

**ECOSYSTEM SERVICES APPROACH TO THE INTERLINKAGES
BETWEEN KOLE WETLAND FARMING AND HUMAN WELLBEING
IN KERALA**

**Thesis Submitted to the University of Calicut
for the award of the degree of
*DOCTOR OF PHILOSOPHY IN ECONOMICS***

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August 2026

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I hereby declare that the work presented in the thesis entitled **Ecosystem Services Approach to the Interlinkages between Kole Wetland Farming and Human Wellbeing in Kerala** is based on the original work done by me under the guidance Dr. SIMON. T. D, Professor and Head, Research and PG Department of Economics, Sree Keralavarma College, Thrissur and Co-guide, Dr. ZABEENA HAMEED. P, Associate Professor and Head, Department of Economics, Dr. John Matthai Centre, Aranattukara, and has not been included in any other thesis submitted previously for the award of any degree. The contents of the thesis are undergone plagiarism check using *iThenticate* software at C.H.M.K. Library, University of Calicut, and the similarity index found within the permissible limit. I also declare that the thesis is free from AI generated contents.

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ABBREVIATIONS

ANOVA	Analysis of Variances
CAGR	Compound Annual Growth Rate
CBD	Convention on Biological Diversity
CESS	Centre for Economic and Social Studies
DES	Department of Economics and Statistics
DPSIR	The Driver-Pressure-State-Impact-Response
EPA	Environmental Protection Agency
ESBI	Ecosystem Services Benefit Index
ESS	Ecosystem Services
ETOI	Ecosystem Trade off Index
FAO	Food and Agricultural Organisation
GCA	Gross Cropped Area
GIS	Geographic Information System
GOI	Government of India
GOK	Government of Kerala
IPBES-NCP	Intergovernmental Platform on Biodiversity and Ecosystem Services – Nature’s Contribution to People
KFRI	Kerala Forest Research Institute
LULC	Land Use and Land Cover
MEA	Millennium Ecosystem Assessment
MoAFW	Ministry of Agriculture and Farmer’s Welfare
NAAS	National Academy for Agricultural Sciences
NABARD	National Bank for Agriculture and Rural Development
NAS	Net Area Sown
NAU	Non- Agricultural Use
OECD	Organisation for Economic Co-operation and Development
PES	Payment Ecosystem Services
PLS-SEM	Partial Least Squares Structural Equation Modelling
TCA	Total Cropped Area
TEEB	The Economics of Ecosystems and Biodiversity
TGA	Total Geographical Area
UKNEA	UK National Ecosystem Assessment
UNEP	United Nations Environment Programme

ECOSYSTEM SERVICES APPROACH TO THE INTERLINKAGES BETWEEN KOLE WETLAND FARMING AND HUMAN WELLBEING IN KERALA

Abstract

In a world of urbanization, the availability of agricultural land is decreasing and the use of excessive chemicals in agriculture has become a global trend to overcome it. As a result, agro-ecosystem services have been drastically altered. It is crucial to understand the wellbeing of paddy farmers who depend on this agro-ecosystem for their livelihoods. This study investigates the role of wetland agro-ecosystem services in achieving wellbeing of the farmers living in and around the paddy fields. The primary purpose of this research is to explore the mediating role of wetland ecosystem services to obtain different dimensions of wellbeing of the farmers. The objectives of this study include examining the dynamics of paddy land use, analysing the impact of paddy farming practices on different paddy wetland ecosystem services, and assessing their influence on the wellbeing of paddy farmers. A mixed methods approach has been adopted, combining quantitative and qualitative survey data collected from 393 farmer households residing around the Kole wetland area in Thrissur district of Kerala state. To measure the dynamics of paddy land use in Kerala based on land use pattern and cropping pattern, 40 years of time series data have been examined and it has been found that initially paddy fields were converted to perennial crops such as coconut, banana, and rubber and later converted to non-agricultural purposes. It has been found that the same pattern of conversion is observed in the entire Thrissur district and especially in the Kole wetland area. The assessment using CAGR and the Cuddy Della Valle Index found that productivity is increasing in Kerala even as the area under paddy cultivation is decreasing. But productivity is decreasing in the Kole wetlands, even as the area under paddy cultivation has been increasing in recent times. By using the revised Cobb-Douglas production function and cost-benefit analysis, study reveals that although rice farming is profitable, intensive farming practices negatively affect ecological efficiency and also follows diminishing returns in farming. It has been found that the loss of ecological balance via excess chemical input use has led to the tradeoff between provisioning and regulating services while synergy between regulating and cultural services. The study has constructed an Ecosystem Services Trade off supply and Demand Index to assess the supply potential and benefit perception of ecosystem services. It has been found that the expected benefits from ecosystem services exceed supply, leading to overuse of wetlands beyond their capacity. Using the Structural Equation Modelling, the study has found the integration of paddy farming as capabilities and their associated ecosystem services to be

played a significant role in achieving wellbeing of the farmers. The study partially endorses Sen's Capability approach and concludes that paddy farming and the mediating influence of wetland ecosystem services play a critical role in achieving wellbeing to the farmers. The study limited to Kole Wetlands alone, but there exists a scope for comparative analysis with dry lands and future research should explore the nexus between capability-ecosystem-wellbeing under similar ecological conditions across all states.

