 9.3 has been used for displaying, processing and enhancement of the image and for carving out the Kole lands extent from the whole imagery.

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[9] Images taken during November and December have been used.

[10] The processing of satellite imageries has been carried out by SBL, Cochin.

Table 3.1 Kole wetland use (area in sq.km) over different years

Year	1981 (area)	%	1989 (area)	%	1997 (area)	%	2007 (area)	%
Northern Kole								
Built up land	1.08	0.69	1.72	1.10	1.99	1.27	2.06	1.31
Mixed crop	73.48	46.80	75.17	47.88	81.3	51.78	89.44	56.97
Rice	69.5	44.27	65.04	41.43	58.59	37.32	50.38	32.09
Water body	12.94	8.24	15.07	9.60	15.12	9.63	15.12	9.63
Total Northern Kole	**157**	**100**	**157**	**100**	**157**	**100**	**157**	**100**
Southern Kole								
Built up land	2.42	0.62	13.72	3.52	15.25	3.92	21.82	5.61
Mixed crop	192.24	49.39	201.95	51.88	213.98	54.97	210.58	54.10
Rice	181.63	46.66	160.78	41.31	145.23	37.31	135.85	34.90
Water body	12.64	3.25	12.48	3.21	12.39	3.18	12.31	3.16
Water logged					1.09	0.28	5.85	1.50
Waste land	0.32	0.08	0.32	0.08	1.31	0.34	2.84	0.73
Total Southern Kole	**389.25**	**100**	**389.25**	**100**	**389.25**	**100**	**389.25**	**100**
Kole (Total)								
Built up land	3.5	0.64	15.44	2.83	17.24	3.16	23.88	4.37
Mixed crop	265.72	48.64	277.12	50.73	295.28	54.06	300.02	54.92
Rice	251.13	45.97	225.82	41.34	203.82	37.31	186.23	34.09
Water body	25.58	4.68	27.55	5.04	27.51	5.04	27.43	5.02
Water logged	0	0.00	0	0.00	1.09	0.20	5.85	1.07
Waste land	0.32	0.08	0.32	0.08	1.31	0.24	2.84	0.52
Total Kole	**546.25**	**100**	**546.25**	**100**	**546.25**	**100**	**546.25**	**100**

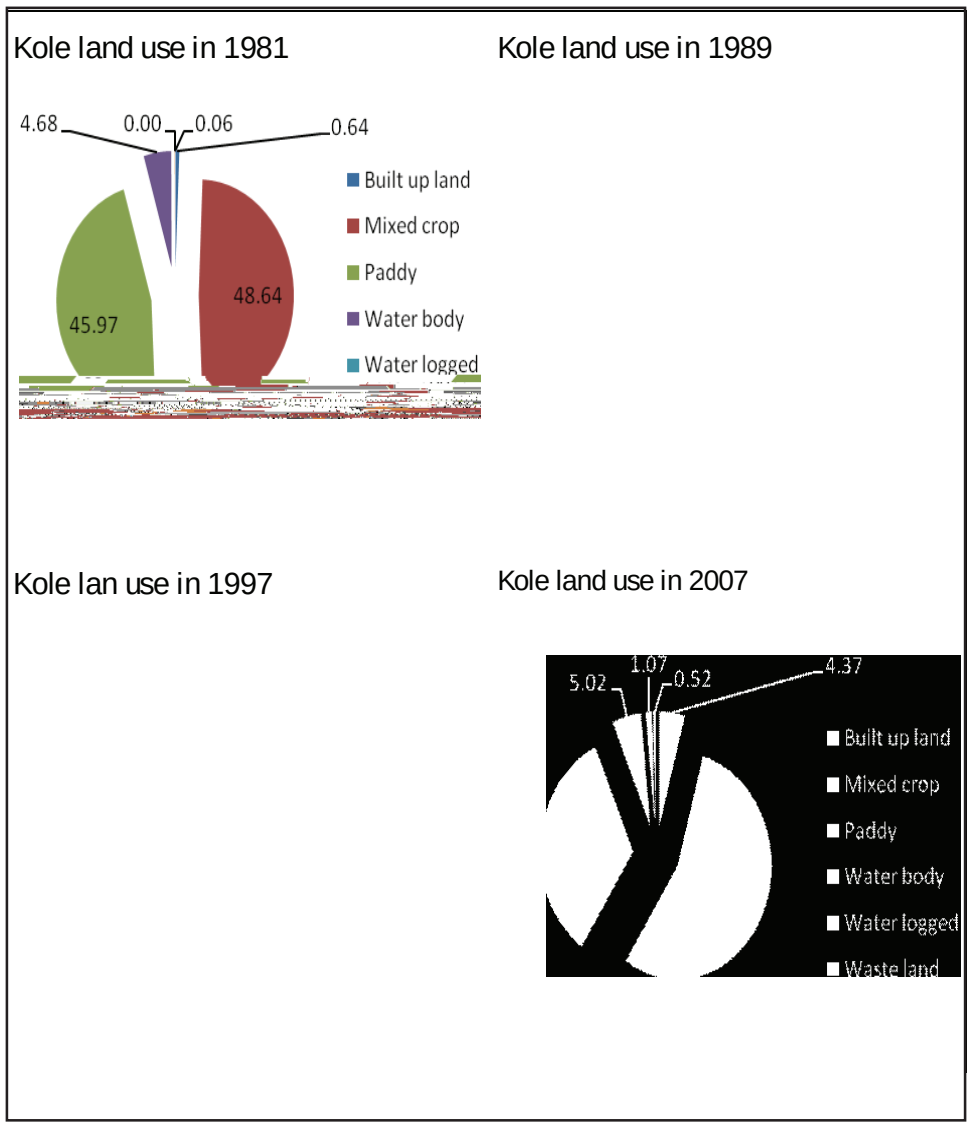
Source: Satellite imageries from NRSA for the years 1989, 1997 and 2007 and SOI toposheet for 1989
Note: Wastelands and waterlogged areas have not been observed in the Northern Kole

ERDAS imagine 9.1 have been used for the development of land use cover classes and for change detection analysis. As pointed in Chapter 1, the Kole area has been classified into mixed, crop, rice, built up land, water body, water logged and wasteland areas. The areas estimated under various land use categories are given in table 3.1. The total estimated area of Kole wetlands works out to 546.25 sq.km of which over 70 per cent (389.25 sq.km) is in the Southern Kole and the rest in Northern Kole (157 sq.km). In terms of percentage of area under various uses, it is found that mixed crops and rice are the major land use categories. In Northern as well as Southern Kole land, the area under mixed crops and rice has undergone considerable changes. In the southern Kole land, mostly in the Thrissur district, the area under rice steadily decreased from 181.63 sq.km in 1981,

to about 160.78 sq.km by 1989 and further to 135.85 sq.km by 2007 (Table 3.1). It may be noted that total area under rice in Kerala which was 8.76 lakh hectares in 1975-76 declined to 2.29 lakh hectares by 2007-08, a staggering 73.86 per cent decline over a span of about 32 years (Government of Kerala, 2009). When compared to the general trend in Kerala, the loss of rice land is comparatively low in the Kole lands largely due to the nature of the Kole lands submerged under water for almost six months in a year. In percentage terms, rice accounting for about 46.66 per cent of the total Kole area in 1981, consistently declined to about 35 per cent by 2007. A similar trend has been observed in the Northern Kole as well. While the area under rice land declined in both Southern and Northern Kole, the area under mixed crop showed a sharp and consistent increase from only 265.72 sq.km or 49 per cent in 1981 to about 300 sq.km or 55 per cent of the total area by 2007. The trends observed are similar across both Northern and Southern Kole lands. While in Northern Kole, no significant area under water logged or wasteland has been observed there exists wastelands in Southern Kole and water logged area since 1997 although their respective percentage shares in the total area still remain marginal. However, the emergence of this new category of land use is a source of major concern. The following figure 3.1 shows the percentage change in the area under various uses in the Kole wetlands.

Another important point observed is the increase in the area under built up land confirming that Kole land has been converted to non agricultural uses, especially house construction. This has largely occurred near Thrissur town reflecting the urban development pressures facing this wetland. Land use maps for various years are given in the Appendix 3A. The Southern Kole has recorded a considerable increase in the area under built up land as compared to the Northern Kole with major changes occurring during 1981-1989. This period also coincided with the construction boom in Kerala when most rice fields were being converted to non agricultural uses. In the Kole wetlands, given its peculiar wetland character, conversion as built up area took place wherever it was possible and economical. Based on maps, it is seen that most of the conversions took place in the North eastern side of the Southern Kole and South eastern side of the Northern Kole.

Figure 3.1. Kole land use over various years



Source: Satellite imageries from NRSA for the years 1989, 1997 and 2007 and SOI toposheet for 1981

We also have tried to examine the rates at which various land use changes have been taking place over the years. Compound growth rates estimated for various periods are given in table 3.2. It is seen that during the period 1981-89 considerable changes in land use took place in the Kole lands. During this period, the area under rice declined at a rate of 1.32 per cent per year across entire Kole lands and at 1.51per cent in the Southern

Figure 3A.2 Land use categories in the Southern Kole (1981)

Figure 3A.3 Land use categories in the Northern Kole (1989)

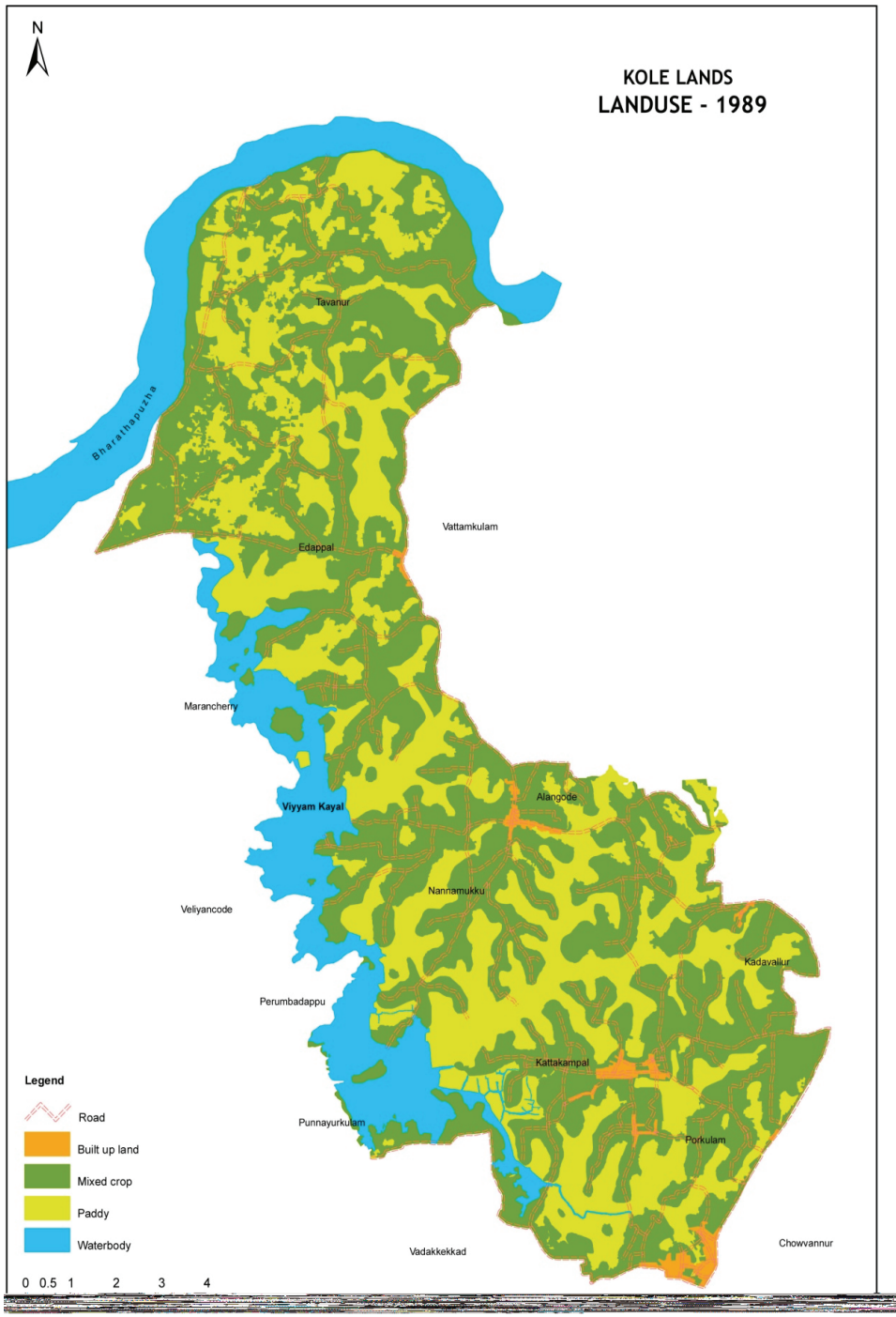


Figure 3A.4 Land use categories in the Southern Kole (1989)

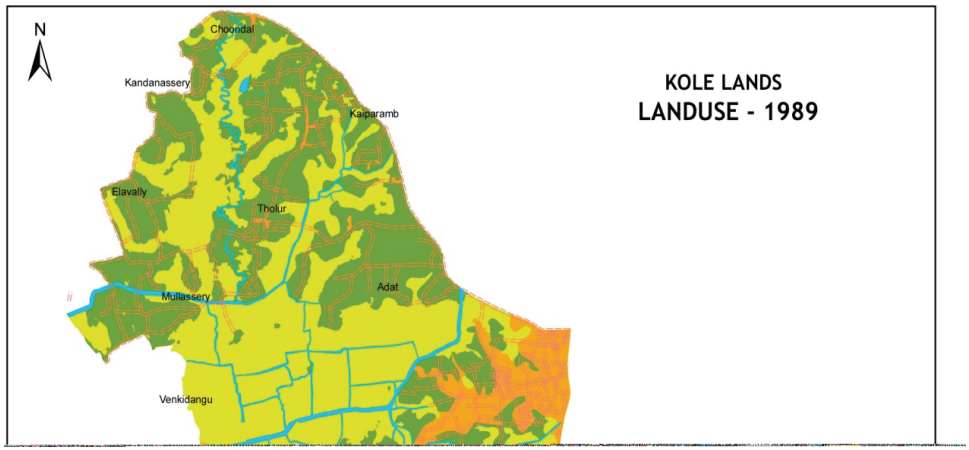


Figure 3A.5 Land use categories in the Northern Kole (1997)

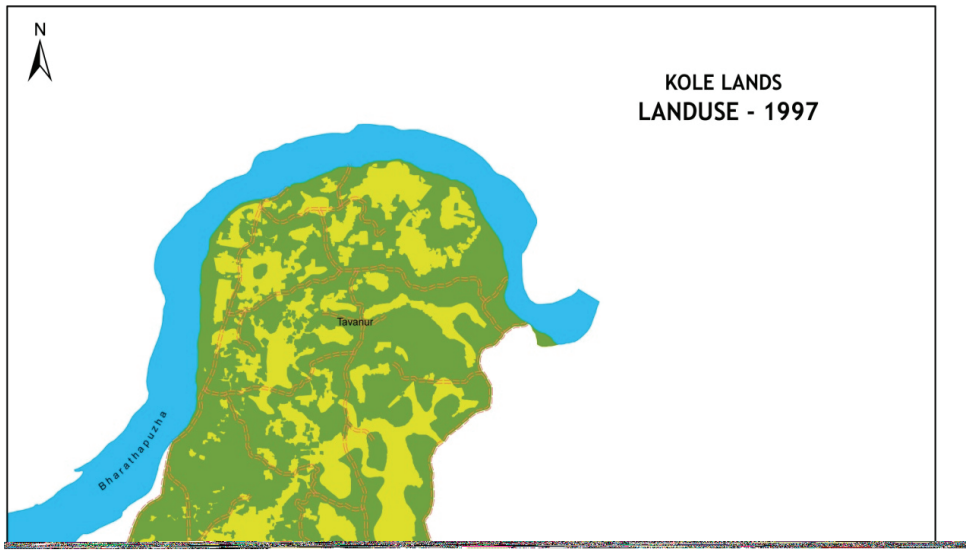
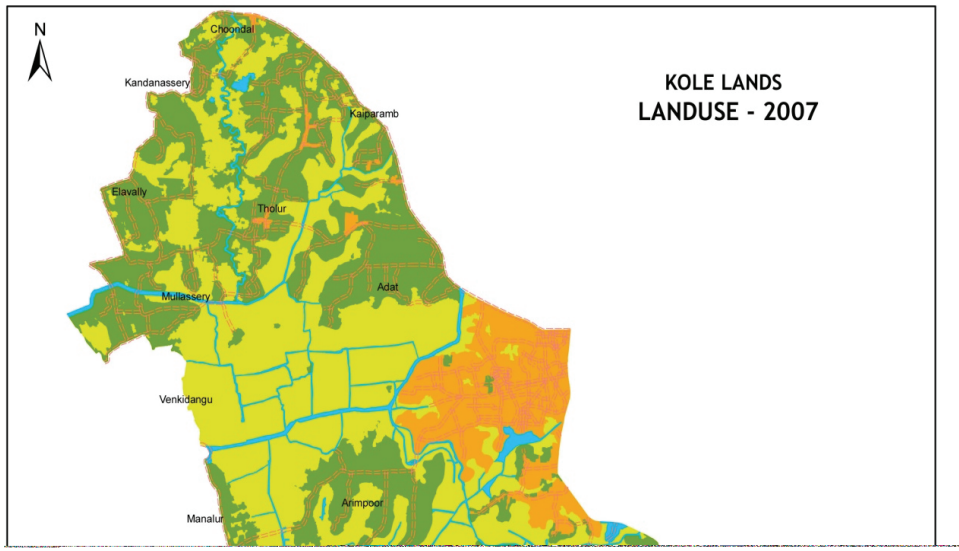


Figure 3A.6 Land use categories in the Southern Kole (1997)

Figure 3A.8 Land use categories in the Southern Kole (2007)



Chapter 4
Ecosystem Services and Agriculture-wetland interactions in the Kole Land

4.1 Introduction

This chapter provides important insights on the major ecosystem services provided by the Kole wetland and also discusses important agriculture wetland interactions. As already discussed in the previous chapter, each wetland is unique by itself and the relative importance of various services provided by each one of them also varies according to their structural characteristics. Exploring agriculture wetland interactions is important not only to understand and appreciate the challenges in balancing demands on the various ecosystem services provided by each wetland but also to adopt guidelines or policy measures to strike a balance in terms of the exploitation of various goods and services provided by it. Across the world, exploitation of provisioning services of wetlands in relation to other regulating and cultural services has been increasing. A better understanding of the key characteristic features of wetlands would help efficient management of wetlands by reducing the negative impacts associated with the increased exploitation of provisioning services or direct use of wetland resources. This is important to ensure the sustainability of production across wetland areas, which for local population, is dominated by agricultural production. Agricultural production, in the broadest sense includes not only crop production, but also fisheries, aquaculture, etc. Examining linkages and interactions between various ecosystem services or functions helps determine those uses or services which are mutually supportive or otherwise. This information is crucial for the sustainable development and management of wetland resources. While examining the above issues, perhaps greater importance is given to wetland-agriculture interactions, that is, Kole rice and agriculture related aspects.

4.2. Ecosystem services provided by the Kole wetland

Using the terminology of the ecosystem assessment, we have tried to classify some of the important functions and benefits of the Kole wetland. For this we use classification of ecosystem services provided by wetlands presented in Chapter 2.

a. Provisioning services

The Kole wetland provides multiple products and services only some of which are physically found on the wetland itself. Provisioning services are those tend to be associated

with the direct exploitation of wetland products for economic gain or subsistence. Due to water and terrestrial related properties of Kole land, various types of economic activities are undertaken supporting livelihoods of the local population either directly or indirectly. Since the Kole land is a seasonally inundated one, various ways and methods are found to be in existence to maximize the use of this area throughout the seasons that is both during the flood period and after it recedes. This includes fishing or fishing farming during flood period, agriculture in the rest of the season. Apart from these activities like mining etc are also undertaken.

Rice cultivation

Rice is the most important crop cultivated in the Kole land. It is said that rice cultivation in the region started about 300 years ago. In those days flood waters from the Karuvanoor river used to be discharged to sea at Enamakkal after flowing through Perumpuzha (District Plan, Thrissur undated). In earlier days only half of the wetland used to be cultivated while the other half left fallow and was rainfed. Later when cultivation was extended to entire Kole land irrigation became a major issue. Peechi and Mupli-Chimmony dams were constructed to meet the irrigation requirements.

The crop seasons in the Kole lands are as follows: *Virippu* is usually cultivated in higher rice fields around the Kole land where the duration of floods lasts only for a few days. Here sowing is carried out with the onset of monsoon and by the time flood water reaches the field, the crop will have been 30-40 days old. Varieties which can withstand floodwater for a few days are usually cultivated in *Virippu*. *Mundakan* is cultivated on medium elevation fields around the Kole land where flood water recede by August. *Kadumkrishi* in Kole land coincides with *Mundakan* across normal lands, but usually it starts by September. However, in order to undertake *Kadumkrishi*, the Kole land is protected by bunds. When flood waters in the Kole field start subsiding by the end of South west monsoon season, pumping out of water is carried out in 10 to 15 days. Dewatering is carried out using *petti and para* which is an indigenous device developed for dewatering the Kole field. After this, bunds around the fields or *padavu's* are raised and strengthened by means of locally available materials and laterite soils to a height of 1 to 1.5 m above the field level. Crop is directly sown or transplanted when water is around 10 to 15 cm deep. In *Kadumkrishi* water management is very important as it requires continuous pumping out of water and towards the end of the crop season there is a need for supplying irrigation water as well.

Table 4.1. Crop Seasons of Rice in the Kole land, Thrissur

	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
Virippu (at higher elevation field)												
Single crop *Kadumkrishi/ Mundakan*												
Single Crop *Puncha*												
Double Crop *Additional Crop, Puncha*												

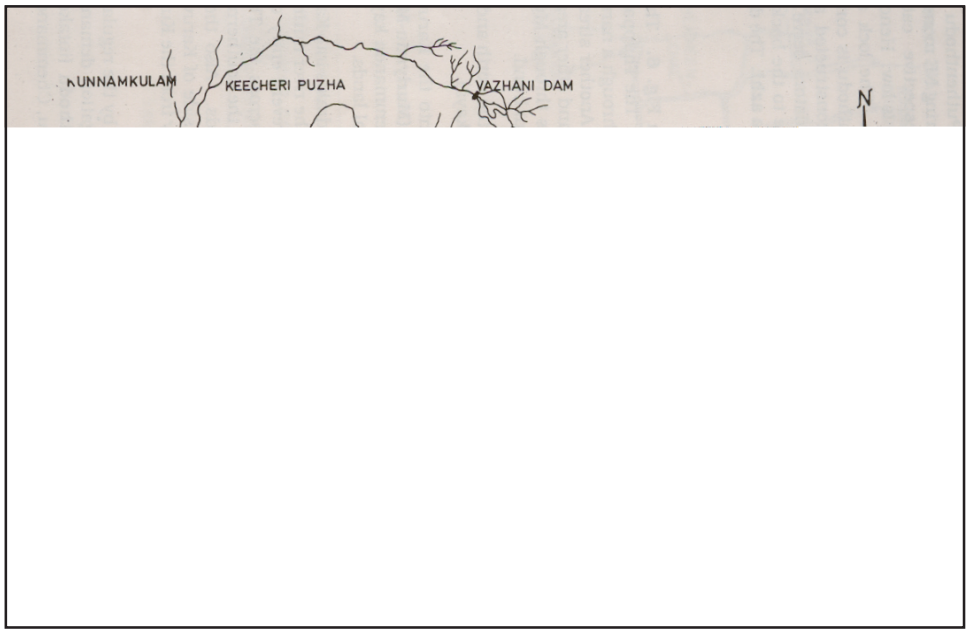
Source: Johnkutty and Venugopal (1993).

Punja is a crop raised across the entire Kole area. Wherever bunds have not been raised for *Kadumkrishi,* temporary earthern bunds are put up around groups of rice fields or P*adasekharams*[11] during December-January. Water requirements for *punja* in the early stages of crop are met with summer flow in the rivers and storage canals and in later stages, water from dams is used for irrigation. Since late 1980s, the North Kole is divided into three zones for *Punja* cultivation. Usually in the first and second zones, only *punja* is taken and in the third zone an additional crop or *kadumkrishi* is also raised.

A net work of main and cross canals provides external drainage besides connecting different regions of the Kole to the rivers. Below we present a brief overview of the river and canal systems of the Kole wetland which is very crucial for Kole agriculture.

[11]Padasekharams are institutional arrangements for carrying out rice cultivation. The size of individual holding in each Padasekharam ranges from 20 cents to 5 acres.

Figure 4.1: Kole lands in Thrissur: Kecheri and Karuvannur River Systems

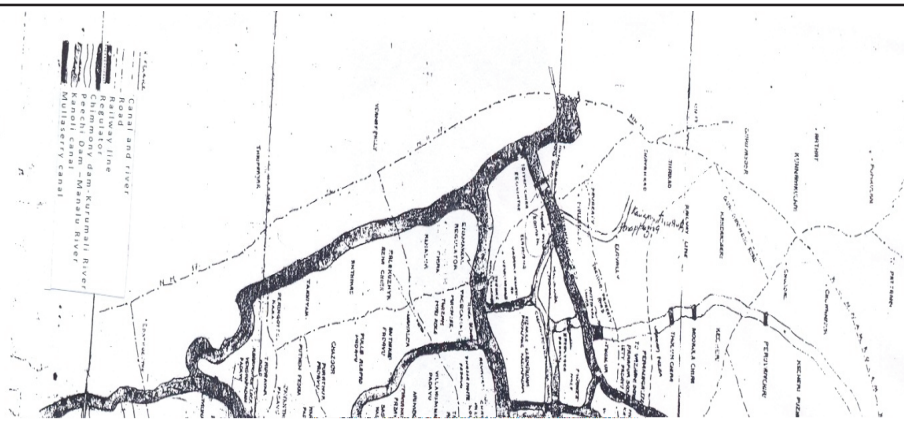


Source: Johnkutty and Venugopal (1993)

The Thrissur North Kole rice field is a stretch of low lying lands extending from the Karuvannur River in the south to Kaiparamba in the north. The Thrissur North Kole is divided into three basins, namely the north covering *Kechery*, *Peramangalam* and *Chemmen* basins, the central comprising *Puzhakkal Naduthodu, Chiyyaram* and *Kokkala* basins while the south consisting of *Puthenthodu, Herbert Canal* and *Chirakkal thoudu* basins[12] . The main exits for flood waters that enter the Kole fields are *Enamakkal* and *Idiyanchira* regulators. These regulators also serve as salt barriers and divert part of flood waters of northern Kole to the backwaters through *Kanoli* canal and subsequently to the sea through *Chettuva azhi*. On the other hand, the main discharge of water into the South Kole area is through *Thuppanthodu* which enters the Kole land from *Villichira* regulator. Another stream Nedumthodu enters this area draining *Thommana* and other areas of east and north-east of Irinjalakuda town. Panoli canal flows through north and north-west of *Irinjalakuda*, draining finally into the *Chemmanda kayal. Thamaravalayam* canal from the *Muriyadu* area drains into *Karuvannur* River during monsoon conveying irrigation water from the river to crops during crop periods.