(Key words: Capabilities, ecosystem services, paddy farming, trade off, wellbeing, wetlands)

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വിശകലനം ചെയ്യുന്ന ആവാസവ്യവസ്ഥാ സേവന സമീപനം

സംഗ്രഹം

നഗരവൽക്കരണം അതിവേഗം പുരോഗമിക്കുന്ന ഇന്നത്തെ സാഹചര്യത്തിൽ കാർഷിക ഭൂമിയുടെ ലഭ്യത ക്രമേണ കുറഞ്ഞുവരികയാണ്. ഇതിന് പുറമെ, കുറഞ്ഞുവരുന്ന കാർഷിക ഉൽപാദനക്ഷമത മറികടക്കുന്നതിനായി കൃഷിയിൽ രാസവസ്തുക്കളുടെ അമിതമായ ഉപയോഗം ആഗോളതലത്തിൽ വ്യാപകമായ ഒരു പ്രവണതയായി മാറിയിട്ടുണ്ട്. ഈ മാറ്റങ്ങൾ കാർഷിക-ആവാസവ്യവസ്ഥകൾ നൽകുന്ന വിവിധ ആവാസവ്യവസ്ഥാ സേവനങ്ങളിൽ ഗണ്യമായ വ്യതിയാനങ്ങൾക്ക് കാരണമായിട്ടുണ്ട്. ഉപജീവനത്തിനായി ഇത്തരം കാർഷിക-ആവാസവ്യവസ്ഥകളെ ആശ്രയിക്കുന്ന നെൽകർഷകരുടെ ക്ഷേമത്തെക്കുറിച്ച് മനസ്സിലാക്കുന്നത് ഈ സാഹചര്യത്തിൽ ഏറെ പ്രാധാന്യമർഹിക്കുന്നു.

നെൽവയലുകളിലും അവയോട് ചേർന്ന പ്രദേശങ്ങളിലും ജീവിക്കുകയും ഉപജീവനത്തിനായി അവയെ ആശ്രയിക്കുകയും ചെയ്യുന്ന കർഷകരുടെ ക്ഷേമം ഉറപ്പാക്കുന്നതിൽ തണ്ണീർത്തട കാർഷിക-ആവാസവ്യവസ്ഥാ സേവനങ്ങൾ വഹിക്കുന്ന പങ്കാണ് ഈ പഠനം പ്രധാനമായും അന്വേഷിക്കുന്നത്. കർഷകരുടെ ക്ഷേമത്തിന്റെ വിവിധ മാനങ്ങൾ കൈവരിക്കുന്നതിൽ തണ്ണീർത്തട ആവാസവ്യവസ്ഥാ സേവനങ്ങൾ വഹിക്കുന്ന മധ്യസ്ഥ പങ്ക് കണ്ടെത്തുകയാണ് ഗവേഷണത്തിന്റെ പ്രാഥമിക ലക്ഷ്യം. ഇതോടൊപ്പം, നെൽഭൂമി ഉപയോഗത്തിലെ കാലാനുസൃതമായ മാറ്റങ്ങൾ പരിശോധിക്കുക, വിവിധ നെൽവയൽ തണ്ണീർത്തട ആവാസവ്യവസ്ഥാ സേവനങ്ങളിൽ നെൽകൃഷിരീതികൾ ചെലുത്തുന്ന സ്വാധീനം വിശകലനം ചെയ്യുക, അതുവഴി നെൽകർഷകരുടെ ക്ഷേമത്തിലുണ്ടാകുന്ന പ്രത്യാഘാതങ്ങൾ വിലയിരുത്തുക എന്നിവയും പഠനത്തിന്റെ പ്രധാന ലക്ഷ്യങ്ങളാണ്.