[12] For details of Canal system in the Kole lands refer Johnkutty and Venugopal (1993).

Figure 4.2: Canal System in the Thrissur Kole



Source: KLDC

In order to tackle water management problems, zonal system of cultivation is practiced. Kole farms in the north of Karuvannur River are divided into 3 zones and that of south into two zones. Under this system, dewatering is carried out zone wise. Water pumped out from one zone is collected in other zones and used as irrigation water as and when required. Dates are specified in advance for starting and ending dewatering in each zone by the District Administration in consultation with *Padasekhara Committees* who carry out pumping operations. It may be recalled that Kole farms are divided into various *padasekharams* which are contiguous farms, often sharing same canal for irrigation water. The dates for starting dewatering and completing sowing operations in each zone are usually decided in a meeting with farmers and government officials from the concerned departments. The normal practice is to start dewatering by second week of November and complete sowing by first week of December in zone 1. Water pumped out of zone 1 will be collected in zone 2 which in turn is used as irrigation water for zone 1 and zone 3. Zone 3 would be under *mundakan* crop by then. The *mundakan* crop would have started by third week of September and lasts until end of December. Once the harvest is completed, by December end, water from Zone 2 is pumped out and stored in zone 3. Zone 3 would be under water for almost one month after which the fields will be prepared for *punja* crop. The water which is now pumped out of zone 3 would be stored in the Kole canals for summer irrigation. Co-operation and collective action by farmers are very important in this zonal system. In order to maintain water levels, the Enamakkal regulators, Munayam bund, Chirakkal thodu and Herbert canals are all closed on specified dates. Additional irrigation water requirements are met with Peechi and Chimony dams. The farmers consider the zonal system of cultivation as, the most practical and convenient way for undertaking cultivation in the Kole fields by managing flood water in an efficient manner. Electricity connection for dewatering will be given as per the dates decided in the meeting.

It is also recommended to use variety of seeds with same duration of maturity in each zone to facilitate zonal system of cultivation. A few decades back, a number of local varieties of rice used to be cultivated on the Kole fields. Over the last few decades, *Jyothi, Uma* and *Jaya* varieties of rice have come to be cultivated. Farmers prefer 'Jyothi' because it fetches better price and is relatively better in taste. Although according to farmers, the productivity of 'uma' is slightly higher than that of 'jyothi' taste wise it is not as good as *Jyothi*. For almost 20 years 'Jyothi' is cultivated across the Kole land. Earlier seeds used to be prepared by farmers themselves, however, now they are supplied by the National Seeds Corporation or State Seed Development Authority or the Karnataka Seeds Corporation (mainly Uma). Farmers are given various types of subsidies for carrying on rice cultivation on the Kole fields. This includes subsidies for dewatering, purchase of

seeds, fertilisers, and pesticides. Harvested rice is procured through Civil Supplies Corporation.

Fish farming

Fish farming is yet another provisioning service provided by the Kole wetland which provides direct as well as indirect livelihood option to several people. In some of the Kole farms, rice and fish are cultivated alternatively. In earlier times, only natural fishing used to be practised and that too by a community called *Padanna*. *Bral, Karimeen, Mundathi, Kolaan, Mushi, Koori, Aral, Kadu, Vala, pallathy, paral, Potta, Cheekkori, Kalluthy, Kadu, Malinjeen, chelli* are some of the important local fish species found across the Kole lands. Fishing in the Kole farms used to be a localised economic activity with a substantial nutritional dependence on this resource as fish are a crucial source of protein. However, it is now more of a commercialised activity and is cultivated after rice harvest when the fields are flooded. The fish lings are grown in ponds until the rice harvest is completed while fish are harvested at least 10 days before the agricultural operations for rice cultivation starts. In Kole fields where one rice crop and fish are cultivated, sowing will be completed by October 15. The varieties of rice cultivated are most often 'Jyothi' (120 days) or 'Uma' (130 to 140 days). Almost 15 days after harvest, water will be pumped in for fish farming. For removing the negative effects of fertilisers and pesticides used for fish farming. Fish farming is usually carried out from March to September. The farms are leased out for about 3 years for fish farming. Katla, Rohu, Prawn are the major varieties cultured. It is reported that fish lings are mostly imported from Andhra Pradesh while fish harvesting is carried out with the help of labourers from Tamil Nadu.

Mining

Unlike, agriculture and fishing, mining is a non agricultural activity which has become highly controversial. It is found that the year 1976-77 marked the beginning of clay mining in the Kole land because of the presence of deposits of clay and sand. In some places, it started off as some individuals' own business activity, mostly as a source of raw material to their own tile industry. However, mining soon emerged as a major non agricultural activity in the Kole land. Once clay and sand are mined out the land virtually becomes unfit for cultivation. It is said that for taking up clay mining in the area, permission from RDO, geology department, Village officer, Tahasildar, two members of Padasekhara committee is required. In addition to this, permission from Kole Development Agency is also required. Usually after obtaining permission from them agents buy land usually at the centre of the Kole farm at a comparatively higher price from farmers. As per law, after removing top soil and mining clay, the remaining pit has to be covered using the same top soil. However, in reality both top soils and the clay

beneath it are mined. This not only obstructs water flow but also leads to soil erosion in the nearby places resulting in pollution of wells in the neighbourhood. As a result, surrounding areas also become unsuitable for cultivation. Abandoned pits of about 7 meters are found in several parts of *Muriyad* (Refer maps given in Chapter 3). The use of diesel engines for sand mining has become widespread with vast tracts of the Kole land becoming unsuitable for cultivation within a short period. Although mining is banned now, it is reported that at least in some parts it is being carried out illegally.

Other provisioning services

The Kole land is also used for other uses besides rice cultivation, such as duck rearing, lotus farming, livestock grazing, agro biodiversity, collection of medicinal plants and other herbs etc.

b. Regulatory services

Wetlands are generally considered as carbon sink and Kole wetland is no exception. Although the extent to which Kole land actively mitigate carbon dioxide emissions is not researched, it is known that destruction of wetlands results in the release of carbon into the atmosphere. The Kole land provides important hydrological services. It is reported that about 233.74 mm^3 water is contained in the Kole land which is in fact more than what is stored in the Chimmony and Peechi dams for irrigation for summer crop in the Kole land (District Plan Thrissur, Undated). It also plays an important role in water table recharge and discharge. The water levels in the nearby well are largely dependent upon the Kole land. Besides it acts as a water purifier. Research on the ability of wetlands to purify water has shown that anaerobi conditions, which exist within wetlands, enhance the retention of many compounds and facilitate processes such as denitrification, ammonification and the formation of insoluble phosphorous-metal complexes.

c. Supporting services

As noted earlier, these services refer to the key processes or factors necessary for maintaining the ecosystem services provided by wetlands. They include the major environmental cycles involved with hydrology, nutrient flows and soil formation (FAO, 2008). The Kole wetland is a flood plain area and soil formation and sediment trapping are very important.

d. Cultural services

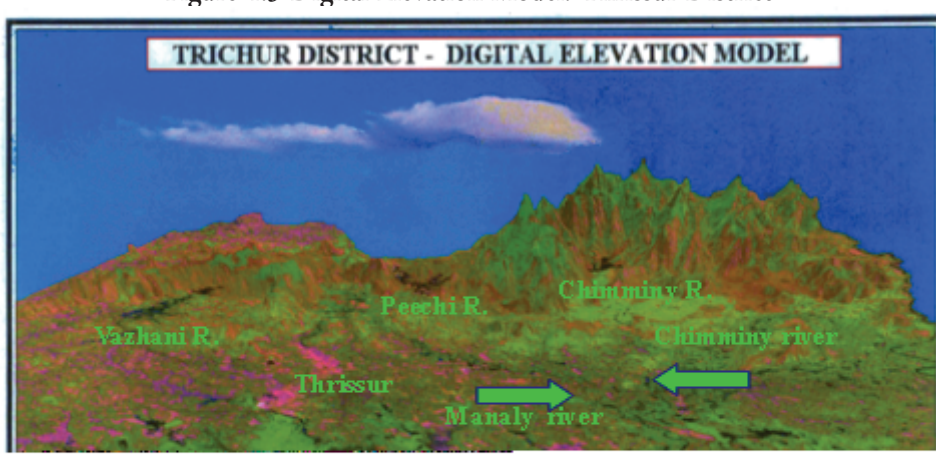
The water body and network of canals is important for water transport and tourism activities. The Kole wetland is an important Ramsar site for migratory birds and tourism can be promoted as an important activity. It in fact supports a large number of birds

which are endangered. Besides it also provides opportunities for research and educational activities. It is also said that major cultural activities in Thrissur are associated with harvest of rice in the Kole farms.

4.3. Agriculture and wetland interactions in the Kole land: some observations

In examining the relationship between wetlands and agriculture a distinction is usually made between in situ interactions and external interactions. By in situ we mean where there is direct agricultural intervention within wetlands and external interactions where the effects of external (upstream, downstream or peripheral) agricultural activities affect the wetland and its ecosystem services (FAO, 2008). The digital elevation model of Menon (undated) helps to locate the kind of *in situ* or external interactions in the Kole lands. However, no attempt has been made to quantify the interactions because of the lack of availability of adequate data.

Figure 4.3 Digital Elevation Model: Thrissur District



Source: Menon, RRR (undated), KFRI, Thrissur

In situ agricultural interactions can be characterised in terms of either full or partial transformation of the wetland from flooded form to agricultural use. This transformation is likely to alter the regulating services of the wetland. The transformation of the wetland involve various processes and practices that creates pressures on the wetland ecosystem such as dewatering, construction of bunds, application of lime to correct the pH of the soil, application of weedicides, pesticides and fertilisers. However, it is to be noted that the cultivation of rice does not transform the wetland environment, but the agricultural practices adopted can have implications on the regulatory and other services provided by the wetland. Similarly, activities like fishing is expected to have no or minimal transformation of the wetland environment. However, fishing farming practices, including pollution of fish farms due to waste discharge and excessive use of chemicals can affect the services of the wetland. If one have a closer look into the traditional practice of alternative rice and fishing in the Kole land, one can understand that the uses have been adapted to suit the natural wetland environment and manipulated in such a way to make best use of the Kole land. The traditional practice of construction of bunds using locally available materials ensured that the wetland water flows and ecohydrology was restored after each agricultural season during the flood season. However, it is generally observed that construction of permanent bunds to minimize economic losses incurred during cultivation and to facilitate cultivation disturbed this natural cycle. Since the free flow of water is disturbed faster weed growth is reported in many places. On the other hand, there is a more straightforward case for the transformation of wetland ecohydrology in the case of non agricultural activities like mining.

As pointed out, external interactions are those between the wetland ecosystem and agricultural/ other activities that are external to the wetland itself. It is seen from the digital elevation model that the upstream areas are forested mountainous regions where some of the dams are constructed for irrigation in the Kole land. While construction of dams on the one hand supplied irrigation water, it seems to the inflow of water into the rivers downstream. While the Kole wetland is still a high fertile area, farmers are of the opinion that the quality of soil is getting deteriorated. A considerable extent of silt is getting deposited in the canals leading to water logging, weed growth and overall affecting the health of the soil. Some of the important crops cultivated in the peripheral areas are coconut, arecanut, nut mug, tapioca, banana, etc. There seems to be an extension of these crops into the Kole wetland as is evident from the land use change analysis. This not only resulted in the reduction in the area of the wetland, though difficult to measure quantitatively, but can have an effect on water table and accommodation of runoff.

One of the major downstream activities which have impact on the Kole wetland is that of water regulation through regulators aimed at controlling intrusion of sea water.

Downstream activities, including increase in irrigation and domestic requirement of water may result in the alteration of hydraulic gradient and result in more rapid release of water from the wetland and lowering of water table. This results in the increased threat of sea water intrusion. The above discussed interactions can have socio economic implications apart from environmental impacts which are difficult to measure quantitatively.

The DPSIRs

A major challenge in wetland use and management is to pursue a more equitable balance in the use of wetland ecosystem services. While wetlands may be used more for provisioning services, it needs to be remembered that a certain level of support and regulating services are critical for the maintenance of provisioning services. Therefore, addressing the issue of trade-offs between different ecosystem services in order to meet the needs of different stakeholders assume centre stage in wetlands management. Here we use Driver Pressure State Impact Response Framework to analyse the situation in Kole wetland. Since operationalising this framework in the case of the Kole wetland is challenging, the attempt we make here is to largely describe them qualitatively and to the extent possible with the available data and information quantitatively. Recalling DPSIRs defined in FAO (2008) it may be stated that, drivers are any natural or human induced factors that lead directly or indirectly to a change in the wetland ecosystem or in socio economic processes that influence wetlands and the agriculture wetland interactions. This can include government policies, population dynamics, market etc. These may be seen as some of the causes that influence ecosystem processes. Pressures, on the other are how drivers manifest themselves on wetlands and wetland related societies through processes related to transformation of wetlands or the disturbances of their ecological state. An example is agricultural intensification. State changes are defined in terms of changes in biophysical process both in quantity and quality that determine the ecological character of the ecosystem. These are by and large the regulating and supporting services. Impacts are the socio economic results that come from changes in the state of the environment. For example, changes in livelihood options, emergence of new stakeholders and conflicts, etc. Finally, responses are actions in response to drivers, pressures, state changes and impacts, and vary from technical, institutional or policy related.

Drivers

Some of the important drivers identified are related to population dynamics and government policies related to agriculture and food production. Population has been growing steadily during the last few decades as a result of natural growth as well as in-migration from other parts of Kerala though the rate of increase has slowed down now.

The population growth has had led to increased pressures on land resources for food production and housing requirements. This led to conversion of Kole land to other uses and also a reduction in food production. As per the Thrissur District Plan (undated), the annual per capita production of rice which was 76.75 kilograms in 1970-71 in Thrissur district declined to 30.32 kilogram by 1997-98 and further down to 29.34 by 2002-03.

While on the one hand population growth and the demand for land to meet urban development requirements resulted in conversion of the Kole land, on the other hand, the focus on food self sufficiency in the post independent India resulted in the adoption of policies for agriculture intensification. The state policies have given more emphasis on the modernization of rice cultivation leading to interventions in the wetland ecosystem right from the creation of irrigation infrastructure to intensification of inputs. In addition to the creation of infrastructural facilities, agricultural intensification has been encouraged through various subsidies. Adoption of 'green revolution' technologies had, to a large extent, transformed it into an ecosystem affected by various human interventions. In a nut shell, the national priority of food self sufficiency has led to the focus on the exploitation of a single provisioning service-agriculture. For example, an improvement in the Kole cultivation was achieved by storing part of the pumped out water in the adjacent high lying lands where no crop could be taken up. Also with the commissioning of the Peechi reservoir and the Chimmony dam efforts were made to stabilise Kole cultivation and to bring the entire area under Punja crop. In fact, mechanisation of cultivation started in the Kole lands since 1960. Around this time, spread of improved varieties of seeds also began to take place. This was a beginning of agricultural intensification in the area and even now intensified use and often indiscriminate and excessive use of agricultural inputs is found in the Kole land. Indiscriminate and excessive use of pesticides adversely affecting the ecological sustainability is also practiced in the study area. Moreover, a shift from subsistence to market oriented cultivation meant negligible concerns by the farmers for food safety and an intensified use of chemical inputs even if at the cost of ecological sustainability. Improved markets also led to intensification of other activities undertaken in the Kole land. For example, natural capture fishery undertaken when the Kole land were in an inundated state gave way to fish farms and culture fisheries and resulted in increased use of inputs.

Another important driver was the enactment of Land Reforms Act in 1964 which while giving ownership rights to the farmers, also imposed a ceiling on individual holdings. This led to subdivision and fragmentation of holdings and given the nature of Kole farming, the holding size became uneconomical for cultivation. In the subsequent periods demand for land for non agricultural uses also increased opening up markets for Kole

land. Increased construction activities since early 1980s also led to the conversion of Kole land in a relatively higher elevation places, as housing sites. Non-agricultural activities like mining can also be considered as an off shoot of the construction boom that largely took place as a result of migration to Gulf countries.

Pressures

Some of the important pressures that result from the drivers discussed above mostly influence the Kole wetland ecosystem and its transformation. We group the pressures due to agricultural intensification and those due to demand for land for non agricultural uses. Apart from the intensified use of agricultural inputs, efforts were also made to facilitate double cropping in the Kole land through various types of engineering interventions aimed at improved drainage and water management. In addition to this, other infrastructural developments have been carried out by Kerala Land Development Corporation and Kole Development Agency in the Kole land like construction of canal, bunds and roads. This has sometimes altered the ecology of the Kole wetlands in some places. Intensified rice production along with intensified fishery activities also exerts pressure on the wetland. In earlier times, rice and fish farming were carried out in alternative seasons and were considered as mutually beneficial activities. But of late, it has been pointed out that they are not very mutually supportive activities because of the negative externalities generated by them. In order to carry out agricultural activity, the wetland undergoes a complete or partial transformation from its flooded state when natural fishing or even aquaculture is carried out. The wetland undergoes pressures in terms of drainage activities, application of fertilisers and pesticides etc. While crop residues are considered as feed for fish, the chemical contaminants originating from crop cultivation prove harmful to the fish stock.

While construction of road facilitated movement of agricultural inputs and outputs, it facilitated conversion of Kole to non agricultural uses like mining. Mining activities not only resulted in the transformation of the wetland, but also exerted increased pressure on agricultural activities. Similarly, increase in the built up area and area under mixed cropping due to land filling also has resulted in the progressive reductions of the flood retention capacity of the wetland. Going by the current status and trends in land use, flood risks become a prominent pressure on this wetland. Other interventions for intensifying cultivation of rice or aquaculture have often altered the flow of water across the Kole land creating ecological and socio-economic pressures. These infrastructure developments together with intensified input use in agriculture also alter water quality parameters and also modify aquatic habitats adversely affecting the various ecosystem services provided by the wetland.

State

Diverse and multiple state changes or the changes in the ecosystem services are also found in the Kole land. As pointed out earlier, state changes can be described in terms of biophysical processes that determine the ecological character of the ecosystem and / or the natural resource base. Changes in the quantity and quality of soil, water etc is included here. Acidification of soil, decline in the quality of soil due to unscientific and increased use of chemical fertilisers and pesticides have been reported from Kole land. Moreover, water logging, siltation, presence of water hyacinth etc, adversely affecting water flow, are some of the common problems. These may directly impinge upon the ecological character of the ecosystem. There is an increasing trend of Kole land tracts lying as fallow lands. This is due to a host of factors like high wage rates and non availability of labour, low price of rice, difficulty in using mechanised farming on some fields. Loss of biodiversity which can undermine the ecological character and resilience of the ecosystem, is a common trade off associated with intensification of agricultural activities. A decrease in farmer friendly micro organisms and other birds and reptiles is reported from the Kole land. It is reported that frogs, snakes and owls which used to destroy crop damaging organisms have almost disappeared from the Kole land. Increased mining activities have not only rendered the mined lands unsuitable for any agricultural activity but also have led to the creation of fallow lands of nearby lands.

Impacts

As noted earlier, impacts are the socio-economic results of changes in the state of the wetland environment. The impacts of the state of the ecosystem are highly diverse and vary across different types of uses. The challenge is to identify the multiple stakeholders and the type of impact on each of them. While some stakeholders appear to have gained at least in the short run due to changes effected to ecosystem, it is a loss for other primary stakeholders. In other words, exploitation of specific ecosystem services often lead to changes in the benefits reaped by other stakeholders from other ecosystem services. For example, intensified agricultural activities undertaken by rice farmers adversely affect the communities dependent on fishery resources. Also, the crop duration makes alternative farming economically unviable. For example, if a farmer waits for the fish stock to grow to full size so as to fetch a better price, rains would in the meanwhile, damage the rice crop resulting in huge economic losses for the farmer. On the other hand, if the fish stock is harvested before full maturity in order to accommodate rice cultivation, then fish farmer might end up with huge looses. Thus, there is a clear trade off. Here there is an added complexity in that as farms are leased out for fish farming after rice harvest, the farmer has to wait until the end of the contract period for initiating rice cultivation. While livelihood based on one activity benefits, the other one suffers. Further such tradeoffs can create conflicts between different interest groups.Moreover, fisheries as an

activity also has changed from subsistence oriented one to commercial and contract based one. In this case, it is the livelihood of traditional fishing communities that gets affected. This represents an overall trade off in economic benefits and livelihoods rather than transformation of livelihoods themselves that is, traditional fishing communities themselves becoming commercial fish farmers.

Mining backed by a thriving construction industry provided livelihood options to many during the late 70s and 80s. However, it was not sustained as a major source of livelihood. Nevertheless, it impacted in the form of a growing competition for land resources for accumulating wealth from mining activities. This effectively gave rise to competition for land resources for accumulating wealth from mining activities and conflicts with other resource users. In some cases, this competition and conflicts stemmed from intensification and expansion in one or both of the activities and increased claims over the available resource. The competition and the resultant conflicts can be considered as a direct trade-off of realized gains in the context of provisioning services. In effect, there occurred a shift or transfer of economic benefits, mainly between agricultural and mining (industry) sectors, and individual stakeholders. However, given the data limitations, it is difficult to assess the extent of shifts in economic benefits across sectors and stakeholders. However, the emergence of diverse interest groups with varying degrees of political power has been observed. The pits that remained after mining of clay and sand were not suitable for cultivation, resulting in water stagnation, and even pollution in the surrounding wells used for drawing water for drinking and other domestic uses.

Responses

The responses to various drivers, pressures, state changes and impacts though multiple, are by and large, focussed on wetland agriculture. These include responses in the early time period and to the most recent. Among the responses in the early time period include, the formation of *Padasekhara Samithis* which was a spontaneous response for carrying out farming in the Kole land subsequent to the enactment of the land reforms Act. As certain agricultural operations like dewatering of the Kole land cannot be carried out individually, the role of *Padasekharam's and Padasekhara* committees assume importance. A collection of contiguous rice fields is called a '*padasekharam*' or '*padavu*'. The land owners organise themselves into groups to form a padasekhara committee in a democratic way under section 7 A of the Kerala Land Development Act, 1964, and registered under the Societies Act. *Padasekhara* committee carries out dewatering and related activities collectively the cost of which is shared by the individual farmers according to their size of holdings. The decisions on when to start dewatering and agricultural operations are taken by the *Padasekhara* committees in consultation with individual farmers and in some places also with the representatives of co-operative banks which

advance loans for common agricultural operations like dewatering, bunding, cleaning of canals etc. However, there exists heterogeneity in the practices across *Padasekharams*. The District Administration, in consultation with the *Padasekhara samithis* prepares guidelines for carrying out various farming activities with a particular focus on water management issues.

The important responses from the state are in the form of various infrastructural facilities and financial support by way of various subsidies for carrying out cultivation in the Kole farms. To solve the problems of irrigation the Peechi Irrigation System was commissioned in 1958 and this together with the Enamakkal and Kottenkottuvalavu regulator and Karanchira lock controlled the water level in the Kole canals. Based on the Vasudev Committee Report of 1969, the construction of permanent bunds and widening of Kole canals to prevent Kole land from getting water logged were undertaken by the Kerala Land Development Corporation. Later Chimoni-Mupli Kole project was also commissioned to solve the irrigation water problem in the summer.

Punja Special Office was set up as per the Kerala Irrigation Works (Execution of Joint Labour) Act 1967 in order to look after pumping in and out of water from Kole fields for facilitating cultivation. As different agencies engaged in the development of Kole land had been acting rather independently, the Kole Land Development Agency was set up in 1992 for the overall development of the Kole areas by coordinating activities of different government departments and agencies. Setting up of this agency with a primary objective to raise production and productivity of the Kole land was an important response by the state government. However, the wetlands perspective was not given much emphasis in the activities of Kole Land Development Agency. The major activities of the agency included improvement of the infrastructural facilities like the construction of permanent bunds, canals, providing engine sheds, irrigation and dewatering equipments like petty and para, construction of regulators, farm roads, etc.

Among the recent responses include the enactment of Kerala Conservation of Paddy Land and Wetland Act, 2008, which envisages to conserve the paddy land and wetland and to restrict the conversion or reclamations thereof, in order to promote growth in the agricultural sector and to sustain the ecological system, in the State of Kerala. Mining activities are also recently banned in the Kole land and there are also efforts to bring the lands that became unfit for cultivation back to cultivation. The inclusion of Kole as a Ramsar site is the most important recent response towards the conservation of Kole land at the national and international levels. With the inclusion of Kole lands as a Ramsar site, efforts are on to initiate a comprehensive conservation programme. Besides these, the tourism potential of the Kole lands as a Ramsar site is also under consideration.

Also, there is an increased awareness among some of the farmers regarding the harmful effects of the indiscriminate use of pesticides and chemicals on food and soil. There is a move towards organic farming in some places. One of the reasons for Kole lands being left fallow is labour shortage and increased cost of production as some of the activities are highly labour intensive in nature. Therefore, there is a move towards increased mechanisation of farming though it is far from complete. The lack of timely availability of machines gives rise to high transaction costs in procuring them. The government is providing several incentives to the farmers to prevent them from leaving the Kole tracts fallow. For example, the government is providing some financial incentives to initiate cultivation on fallow land. Some of the uses of Kole land like lotus cultivation, duck penning etc are also promoted not only to supplement the farmers income but also to restore the fertility of soil and ecological balance since these uses do not transform the ecosystem. The table 4.4 below summarise the DPSIRs discussed here.