കേരളത്തിലെ തൃശൂർ ജില്ലയിലെ കോൾ തണ്ണീർത്തട പ്രദേശത്ത് താമസിക്കുന്ന 393 കർഷക കുടുംബങ്ങളിൽ നിന്ന് ശേഖരിച്ച ഗണപരവും ഗുണപരവുമായ സർവ്വേ വിവരങ്ങൾ സംയോജിപ്പിച്ചുകൊണ്ട് മിശ്രിത ഗവേഷണരീതി (Mixed Method Approach) ആണ് പഠനത്തിൽ സ്വീകരിച്ചിരിക്കുന്നത്. ഭൂവിനിയോഗ രീതികളുടെയും വിളവിന്യാസത്തിലുണ്ടായ മാറ്റങ്ങളുടെയും അടിസ്ഥാനത്തിൽ കേരളത്തിലെ നെൽവയൽ ഉപയോഗത്തിന്റെ ചലനാത്മകത മനസ്സിലാക്കുന്നതിനായി 40 വർഷത്തെ സമയശ്രേണി വിവരങ്ങൾ വിശകലനം ചെയ്തു. പഠനത്തിൽ നിന്ന് ലഭിച്ച ഫലങ്ങൾ പ്രകാരം, ആദ്യഘട്ടത്തിൽ നെൽവയലുകൾ തെങ്ങ്, വാഴ, റബ്ബർ തുടങ്ങിയ ദീർഘകാല വിളകളുടെ കൃഷിയിടങ്ങളാക്കി മാറ്റുകയും തുടർന്ന് അവ കാർഷികേതര ആവശ്യങ്ങൾക്കായി പരിവർത്തനം ചെയ്യുകയും ചെയ്തതായി കണ്ടെത്തി. തൃശൂർ ജില്ലയിലുടനീളം, പ്രത്യേകിച്ച് കോൾ തണ്ണീർത്തട മേഖലയിലും സമാനമായ ഭൂവിനിയോഗ പരിവർത്തന പ്രവണത നിലനിൽക്കുന്നതായി പഠനം വ്യക്തമാക്കുന്നു.

സംയുക്ത വാർഷിക വളർച്ചാനിരക്ക് (CAGR), കഡ്ഡി-ഡെല്ല വല്ലെ അസ്ഥിരതാ സൂചിക (Cuddy-Della Valle Index) എന്നിവയുടെ അടിസ്ഥാനത്തിലുള്ള വിശകലനത്തിൽ, കേരളത്തിൽ നെൽകൃഷിയുടെ വിസ്തൃതി കുറയുന്നുണ്ടെങ്കിലും ഉൽപാദനക്ഷമതയിൽ വർധനവ് ഉണ്ടായതായി കണ്ടെത്തി. എന്നാൽ സമീപകാലത്ത് നെൽകൃഷിയുടെ വിസ്തൃതി വർദ്ധിച്ചുവരുന്ന സാഹചര്യത്തിലും കോൾ തണ്ണീർത്തട മേഖലയിൽ നെൽകൃഷിയുടെ ഉൽപാദനക്ഷമതയിൽ കുറവ് അനുഭവപ്പെടുന്നതായി പഠനം കണ്ടെത്തി.

പരിഷ്കരിച്ച കോബ്-ഡഗ്ലസ് പ്രൊഡക്ഷൻ ഫംഗ്ഷൻ (Cobb-Douglas Production function) നും ചെലവ്-ആനുകൂല്യ വിശകലനവും (Cost Benefit Analysis) ഉപയോഗിച്ചുള്ള പഠനത്തിൽ, നെൽകൃഷി സാമ്പത്തികമായി ലാഭകരമാണെങ്കിലും തീവ്രമായ കൃഷിരീതികൾ പാരിസ്ഥിതിക കാര്യക്ഷമതയെ പ്രതികൂലമായി ബാധിക്കുന്നതായും കൃഷിയിൽ നിന്നുള്ള വരുമാനത്തിൽ കുറവുണ്ടാകുന്നതായും കണ്ടെത്തി. പ്രത്യേകിച്ച്, രാസവളങ്ങളും മറ്റ് രാസ ഇൻപുട്ടുകളും അമിതമായി ഉപയോഗിക്കുന്നതിലൂടെ ഉണ്ടാകുന്ന

പാരിസ്ഥിതിക സത്തുലിതാവസ്ഥയിലെ തകർച്ച, പ്രൊവിഷനിംഗ് സേവനങ്ങളും (provisioning Services) റെഗുലേറ്റിംഗ് സേവനങ്ങളും (Regulating Services) തമ്മിൽ ഒരു ട്രേഡ് ഓഫിനും (Trade off), റെഗുലേറ്റിംഗ് സേവനങ്ങളും (Regulating Services) സാംസ്കാരിക സേവനങ്ങളും (Cultural Services) തമ്മിൽ ഒരു സിനർജിക്കും (Synergy) കാരണമാകുന്നതായി പഠനം കണ്ടെത്തി.