Table 4.2. DPSIR Indicators and Characteristics

Drivers	
Population	Growth in district population
	Increase in the density of population (For eg. 903 people per sq.km in 1991 to 981 in 2001 as against respectively 749 and 819 in Kerala)
	Per capita availability of land
Intensification of agricultural activities	Adoption of green revolution technologies Increased input use Creation of irrigation infrastructure
Land use change	Conversion to non agricultural uses
Land tenure changes	Enactment of Land Reforms Act in 1964 resulted in subdivision and fragmentation of holdings as a result of which holding size became uneconomical for cultivation
Subsidies	Resulted in indiscriminate use of chemical fertilisers and pesticides adversely affecting the sustainability of crop production
Urbanization	Developmental pressures Housing demand
Pressures	
Increased cropping intensity	Attempts to cultivate two crops instead of a single crop
Intensification of fisheries	Change from capture to commercial fisheries

Infrastructural development	Development of irrigation infrastructure, farm roads, etc
Urbanization	Increased demand for housing sites, conversion to non agricultural uses
Threats to migratory birds	Poisoning and killing of migratory birds
State	
Acidic content of soill	Increase in the acidic content of soil
Decline in soil quality	Increased use of chemical fertilisers and pesticides
Siltation of canals	Faulty design of bunds and canals
Water logging	Silt deposits in bunds and canals
Presence of water hyacinth	Due to water logging and obstruction of free flow of water
Increase in fallow lands	Due to mining Increased cost of cultivation, shortage of labour etc
Loss of native plant and animal biodiversity	Decrease in farmer friendly plants and micro organisms, birds and reptiles
Impact	
Intensified agricultural activity and its effect on fisheries	Intensified agricultural activity adversely affected fisheries
Change from subsistence to commercial fisheries	Adversely affected traditional fishing communities Loss of fish biodiversity
Resource use conflicts	Conflicts between agriculturists, miners, fishers etc
Increased fallow land	After mining large tracts of land became unsuitable for cultivation
Response	
Emergence of new institutional arrangements for management	Formation of groups of farmers, the *Padasekhara Samithis*

Increased infrastructural and financial support for rice cultivation	Commissioning of Peechi, Chimni-Mupli dams and other regulators and bunds
Setting up of new institutions for providing support to agriculture in Kole land	Set up Punja Special Office, Kerala Land Development Agency, etc.
Inclusion of Kole as a Ramsar site	To initiate a comprehensive conservation programme Kole land was declared as a Ramsar site 2002

4.4 Conclusion

The Kole wetland, which is subjected to seasonal alterations provide various ecosystem services. Agriculture tops as the single most exploited provisioning service of this wetland though most other services are also equally important. Various types of activities are undertaken in the Kole land supporting livelihoods of a large number of populations either directly or indirectly. However, these activities are often in conflict with each other. As a result, this ecosystem is under various pressures. The importance of this wetland can be understood from the inclusion of it as a Ramsar site. It might appear that that fewer and fewer households consider the Kole land as their exclusive source of livelihood. However, this changing trend does not in any way reduce the pressures on the Kole land, instead exposes it to different types of interrelated pressures which are very complex to explore. In such a situation, there is a need to disentangle the complex web of interrelated pressures on this wetland ecosystem beyond its significance in terms of supporting immediate local land based livelihoods either directly or indirectly. Or else, there is a chance of undermining its ecological importance if viewed only from livelihoods angle with fewer and fewer households considering it as their exclusive source of livelihood.

Chapter 5
Rice Cultivation in the Kole Land

5.1. Introduction

As pointed out in previous chapters, rice cultivation is the most important use of Kole wetland. Any analysis of rice cultivation undertaken on Kole land would be incomplete without keeping the larger perspective in view. The share of area under rice, a major food crop of Kerala, in the total cropped area declined from 32 per cent in 1961-62 to about 8 per cent by 2007-08. In absolute terms, the area under rice which had reached to 8.76 lakh hectares during 1975-76 from 7.53 lakh hectares during 1961-62 recorded a steady decrease, since then only to touch 2.29 lakh hectares by 2007-08, a staggering 73.86 per cent decrease over a span of about 32 years. The production of rice accounting for 97 per cent of the total food grain production in the state, was 9.88 lakh tonnes in 1960-61, but declined to about 5.28 lakh tonnes by 2007-08, registering a decline of about 47 per cent over this period (Government of Kerala, 2009). The decline in the production of rice accounted for 2 per cent per annum in the 1980s and 2.9 per cent per annum in the 1990s (Jeromi, 2003). As a result of the decline in area and production despite an increase in productivity, the state depended on the neighbouring states for almost 80 per cent of its food requirements. During this period, the share of area under commercial crops steadily increased. Among the major reasons for changes in cropping pattern were lower profitability of food crops, export prospects of commercial crops, increase in the number of absentee land owners, inter-crop variations in land prices and shortage of agricultural labourers, specifically for field crops like rice (Thomas, 1999). The emergence of small and unviable holdings as a consequence of the implementation of land reforms also led to the conversion of agricultural land to real estate (Balakrishnan, 2008).

However, with the changing scenario of increasing food prices and global food crisis, there has been an increased awareness of the need to be food secure and food self sufficient. As a result, there is an increased interest in the state not only to retain and conserve whatever rice field lands and other wetlands are remaining, but also to increase the area under rice cultivation. Towards this end, the state Government has recently taken a series of measures to bring more and more areas under rice cultivation. In fact, after a long period of continuous decline, area under rice increased from 2.29 lakh ha in 2007-08 to 2.34 lakh ha in 2008-09 (Government of Kerala, 2009). Among the other initiatives

to increase area under rice cultivation, the enactment of the Kerala Conservation of Paddy Land and Wetland Act, 2008, envisages to conserve the paddy land and wetland and to restrict the conversion or reclamations thereof, in order to promote growth in the agricultural sector and to sustain the ecological system, in the State of Kerala. Even then small and unviable holdings still continue to be an important constraint in promoting rice cultivation. As almost 95 per cent of the holdings in the state are marginal in nature, it is important to understand the major constraints that marginal landholding cultivators face in cultivating rice and how best rice cultivation can be sustained over time. Against this background, this chapter attempts to examine the case of rice cultivation in the Kole land. More specifically, in this chapter, we analyse the state of rice cultivation in Kole land in terms of input use, yield and profitability with a view to identifying major constraints and opportunities in carrying out and sustaining rice cultivation.

5.2. Socio economic profile of the sample farmers

Before presenting the economic aspects of rice cultivation, a brief profile of the sample farmers is presented here. To begin with, over 77 per cent of the households are headed by males and by religion are Hindu households. Christians and Muslims constitute about 12 and 11 per cent respectively. It is only in the medium size padasekharams where no Christian households have been reported. In terms of social category, a majority of the households belong to socially marginalised communities 54 per cent belonged to Other Backward Communities (OBC) and another 16 per cent to Scheduled Castes (SC). However, only in small padasekharams are there more number of SC households and very few OBC households. In concurrence with the general trends observed in Kerala with an exception of the 13 per cent of illiterates or literates without any formal education, a majority of the heads of the households have attained education levels of at least primary and above.

Table 5.1 Socio economic profile of the sample households

Items	Padasekharams size class			Landholding size class		
	Small	Medium	Large	Marginal	Small	All
Average Family size	4.5	4.2	4.1	4.2	4.9	4.2
Gender of HH						
Male	28 (75.7)	47 (74.6)	102 (77.9)	170 (76.9)	7 (70.0)	177 (76.6)
Female	9 (24.3)	16 (25.4)	29 (22.1)	51 (23.5)	3 (30.0)	54 (23.4)
Total	37 (100)	63 (100)	131 (100)	221 (100)	10 (100)	231 (100)
Religion						
Hindu	30 (81.1)	39 (61.9)	109 (77.1)	170 (76.9)	8 (80.0)	178 (77.1)
Christian	7 (18.9)	0 (0)	20 (15.3)	26 (12.0)	1 (10.0)	27 (11.7)
Muslim	0 (0)	24 (38.1)	2 (1.5)	25 (10.8)	1 (10.0)	26 (11.3)
Total	37 (100)	63 (100)	131 (100)	221 (100)	10 (100)	231 (100)
Social Category						
OC	6 (16.2)	4 (6.3)	5 (3.8)	14 (6.5)	1 (10.0)	15 (6.5)
OBC	9 (2.3)	23 (36.5)	93 (71.0)	120 (54.2)	5 (50.0)	125 (54.1)
SC	14 (37.8)	12 (19.0)	10 (7.6)	35 (15.15)	1 (10.0)	36 (15.6)
Others	8 (21.6)	24 (38.1)	23 (17.6)	51 (23.1)	3 (30.0)	55 (23.8)
Total	37 (100)	63 (100)	131 (100)	221 (100)	10 (100)	231 (100)
Education						
Illiterate	8 (21.6)	11 (17.5)	10 (7.6)	28 (12.7)	1 (10.0)	29 (12.6)
Less than primary	9 (24.3)	17 (27.0)	29 (22.1)	52 (23.5)	3 (30.0)	55 (23.8)
Middle	7 (18.9)	15 (23.8)	41 (31.3)	60 (27.1)	3 (30.0)	63 (27.3)
Matriculate	11 (29.7)	17 (27.0)	34 (26.0)	61 (27.6)	1 (10.0)	62 (26.8)
Intermediate	1 (2.7)	1 (1.6)	7 (5.3)	8 (3.6)	1 (10.0)	9 (3.9)
Above intermediate	1 (2.7)	2 (3.2)	10 (7.6)	12 (5.4)	1 (10.0)	13 (5.6)
Total	37 (100)	63 (100)	131 (100)	221 (100)	10 (100)	231 (100)
Main occupation						
Own farm activities	13 (35.1)	38 (60.3)	62 (47.3)	110 (49.8)	3 (30.0)	113 (48.9)
Agricultural labour	1 (2.7)	1 (1.6)	4 (3.1)	6 (2.7)	0 (0)	6 (2.6)
Non agricultural labour	3 (8.1)	1 (1.6)	3 (2.3)	6 (2.7)	1 (10.0)	7 (3.0)
Salaried/self employed	6 (16.2)	5 (7.9)	25 (19.1)	33 (14.9)	3 (30.0)	36 (15.6)
Not working/ Not in work force	14 (37.8)	18 (28.6)	37 (28.2)	66 (29.9)	3 (30.0)	69 (29.9)
Total	37 (100)	63 (100)	131 (100)	221 (100)	10 (100)	231 (100)

Figures in brackets are percentages

Source: Primary survey

Own farming activities constitute the main occupation for approximately 50 per cent of the head of the households surveyed and nearly 30 per cent are either not working or not in labour force due to old age and other illnesses. In addition to this, another 16 per cent are either salaried or self employed. The status of occupation of the heads of the households surveyed shows that Kole agriculture is still a major economic activity for them.

5.3. Details of Rice Cultivation

Average size of landholdings and yield of rice per hectare

The average size of individual land holdings across all *padasekharams* in the Kole land works out to 0.36 ha (Table 5.2). Marginal farmers hold an average area of 0.31 ha while small farmers 1.25 ha. The average the size of individual holdings is lowest at 0.33 ha in the large *padasekharam* followed by small *padasekharam* with 0.35 ha.

Table 5.2 Average size of landholding and yield of rice per hectare in the Kole land by size class of *padasekharam* and landholding

Size class	Average area (in ha)	Average yield (in kg/per hectare)
Padasekharam		
Small	0.35	4793.45
Medium	0.40	5287.99
Large	0.33	5221.80
Landholding		
Marginal	0.31	5162.05
Small	1.25	5065.36
Total	0.36	5157.27

Source: Primary survey

A comparison of per hectare yield of rice from Kole land farms with that of Kerala and India as a whole confirms the widely held view that yield levels of rice from Kole land farms are very high. The average yield of rice per hectare from Kole farms is found to be 5162 kgs as against 3705 kg/ha for Kerala during 2006-07. The corresponding all India figures work out to 2145 kg/ha for 2007-08 which in fact had registered an increase from 2074 kg/ha for 2006-07 (CACP, 2010). Such yield levels were observed in Kole farms when rice cultivation was more of traditional in nature and when no manuring was done due to high risks involved. One of the earlier studies on Kole lands carried out by the KLDC (1975) has estimated a yield of 2500 kg per hectare in *Punja* and 2000 kg in *Mundakan*. The high levels of yield found in Kole land farms are generally not observed in several places in India. For instance, within India, Punjab leads with a yield level of

4019 kg/ha, followed by Haryana (3361kg/ha), Andhra Pradesh (3344kg/ha) and Tamil Nadu (2817 kg/ha) (CACP, 2010). The yields here are even higher than the world average of 4.1 tonnes per hectare but lower than China's average rice yield of 6.3 tonnes per hectare (Government of India, 2008). Also, there is no statistically significant difference between the yield levels of marginal and small holdings and also between medium and large *padasekharams*. The lowest yield levels have been observed from small *padasekharams*. However, it is also a widely held view that high levels of yields are maintained with a higher input mix and, therefore, at a higher cost of production.

Input use in the Kole rice cultivation

As noted earlier, the first step in undertaking rice cultivation is dewatering of fields. The whole process of dewatering using *petti and para* is energy intensive. However, the cost of energy is not included in the individual farmer's cost benefit calculations as electricity for dewatering is provided free of charges to *padasekharams* by the government. Labour and other costs incurred for dewatering are shared by the individual farmers according to the size of their land holdings. After dewatering, tilling of the land mostly using power tillers and construction of bunds is carried out by farmers independently. Power tillers are used for nearly 15 hours for tilling a hectare of rice land. At this stage, lime is applied to the soil. As soil in the Kole land is acidic in nature, application of lime based on requirement and letting in water and subsequent drainage are absolutely necessary for correcting acidity content and associated toxicants. Almost 90 per cent of the farmers have reported lime application on their fields. The average quantity of lime applied per hectare of rice land has been found to be 267 kgs (Table 5.3). Besides lime, roughly 44 per cent of the farmers have reported application of organic manure at the time of land preparation. When compared to 192 kgs per hectare of organic manure applied in Kerala, for Kole rice lands it is found to be 160 kgs while the medium *padasekharams* have reported the lowest average of 70 kgs per hectare. Across both size classes of farmers, although marginal farmers are found to have applied slightly higher quantity of organic manure, the mean difference is not statistically significant. It is estimated that about 150 kgs of seeds are used for cultivating a hectare of rice in the Kole land farms. A high seed rate in the study area has been observed in some of the earlier studies as well (Johnkutty and Venugopal, 1993). Farmers are tempted to use more seeds because of the fear of seed germination problems and survival of plants and also due to the presence of acidic and other toxic elements in the soil systems. Both broadcasting of seeds and transplanting of saplings after raising them in seed beds are in practice. However, only 10 farmers of those surveyed have reported the use of any transplanting machine.

Use of chemical fertilisers per hectare of rice is found two times more than that of all Kerala average. While the quantity of chemical fertilisers used comes 123 kgs per ha for

Kerala (CACP, 2010), it is as high as 282 kgs per ha for the Kole fields. Across different size classes of *padasekharams*, relatively higher amounts of fertiliser use have been observed in the case of medium size *padasekharams* which incidentally have reported smaller amounts of organic manure application. When compared to marginal cultivators, small cultivators use almost one and half times the quantity of chemical fertilisers. A mean difference of 139 kgs in fertiliser use per hectare of rice land with respect to small and marginal farmers is found statistically significant at one per cent level.

Table 5.3. Use of input mix per hectare in the Kole land rice cultivation

Size class	Tiller (hrs)	Lime (kgs)	Organic manures (kgs)	Seeds (kgs)	Chemical fertilisers (kgs)	Insecticide (Rs)	Labour (days)
Padasekharam							
Small	13.38	258.58	208.85	154.25	250.78	1727	204.24
Medium	14.25	243.45	69.8	155.76	315.27	2084.12	159.53
Large	15.57	287.72	206.63	141.74	270.86	1665.64	176.54
Landholding							
Marginal	14.91	269.87	163.47	149.77	275.05	1844.62	178.48
Small	10.21	206.2	102.72	135.34	413.78	1360.53	135.88
Total	14.67	266.72	160.47	149.06	281.91	1820.68	176.37

Source: Primary survey

The use of pesticides and weedicides is also high in Kole land farms. Various types of weeds such as *Cyperus Rotundus, Cyperus Difformis, Fimbristylis Miliacea, Marsilea Quadrifolia, Oryza Rufipogon, Ischaemum Rugosum, Echinochloa Crusgalli, Monochoria Vaginalis, Cynodon Dactylon, Sacciolepis Interrupta, Marsilea Spp* are found here. Both manual weed removal and use of weedicides are practised in the Kole land farms. Similarly, various types of plant diseases at various stages of plant growth are also reported. On an average, insecticides worth Rs 1820 are applied per hectare of land. Here again medium size *padasekharam* have reported higher use.

A look into the labour input shows that it is almost twice the average labour use reported for all Kerala. Labour as pointed out in chapter 1, consists of male and female family as well as hired labour. Almost 176 human days are employed per hectare of Kole land rice cultivation whereas it was 98 man days during 2006-07 for all Kerala as per the reports of the CACP (2010). Highest amount of labour use has been reported from small

padasekharams. Activity wise, labour use shows that almost 32 per cent of the total labour force is used for land preparation and construction of bunds followed by 21 per cent for weed control including manual removal and application of weedicides etc. In the focus group discussions also, farmers have pointed out that weed control and management has become a serious problem in the recent years. The next major share of labour is used for transplanting of rice plants (17 per cent) and 15 percent for harvesting and threshing operations. Here it is to be noted that the use of machines especially for transplanting and harvesting is dismal due to various reasons such as the non availability of adequate number of machines whenever needed, and the small size of holdings etc, while labour used for disease control accounts for about 6.50 per cent. On the whole, it is seen that a higher yield of rice per hectare in the Kole land is attained with a higher per hectare input mix.

Estimation of Cobb-Douglas production function

The following Cobb-Douglas production function (log linear) has been fitted to examine the input-output relationship and also to estimate returns to scale.

$$LnY_i=\beta_0+\beta_1 LnX_{1i}+\beta_2 LnX_{2i}+\beta_3 LnX_{3i}+\beta_4 LnX_{4i}+\beta_5 LnX_{5i}+\beta_6 LnX_{6i}+\mu_i$$

Whre LnY_i=log of rice yield in kilograms per hectare; LnX_{1i}= log of labour used per hectare in labour days; LnX_{2i} = log of quantity of chemical fertilisers used per hectare in kilograms; LnX_{3i} = log of value of pesticides and weedicides applied per hectare in Rupees; LnX_{4i} =log of use of power tillers for land preparation in hours per hectare; LnX_{5i} = log of quantity of seeds used per hectare in kilograms; LnX_{6i} = log of other costs incurred per hectare in Rupees; μ_i = random error term.

In the regression, we have not explicitly included water as an input. Water is assumed to be a non-binding factor because of favourable irrigation conditions as reported by the farmers. However, the cost incurred, if any, on irrigation is included in X_6 (other costs).

Estimated Coefficients of the Cobb-Douglas production function

The sign and significance of the estimated coefficients of the Cobb-Douglas production function indicate that seed, application of chemical fertilisers and insecticides, human labour, and tilling hours influence yield levels to a great extent. The coefficients for seed and chemical fertilisers are found of higher magnitude indicating a higher marginal efficiency with respect to these two inputs (Table 5.4).

Table 5.4. Estimated Production function of rice

Variables (in Logs)	Coefficient	Std. Error	t value
Labour used per ha in labour days (X_i1)	0.108542**	0.052438	2.07
Qty of chemical fertilisers used per ha in kgs (X_2)	0.143275*	0.040992	3.5
Value of pesticides and weedicides applied in Rs per ha (X_3)	0.134541*	0.032686	4.12
Use of power tillers in hrs per ha (X_4)	0.105578**	0.049064	2.15
Qty of seeds per ha in kgs (X_5)	0.22611**	0.097226	2.33
Other costs in Rs per ha (X_6)	-0.02817	0.038963	-0.72
Constant	5.005403*	0.637123	7.86
Number of obs = 182 F(6, 175) = 11.04; Prob > F = 0.0000 R-squared = 0.2745; Adj R-squared = 0.2497 *, ** are respectively 1 and 5 per cent level of significance			

Source: Primary survey

The coefficient of the variable X_6 (other costs) although had an unexpected negative sign was however not significant. While a study conducted by Muraleedharan (1987) had reported constant returns to scale (1.10), in the present study returns to scale is found to be only 0.69 indicating that cultivation of rice in the study area is at a diminishing returns to scale.

Economic viability of rice cultivation in the Kole lands

In order to see the economic viability and sustainability of rice cultivation in the Kole farms, it is important to look into the costs and returns for farmers. As pointed out in Chapter 1, details of various inputs used including material inputs, their quantities and prices, and managerial inputs apart from rice output have been collected and valued in monetary terms for examining the net returns and profitability aspects. Information on hired labour and family labour, both male and female, was collected separately with value of family labour imputed at the existing average wage rates for males and females respectively. It is seen that irrespective of the size of the landholding or *padasekharam*, the cost of cultivation of rice per hectare amounts to about Rs 45588 (Table 5.5). Based on landholding size, the cost of cultivation shows that small cultivators incur a significantly lesser cost. While the cost incurred by marginal farmers works out to Rs 46503 per hectare, it is only Rs 27983 for small cultivators. The mean difference of Rs 18520 across small and marginal farmers is found statistically significant at 5 per cent level of significance.

Table 5.5. Per hectare cost of rice cultivation (in Rs) in the Kole land

Size class	Labour	Tilling	Seed manure	Organic	Lime	Fertiliser	Insecti-cides	Other costs	Total input cost
Padasekharam									
Small	34252.72	2716.82	2048.04	2274.98	1422.19	1630.09	1727.07	4321.06	50392.97
Medium	26709.16	3127.86	2315.23	670.70	1338.98	2049.28	2084.12	3590.01	41885.35
Large	29593.51	3578.33	2107.87	2651.79	1582.47	1760.56	1665.64	3270.76	46210.92
Landholding									
Marginal	30285.37	3297.33	2188.19	1971.60	1484.26	1787.80	1844.62	3644.26	46503.42
Small	15579.10	2334.85	1746.44	529.91	1134.09	2689.57	1360.53	2608.41	27982.89
Total	29558.13	3249.73	2166.34	1900.31	1466.94	1832.39	1820.69	3593.04	45587.57

Source: Primary survey

On the other hand, small *padasekharams* are found to have incurred higher cost of cultivation which is also statistically significant. This could be because small *padasekharams* and marginal holder cultivators are not in a position to take advantage of economies of scale. Among the components of costs considered here, labour cost forms the single largest variable accounting for 65 per cent, while the costs incurred on other inputs vary between 3 to 8 per cent of the total cost. It is seen that small farmers incur approximately 10 per cent less cost on labour and relatively higher cost on fertilisers as compared to marginal farmers.

Table 5.6. Comparison of costs and returns (in rupees) per hectare on rice cultivation in the Kole farms

Size class	Gross value of output	Cost of production	Net returns	Ratio of gross value of output to cost
Padasekharam				
Small	52728.00	50392.97	2335.02	1.30
Medium	58167.94	41885.35	16282.60	1.70
Large	57439.78	46210.92	11228.86	1.53
Landholding				
Marginal	56782.54	46503.42	10279.12	1.49
Small	55718.95	27982.89	27736.06	2.58
Total	56729.95	45587.57	11142.38	1.54

Source: Primary survey

In order to see the economic viability of Kole rice cultivation, one has to look into the profitability aspects. The farmers growing rice in the Kole farms are found to have realised a gross return of Rs 56730 per hectare (Table 5.6).

Output has been valued at the price received by the farmers. The average net return from rice cultivation is found to be Rs 11142 per hectare. This is as low as Rs 2335 for small *padasekharams*. While small cultivators are found to have obtained a net return of Rs 27736 per hectare, it is as low as Rs 10279 for marginal holders. In order to see the level of margins, we also have worked out the ratio of gross value of output to total costs. The ratio shows that the gross value of output exceeds the costs across different size classes of padasekharams, as well as landholding classes. While the ratio is found to be 1.54 for all categories of farmers, it ranges from 1.30 for small *padasekharams* to 2.58 for small cultivators (Table 5.6). It is, however, significant to point out that for almost 32 per cent of the sample farmers, the ratio of gross value of output to total cost per hectare works out to less than one, indicating that cultivation of rice is not economically viable for them- the average ratio is found to be 0.74 for them. For another 43 per cent of the farmers, the ratio of gross value of output to total cost has been found between one and two with an average of 1.42. For these farmers, even a marginal increase in the cost of production or a decrease in the gross value of output or both would make rice cultivation

Table 5.7. Distribution of farmers based on the ratio of gross value of output to costs

Size class	<1	Between 1 and 2	Between 2 and 3	Between 3 and above	Total
			Padasekharam		
Small	19 (51.35)	12 (32.43)	3 (8.11)	3 (8.11)	37 (100)
Medium	13.00 (20.97)	31.00 (50.00)	13.00 (20.97)	5.00 (8.06)	62.00 (100)
Large	27.00 (32.53)	35.00 (42.17)	15.00 (18.07)	6.00 (7.23)	83.00 (100)
			Land holding		
Marginal	57.00 (32.95)	77.00 (44.51)	28.00 (16.18)	11.00 (6.36)	173.00 (100)
Small	2.00 (22.22)	1.00 (11.11)	3.00 (33.33)	3.00 (33.33)	9.00 (100)
Total	59.00 (32.42)	78.00 (42.86)	31.00 (17.03)	14.00 (7.69)	182.00 (100)
Avg. Ratio	0.74	1.42	2.39	3.72	1.54
Avg.Area (in ha)	0.30	0.30	0.46	0.68	0.36

Figures in brackets are percentages
Source: Primary survey

economically non-viable, possibly forcing them to give up rice cultivation. These two categories together comprise almost 75 per cent of the total number of farmers in the Kole land.

It is seen that the degree of margin or profitability improves with the size of holding (Table 5.7). The correlation coefficient between the size of land holding and the degree level of margin has been found to be 0.34 and is statistically significant. For more than 50 per cent of the farmers in small *padasekahram*, the ratio is less than one indicating that rice cultivation is not economically viable for them. Thirty three per cent of marginal cultivators also have reported a ratio of less than one.

5.4. Major opportunities and challenges present in Kole rice cultivation

Using insights from the analysis of farm survey data, including inputs from stakeholder workshop and focus group discussions, in this section, we highlight a few interrelated issues which are mostly underappreciated with respect to Kole rice cultivation from both the wetland ecosystem perspective and the need for ensuring increased food production and food security in the state. We pose the following question in this regard: what are the opportunities and constraints farmers, marginal and small, across this highly potential area for crop production, face due to a) ecosystem characteristics, b) input and output, c) institutional and other services related factors?

Let us briefly examine the opportunities and constraints due to:

a. Ecosystem characteristics.

The biggest opportunity for undertaking rice cultivation in the Kole lands is the fact that it is a flood plain area and, therefore, a highly fertile one. As dewatering and construction of earthen bunds for carrying out rice cultivation are required every year, certain institutional arrangements like *padasekharams* are in place to carry out such operations for which the costs are shared by the individual farmers as members of *padasekharam*. The state also supports this endeavour with free supply of electricity for pumping out water which is both capital and energy intensive. It has also a network of canals which acts as a drainage system and a source of irrigation water supply in the summer. In this context, we may recall the zonal system of cultivation and water management (as explained in Chapter 3) which is the most practical and convenient way of managing flood waters.

It is observed that over the decades, investments in basic infrastructure like farm roads, bunds and canals have been made in the Kole land. Although these are necessary for broad based agricultural growth, inadequate and in some places incomplete construction of bunds and canals and their inadequate maintenance pose major problems as reported

by farmers, resulting in poor drainage and waterlogging in addition to faster weed growth and euotrophication of Kole farms.

Apart from this, the nature of the ecosystem makes it suitable for other uses like fish farming, lotus cultivating, duck sitting, etc. Table 5.8 presents briefly some of the positive and negative aspects of fish farming and duck sitting as reported by the farmers.

While some of these aspects are of complementary in nature other aspects like mining etc are conflicting in nature. With the discovery of under soil clay and sands, mining has of late become a major non agricultural activity in the Kole rice lands. Since both top soil and clay beneath are mined, it obstructs water flow and also leads to soil erosion in the nearby places and besides making surrounding lands unsuitable for cultivation.

Table 5.8. Farmers' perception of positive and negative impacts of fish farming and duck sitting on Kole rice cultivation

Item	Positive Impact	Negative Impact
Fish farming	Additional income to farmers and padasekhara samithis, supply of organic manure, Less weeds	Delays dewatering and timely start of agricultural operations and also increases the risks of crop damage due to rains
Duck penning	Additional income to farmers, Destroys pests and insects, Organic manure, increases soil fertility, cleans up weeds and wastes,	Increases variety of weeds through excreta, spoils bunds, sometimes destroys rice

Source: Primary survey

As pointed out before, Kole wetland is a Ramsar site and supports a large number of birds including endangered and migratory. While there could be several positive externalities, farmers perceive birds as a major threat to cultivation as some of them might destroy crops imposing huge economic losses on the farmers. In response to bird menace, farmers sometimes adopt destructive methods like poisoning and killing of birds even though it is illegal to do so. Reports of the deaths of migratory and endangered birds have been reported in the past. All the same, this is a major threat for carrying out rice cultivation, though the degree of severity of the problem may vary across time and space.

b. Input and output

By far Kole is the major input which contributes about 65 per cent of the total cost of production. The cost of labour services is not only a major component of the total cost of production but also very critical, given the nature of Kole wetland ecosystem. While 32 per cent of the labour requirement is for bunding and land preparation activities, weed control, transplanting, and harvesting and threshing together account for 53 per cent of the total labour requirement. Not only that there is a shortage of hired labour, the supply of family labour is also limited due to small family size and the likely high opportunity cost of employing family members in one's farm as labourers. In a labour surplus economy, small farming households would have employed more of family labour even with low marginal productivity. However, this is not the case with Kole farms. So the alternative is substitution of labour with labour saving capital. Arranging labour or substituting it with capital equipments in activities such as land preparation, planting, weeding, harvesting etc leads to high transaction costs which are mostly non measurable in nature. Here the lack of timely availability of the machinery as well as the inappropriate design of the available machinery for operating on small farms does not contribute to reducing the cost of cultivation. This is a difficult situation that Kole farmers face. However, the situation can be reversed if certain institutional arrangements are in place. In the context of Kole land farming, one must emphasise the fact that potential benefits can be obtained through collective efforts by farmers.

If we take a look at the Kole farming activities in terms of three segments namely i) preparing Kole farms for cultivation from a fully submerged wetland; ii) the actual cultivation stages and; iii) harvest and post harvest stages it becomes clear that there exists to a large extent, a scope for collective action at the land preparation stage and to a lesser extent at the harvesting stage. However, at the middle stage when most other labour absorbing activities are undertaken the extent of collective action by Padasekahara samithis is found very limited. In order to ensure the viability of Kole farming, collective action right from the first to last stage is very crucial as it allows for spreading of costs and helps avail of some of the economies of scale that are generally associated with large farms apart from better performance in terms of monitoring functions.

Although a few decades ago, a number of local varieties of rice used to be, the farmers now mostly depend on seeds supplied by the National Seeds and Karnataka Seeds Corporations at subsidized rates. Jyothi, Uma, Jaya are some of the high yielding varieties found suitable for Kole lands. While farmers are satisfied overall with the supply of seeds, some farmers find germination problems and the delay in obtaining them. Farmers say they are forced to use large quantity of seeds per hectare of rice because of the germination problems due to soil acidification. This is also an important risk for farmers

as the failure of seeds delay all other agricultural activities resulting in considerable economic loses.

Chemical fertilisers, organic manures, pesticides and weedicides are used in the Kole land. As is seen in the analysis presented above, use of chemical fertilizers is very high in the Kole rice fields. Farmers avail of various subsidies for fertilisers. However, the extent of subsidies availed by farmers could not be captured in the present study. Similar is the case with use of pesticides and weedicides. Because of the excessive use of chemicals in the form of fertilisers, pesticides, etc farmer friendly micro organisms and other reptiles like earthworms, frogs, rats, owls etc., have disappeared from the surroundings (as observed by farmers themselves). While there is increased awareness among the farmers of the harmful effects of excessive use of chemical fertilisers and pesticides, they say that unless such inputs are applied in large quantities the productivity will be very low leading to economic loses. Although some *padasekaharams* are in favour of using more organic manures, they complain about their higher prices and also the lack of their availability locally.

At harvesting and threshing stages also farmers face labour shortage. Lack of timely availability of harvesting and threshing machines put the farmers under the high risk of crop loss in case of early rains. Moreover, they also complain that straw will be unusable if machines are used. A majority of the farmers prefer to market the harvested produce instead of retaining at least part of it for domestic consumption. This is largely because of the high labour cost involved in further processing. Harvested rice is procured through Civil Supplies Corporation from the threshing spot as many of the padasekharams do not have any storage facilities. Some farmers also point out the absence of farm roads for transporting inputs and outputs to and from their farms.

c. Institutional and other services

A major challenge facing Kole farmers is the lack of coordination between service delivery agencies. In general, the small scale nature of the Kole farms leads to high unit transaction costs in almost all non-labour transactions in terms of accessing capital, market and technical information, input and output markets and in providing product traceability and quality assurance (Poulton et al, 2010). Timely access to inputs, finance and technical information on farming equipments becomes increasingly important. Here the quality and efficiency of service delivery by various institutions involved in Kole land management and development is of considerable importance to the Kole farmers. Because of small farm sizes, the transactions that take place are also small thus leading to increased cost of servicing of small farms. Although in some cases farmers become victims of opportunism or cheating by some input suppliers, it is reported that at least some farmers also engage in opportunism, by falsely reporting and claiming subsidised benefits.

5.9. Farmers' evaluation of the functions and services performed by various institutions involved in Kole rice cultivation

	Satisfactory		Not satisfactory		Cannot say		Total
	No	%	No	%	No	%	
Padasekhara samiti	104	57.14	50	27.47	28	15.38	182
Kole Karshaka samiti	26	14.29	14	7.69	142	78.02	182
Krishi Bhavan	120	65.93	21	11.54	41	22.53	182
Kole Development							
Authority	9	4.95	11	6.04	162	89.01	182
KLDC	37	20.33	65	35.71	80	43.96	182
Punja Office	19	10.44	10	5.49	153	84.07	182
Civil Supplies corporation	83	45.60	31	17.03	68	37.36	182

Source: Primary survey

In table 5.9 the farmers evaluation of the functions and services performed by various institutions involved in Kole rice cultivation is given. Out of the 182 farmers surveyed, 66 per cent and 57 per cent have reported that they are satisfied with the services of

5.10. Five Major Constraints as Reported by the Kole Farmers

Constraints	Yes	No	Cannot say	No Response	Total
Labour	152 (83.5)	14 (7.7)	-	16 (8.8)	182 (100)
Credit/Finance	94 (51.6)	37 (20.3)	2 (1.1)	49 (26.9)	182 (100)
Lack of timely availability of agricultural machinery for harvesting	82 (45.1)	41 (22.5)	4 (2.2)	55 (30.2)	182 (100)
Lack of timely availability of agricultural machinery for land preparation and transplantation	61 (33.5)	53 (29.1)	2 (1.1)	66 (36.3)	182 (100)
Seed related	34) (18.7	78 (42.9)	3 (1.6)	76 (41.8)	182 (100)

Source: Primary survey

Krishi Bhavan and *Padasekhara samithis*. About 46 per cent of them are also observed satisfied with the services of civil supplies corporation. However, in terms of the services delivered by the Kole Development Authority, Punja Office, and *Kole Karshaka Samithi*, the farmers are by and large not satisfied. Low levels of satisfaction could also be due to the reason that activities of some of these agencies are not directly known to the farmers.

Table 5.10 lists five major constraints involved in carrying out rice cultivation as reported by the Kole farmers. Labour problem has been reported as a major constraint by as many as 83 per cent of the farmers, followed by credit or financial constraints by 52 per cent of the farmers. Lack of timely availability of agricultural machinery followed by quality and timely availability of seeds has also been reported as major constraints faced by the farmers.

5.4. Conclusion

This chapter has examined yield levels, input use, and net returns from rice cultivation in the Kole land, in addition to the major opportunities and challenges facing the Kole rice farmers against the backdrop of the attempts made by the government of Kerala to increase rice production in the state. It is seen that the yield per hectare of rice is very high from the Kole lands. However, this has been attained with increased input use, raising serious concerns relating to both ecological and economic sustainability. The returns to scale indicate that Kole is exhibiting diminishing returns to scale on investment. Labour cost constitutes over 65 per cent of the total cost of cultivation as increased amounts of labour is used for certain activities like land preparation, weed removal, transplanting and harvesting. The increasing trend in the use of weedicides raises serious concerns on soil health and ecological sustainability. For a large number of farmers the cultivation of rice as a major crop has not proved economically viable and as such, they may prefer to exit from cultivation. In such a situation, measures to improve the economic viability of rice cultivation are important instead of recommending double cropping. Better measures for weed control and management would significantly reduce labour cost. Availability and use of machines for transplanting and harvesting is to be improved and promoted. It is seen that medium size padasekharams have become more economically viable than the other two categories. Given the average size of individual land holdings in the Kole land, efforts need to be made to encourage farmers within *padasekharams* to carry out cultivation collectively so as to reap some economies of scale and make rice cultivation economically more remunerative. Similarly, a further subdivision and fragmentation of holdings needs to be controlled and the Rice Land Conservation Act implemented strictly. The study finds a greater role for *padasekharams* and *padasekhara samithis* as institutions for overcoming the constraints concerning the small land holdings. This, together with a more judicious use of chemical inputs would make the Kole land

rice cultivation economically more viable and help contribute significantly to the overall goal of enhancing rice production in the state. In order to achieve this, there are several challenges related mostly to ecosystem characteristics, inputs and outputs, institutions and services that need to be overcome.

Chapter 6
Summary and Conclusions

6.1. Summary

Wetlands are complex ecosystems that provide substantial benefits to human society. However, the global spread of wetlands has been shrinking at an ever increasing rate over the recent decades. It has been estimated that almost about 87 per cent of the wetland loss is mainly due to their conversion to agricultural development, and the rest for urban and other developments. Such conversions are found to have profound ecological as well as socio economic impacts. The intense interactions between agriculture and wetlands assume more importance as demand for food production accentuates pressures on wetlands. Although agricultural development considerably increases the provisioning services of wetlands other services like regulating and supporting services get reduced in the process. The Comprehensive Assessment of Water Management in Agriculture points out that regulating and supporting ecosystem services that wetlands provide are essential for the balanced functioning of river basins, the maintenance of ecological flows and the sustainability of agricultural production.

In this study, we have tried to explore the case of the Kole land, a flood plain of Karuvanoor and Kechery rivers in Thrissur, Kerala, and also an important Ramsar wetland. It is a complex ecological system which lies submerged under water for about six months in a year giving it both terrestrial and water related properties and generates substantial benefits for the society. However, in the recent decades, this wetland has been facing various forms of anthropogenic pressures.

Against this background, the present study set off with the following specific objectives: (1) to review the ecosystem characteristics of wetlands in general and the Kole wetlands in particular in relation to their socio economic importance; (2) to analyse the status as well as the trends in the Kole wetland use over the years; (3) to identify the major ecosystem services provided by the Kole wetland and analyse important agriculture wetland interactions using a Driver Pressure, State Impact Response (DPSIR) framework; (4) to carry out an economic analysis of rice cultivation, which forms the main use of the Kole wetland and finally; (5) to identify the major opportunities as well as constraints in terms of promoting its sustainable use taking into account agriculture-wetlands interactions.

The study is based on both secondary and primary data. A detailed review of literature has been carried out to understand Kole lands as a multiple use ecosystem and to identify some of the major livelihood activities undertaken on it. An analysis of land use dynamics has been carried out using data based on Indian Remote Sensing Satellite Images and Survey of India topo sheets. For this, we have used satellite images for three time points 1989, 1997 and 2007 from the National Remote Sensing Centre. Land use classifications for the area have been developed based on the ready information of the study area and field verifications. The identified land uses include area under mixed crops, area under rice, built up land, water body, water logged and wastelands.

Identification of various benefits of Kole wetlands and activities undertaken has been assessed using the concept ecosystem services, such as provisioning services, regulatory services, supporting services and cultural services. A *Driver Pressure State Impact Response* Framework has been applied to understand wetland agriculture interactions and the various pressures exerted on the ecosystem. Here *drivers* are the underlying causes that lead to pressures on wetlands or agriculture wetland related process. *Pressures* are the direct results of the drivers and *state* refers to the changes in the ecosystem services; *impact*s are the socio economic changes following changes in the state of the wetland; and responses are strategies and interventions concerning *drivers, pressures, state changes and impacts.* A stakeholders workshop, focus group discussions and key informant interviews were conducted for identifying key issues as well as for collecting qualitative data.

A detailed survey of rice farming households using a structured questionnaire was also carried out. As the Kole rice farms are organised under an institutional arrangement called *padasekharams,* in the first stage of sample selection, we purposively selected *padasekaharams after* arbitrarily classifying them into small, medium and large. Farmers in the selected *padasekharams* were further stratified based on their size of landholding with approximately 10 per cent of the farmers from each statum selected for a detailed survey. The survey was conducted among 231 rice farmer households of which 182 which reporting cultivation for the reference period were taken up for a detailed analysis.

Detailed information on the socio economic characteristics of farmers, along with details of output and inputs including material inputs, their quantities and prices and managerial inputs was collected and valued in monetary terms to assess the net returns and profitability aspects of rice cultivation. A Cobb-Douglas production function was applied to examine the input-output relationship and returns to scale. In order to identify the economic viability of rice cultivation, we also calculated the ratio of gross value of output to costs.

From the land use analysis it becomes clear that considerable changes have taken place over the last few decades across the Kole land. The estimated total area of Kole land comes to 546.25 sq.km. of which 389.25 sq.km (70 per cent) is in the Southern Kole (in Thrissur district) and the rest in the Northern Kole (Malappuram district). The area under rice has shown a significant decline across both Southern and northern Kole. In the Southern Kole which mostly falls in Thrissur district, the area under rice shows a steady decline from 181.63 sq.km during 1981, to about 160.78 sq.km by 1989 to 135.85 sq.km by 2007. Area under rice has been declining at the rate of -1.32 per cent per year in the Kole land as a whole and at -1.51 per cent in the Southern Kole. On the other hand, the area under mixed crops has been increasing. The period 1981-89 shows high growth rates of area under built up land. The growth rate in the built up land has again gained momentum during the period 1997-2007, especially in the Southern Kole land. Also what is significant to observe are very high growth rates in the wastelands and water logged areas during 1997-2007. Ground truthing confirms that these lands were once used for mining and later abandoned as they had been found unfit for cultivation.

Kole land which lies submerged under water for most part of the year has a good net work of canals. Apart from rice cultivation which is the most important provisioning service, the Kole land provides a number of ecological services in the form of flood control, recharge of groundwater, nutrient retention, etc. These are basically the regulatory and supporting services of Kole land, which supports provisioning services on which various livelihood activities are based. While certain activities carried out traditionally like rice cultivation, fish farming, etc are by and large complementary in nature; activities like mining are conflicting in nature. At the same time unsustainable farming practices in rice and fish are also found to create livelihood tradeoffs. As the nature of extraction of mining is harmful to the ecosystem, conflicts between various stakeholders are bound to exist. Mining activities are found altering supporting and regulating services of Kole farms which are critical for providing provisioning services.

Important drivers identified using DPSIR framework are those related to population dynamics and government policies pertaining to agriculture and food production. Because of the national priority given to food self sufficiency in the years following independence, intensification of agricultural activities has emerged as a major pressure on the Kole land. Several engineering interventions aimed at improved drainage and water management have been carried out facilitating double cropping. Although the construction of farm roads has helped the movements of tillers and tractors, seeds and fertilisers at reduced costs, it also has facilitated the conversion of Kole land to non-agricultural uses such as mining and other activities leading to transformation of the ecosystem. Acidification of soil, decline in soil quality, water logging due to incomplete

or faulty designs of bunds and canals, presence of water hyacinth etc are some of the state changes reported. Loss of biodiversity which can undermine the ecological character and resilience of the ecosystem is also reported. Impacts of the state of the ecosystem changes are highly diverse and vary across different types of users. Intensified agricultural activities by rice farmers adversely affect communities dependent on fishery resources. Also a shift in the fisheries from subsistence oriented to commercial and contract based one affects the livelihoods of traditional fishing communities. This represents an overall trade off in terms of economic benefits and livelihoods rather than the transformation of livelihoods themselves, that is, traditional fishing communities themselves becoming commercial fish farmers. Mining activities have given rise to competition in the resource exploitation and conflicts with other users because of the increased claims over the available resource.

A positive development as far as the Kole land is concerned relates to the increase in the awareness of its international importance and the declaration of it as a Ramsar site in 2002. The responses to various drivers, pressures, state changes and impacts have been multiple though largely focused on Kole rice cultivation.

A look into the socio economic profile of sample farmers shows that the majority of the households are Hindus by religion and headed by male members. In terms of social category, a majority of the households belong to socially marginalised communities with 54 per cent to Other Backward Communities (OBC) and another 16 per cent to Scheduled Castes (SC). With an exception of 13 per cent illiterates or literates without formal education, a majority of the heads of the households are found to have had education levels of at least primary and above. Approximately 50 per cent of the households have reported rice farming as their main occupation.

Kole rice farms are small farms having an average area of 0.36 ha. The average yield of rice per hectare of land has been found very high as compared to Kerala as a whole. For example, the average yield of rice per hectare from Kole farms works out be 5162 kgs where as it was 3705 kg/ha for Kerala during 2006-07. It is important to note that there is no statistically significant difference observed between the yield levels of marginal and small holdings and also between medium and large *padasekharams*.

Dewatering is the first step to carry out rice cultivation. Electricity is supplied free of cost to farmers for carrying out dewatering activities. Labour and other costs incurred for dewatering are shared by the individual farmers according to the size of their land holdings. As Kole soil is acidic in nature, farmers apply lime at the time of land preparation. It is found that, on an average farmer apply about 267 kg lime per hectare of rice.

Around 44 per cent also have reported application of organic manure at the time of land preparation. It is estimated that about 150 kgs of seeds are used for cultivating a hectare of rice. High seed rate have been pointed out in earlier studies as well. This is because of the uncertainty surrounding seed germination and survival of plants due to acidity and other toxicities in the soil. Uses of transplanting machines are very few in the study sample, where as uses of chemical fertilisers and pesticides are found to be very high. The quantity of fertilisers used per hectare of rice (282 kg) is almost two times more than that of all Kerala average of 123 kg per hectare. Medium size padasekharam has reported a relatively higher quantity of fertiliser use per hectare of rice. Similarly, when compared to marginal cultivators, small cultivators are found to have used larger quantities of fertilisers. Insecticides worth Rs 1820 per hectare are applied by farmers. Here again medium size padasekharam has reported a higher use.

Similarly the use of labour input is also very high in the Kole rice cultivation. It is estimated that almost 176 human days which include females and males as well as hired and family labour are required per hectare of rice whereas it was 98 human days during 2006-07 for Kerala as a whole. Highest amounts of labour use have been reported by small padasekharams. Accounting for over 32 per cent of the total labour use, land preparation and construction of bunds constitute the most labour absorbing activity.

Weed control is the next major labour absorbing (21 per cent) activity followed by transplanting of rice saplings (17 per cent) and harvesting and threshing operations (15 per cent).

The estimated Cob-Douglas production function indicates that the quantity of seeds used, quantities of fertilisers applied, human labour and till hours significantly influence the yield of rice. It is seen that cultivation of rice in the Kole is operating at diminishing returns to scale as is evident from the returns to scale of 0.69.

The economic viability of rice cultivation has been assessed by estimating net returns and the ratio of gross value of output to total variable cost. Per hectare cost of cultivation of rice is found to be Rs 45588. However, statistically significant differences in the cost of cultivation between marginal and small farmers have been observed. While the marginal farmers have incurred Rs 46503, it is only Rs 27983 per hectare for small farmers. Similarly, small padasekharams are also found to have incurred higher cost of cultivation. Labour cost constitutes about 65 per cent of the total cost of production. It is found that small farmers incur approximately 10 per cent less cost on labour and comparatively a higher cost on fertilisers when compared to marginal farmers. After valuing output at the price received by the farmers, it becomes clear that irrespective of the size of holdings

or padasekahrams, farmers have realised a gross return of Rs 56730 per hectare. The average net benefit amounts to around Rs 11142 per hectare. However, the net returns are found to be low for marginal cultivators and those belonging to small padasekharams. The ratio of gross value of output to total cost works out to 1.54 for all categories of farmers and for about 32 per cent of the farmers it is found to be less than one. Average ratio for such groups of farmers is found to be 0.74 indicating that rice cultivation is not economically viable for them. It is also important to note that the level of margin or profitability improves with the size of holding. The correlation between size of landholding and the level of margin is found to be 0.34 and is statistically significant.

6.2. Conclusions and Policy Implications

In this study using insights from stakeholder workshop, focus group discussions, key informant interviews as well as a detailed survey of rice farmers in the Kole, a few interrelated issues with respect to agriculture wetland interactions both from the perspective of wetland ecosystem as well as from the need for increased food production and food security in the state have been raised. The question being asked is: what are the opportunities and constraints farmers who are marginal and small in nature in the high potential area for crop production face due to ecosystem, input-output and institutional and other services related factors.

In order to explore these factors we have the ecosystem characteristics and the various types of activities undertaken on the Kole land, their linkages and tradeoffs. It is significant to note that rice cultivation and fish farming in alternate crops seasons were the two major traditional activities carried out in the Kole land. However, over a period of time other uses, which are potentially harmful to the ecosystem have also been initiated. This is by and large in response to the overall changes that took place in the Kerala economy. Since late 1970s and early 1980s clay and sand mining which was backed by a booming construction industry had become an attractive activity. It was only during the subsequent years that the consequences of the mining started to be felt. Not only that large area under rice was converted for mining, it also created wastelands and waterlogged areas thus affecting the eco-hydrology of the wetland. Although agriculture, which is a main provisioning service of the wetland has been exploited to a great extent, soon it was realised that the supporting or regulating functions on which provisioning services are dependent are also affected due to unsustainable uses of the Kole land. These kinds of non agricultural uses of Kole lands also results in the creation of a different set of winners and losers resulting in conflicts and marginalisation.

Analysis using a DPSIR framework highlights the lack of ecosystem perspective followed in various government policy measures to enhance rice production. A negative off shoot

of intensified agricultural activities has been indiscriminate and excessive use of chemicals and pesticides thus adversely affecting the ecological sustainability. This was evident from the disappearance of farmer friendly micro organisms and other species. Intensification of rice cultivation is also found to have adversely affected communities dependent on fishery. Now the padasekhara samithis lease out Kole land for fish cultivation after the harvest of rice. As a result, fisheries changed from subsistence oriented to commercial and contract based one, where in the contractors are not very much concerned about the ecosystem health. Also there is an overall trade off in economic benefits and livelihoods rather than transformation of livelihoods themselves. For instance, this is not the case where traditional fishing communities themselves becoming commercial fish farmers. In this process, the traditional fishing community lost their right for natural fishing in the flooded Kole lands.

Also Kole is an important site for migratory birds. They are also affected by the indiscriminate use of chemicals and even cases of their being poisoned have been reported from various places. With the inclusion of Kole as a Ramsar site, more conservation oriented measures are expected now.

Padasekhara samithis which emerged as a spontaneous response to carry out farming in the Kole land subsequent to the enactment of land reforms are still very important. Rice cultivation is the most important activity carried out in the Kole lands. The low average size of holdings makes rice cultivation economically unviable for farmers, especially because of the high labour cost and limited scope for mechanisation due to the small and marginal size of individual landholdings. It is seen that land preparation and construction of bunds, transplanting, weeding, harvesting and threshing etc are some of the activities which are highly labour-intensive. Since labour is costly, arranging labour or substituting it with capital equipments leads to high transaction costs for farmers. Not only there is shortage of family labour but also the opportunity cost of employing family members in one's own farm as labourers is very high. Hence, farmers in this respect face a difficult situation. Measures need to be taken for to addressing this issue.

As short term measures, it is important to emphasise the potential benefits of collective action among farmers through *padasekhara samithis*. Marginal farmer and farmers belonging to small *padasekahrarms* are at higher risk of suffering economic losses. This means that as the size of landholding and *padasekharam* increases, there is a possibility of reaping economies of scale and thereby to reduce the cost of production. For example, in order to ensure the viability of Kole farming, collective effort right from the first to last stage is very crucial as it allows for spreading of costs and also help reap some economies of scale that are generally associated with large farms apart from better performance of

monitoring functions. Efforts need to be made to explore the possibility of strengthening *padasekeharams* and *padasekhara samithis* by expanding their sphere of activities. As marginal farms and small padasekharams are found to be economically not so viable, care needs to be taken in order to prevent further sub division and fragmentation. Any infrastructure development including canal and farm road construction in the Kole land has to take this aspect into account. Also the farmers need to be encouraged to take up supplementary income generating activities that are complementary in nature to rice cultivation.

The absence of coordination between various service delivery agencies is also a major challenge that Kole farmers are facing at present. On the one side, small scale nature of farms leads to high unit transaction costs in accessing inputs and other services by the farmers. On the other side, for the service delivery agencies, the cost of servicing small farms is high because of the small size of transactions. This situation has to be tackled so as to improve the quality and efficiency of various service delivery institutions involved in the Kole land management and development.

While rice cultivation is a major provisioning service of the Kole, measures to enhance rice production or other agricultural intensification activities need to adopt an ecosystem perspective. Measures also need to be taken to control the increase in area under waste lands and water logging. Similarly, measures have to be adopted to check non-agricultural uses of Kole wetlands, as this trend tends to alter other regulating and supporting services. Further, there is a need to recognise the national and international significance of Kole wetlands as a Ramsar site in any policy measure aimed at promoting its wise use.

As a long term measure, it would be worthwhile to have a relook into the methods of cultivation in the Kole. Although the productivity of rice in the Kole is very high, it is input intensive, and economically not so viable. Apart from labour shortage along with its high cost, mechanisation is also very limited. The small size of Kole farms is a major impediment in respect of mechanised cultivation. The sustainability of the present practices is doubtful as our analysis shows that rice cultivation is taking place at diminishing returns to scale. If the cost of energy used for pumping out water and the cost incurred for providing irrigation and drainage works are also included in the cost of production, rice cultivation might turn out to be totally economically unviable. Therefore, as a long term objective, there is a need to look for alternative farming practices wherein input costs including those of labour and energy are minimised. For example, in some parts of Kuttanad and other low lying regions traditionally *pokkali* farming used to be carried out, where dewatering and some of the other labour intensive activities were not required. A review of different farming practices within the state and elsewhere and their suitability in the present study context needs to be explored further.

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