ആവാസവ്യവസ്ഥാ സേവനങ്ങളുടെ ലഭ്യതയും അവയിൽ നിന്ന് ലഭിക്കുമെന്ന് പ്രതീക്ഷിക്കുന്ന നേട്ടങ്ങളെക്കുറിച്ചുള്ള കർഷകരുടെ ധാരണയും വിലയിരുത്തുന്നതിനായി പഠനത്തിൽ ഇക്കോസിസ്റ്റം സർവീസസ് ട്രേഡ്-ഓഫ് സപ്ലൈ ആൻഡ് ഡിമാൻഡ് ഇൻഡക്സ് (Ecosystem Services Trade-off Supply and Demand Index) വികസിപ്പിച്ചു. ഈ വിശകലനത്തിൽ നിന്ന്, ആവാസവ്യവസ്ഥാ സേവനങ്ങളിൽ നിന്ന് കർഷകർ പ്രതീക്ഷിക്കുന്ന നേട്ടങ്ങൾ അവയുടെ നിലവിലുള്ള വിതരണശേഷിയേക്കാൾ കൂടുതലാണെന്ന് കണ്ടെത്തി. ഇത് തണ്ണീർത്തടങ്ങളുടെ സ്വാഭാവിക ശേഷിക്കപ്പുറമുള്ള അമിതമായ ഉപയോഗത്തിലേക്ക് നയിക്കുന്നതായി പഠനം സൂചിപ്പിക്കുന്നു.

കൂടാതെ, ഘടനാപരമായ സമവാക്യ മോഡലിംഗ് (Structural Equation Modeling-SEM) ഉപയോഗിച്ചുള്ള വിശകലനം, കർഷകരുടെ ക്ഷേമം കൈവരിക്കുന്നതിൽ നെൽകൃഷിയിലൂടെ ആർജ്ജിതശേഷികളും അതുമായി ബന്ധപ്പെട്ട ആവാസവ്യവസ്ഥാ സേവനങ്ങളും തമ്മിലുള്ള സംയോജിത പങ്ക് നിർണായകമാണെന്ന് വ്യക്തമാക്കുന്നു. കർഷകരുടെ ക്ഷേമം കേവലം സാമ്പത്തിക നേട്ടങ്ങളുടെ ഫലമല്ലെന്നും, നെൽകൃഷിയുമായി ബന്ധപ്പെട്ട സാമൂഹിക, പാരിസ്ഥിതിക, സാംസ്കാരിക, ഉപജീവന ഘടകങ്ങളുടെ പരസ്പരബന്ധം അതിൽ നിർണായക സ്വാധീനം ചെലുത്തുന്നുവെന്നും പഠനം ചൂണ്ടിക്കാണിക്കുന്നു.

ഈ പഠനം അമർത്ത്യ സെന്നിന്റെ ശേഷിസമീപനത്തെ (Capability Approach) ഭാഗികമായി ഉൾക്കൊള്ളുകയും, നെൽകൃഷിയിലൂടെ ആർജ്ജിതശേഷികളും തണ്ണീർത്തട ആവാസവ്യവസ്ഥാ സേവനങ്ങളുടെ മധ്യസ്ഥസ്വാധീനവും കർഷകരുടെ ക്ഷേമം കൈവരിക്കുന്നതിൽ നിർണായക പങ്കുവഹിക്കുന്നുവെന്ന് നിഗമനം ചെയ്യുന്നു. അതിനാൽ, തണ്ണീർത്തട നെൽകൃഷിയുടെ സുസ്ഥിരത ഉറപ്പാക്കുന്നതിനായി സാമ്പത്തിക ഉൽപ്പാദനക്ഷമതയ്ക്കൊപ്പം പാരിസ്ഥിതിക സത്തുലിതാവസ്ഥയും ആവാസവ്യവസ്ഥാ സേവനങ്ങളുടെ സംരക്ഷണവും ഒരുപോലെ പരിഗണിക്കേണ്ടതിന്റെ ആവശ്യകത ഈ പഠനം വ്യക്തമാക്കുന്നു.

കോൾ തണ്ണീർത്തട മേഖലയെ കേന്ദ്രീകരിച്ചാണ് ഈ പഠനം നടത്തിയിരിക്കുന്നത്. എന്നിരുന്നാലും, സമാനമായ വിശകലനം കരനെൽകൃഷി (Drylands/uplands) താരതമ്യപ്പെടുത്തുന്നതിനു കൂടുതൽ വിശാലമായ ഗവേഷണസാധ്യതകളുണ്ട്. ഭാവിയിലെ പഠനങ്ങൾ കേരളത്തിലെ വിവിധ പ്രദേശങ്ങളിലും ഇന്ത്യയിലെ മറ്റു സംസ്ഥാനങ്ങളിലുമുള്ള സമാനമായ പാരിസ്ഥിതിക സാഹചര്യങ്ങളിൽ ശേഷി-ആവാസവ്യവസ്ഥാ സേവനങ്ങൾ-ക്ഷേമം (Capability- Ecosystem Services – Wellbeing) എന്നിവ തമ്മിലുള്ള പരസ്പരബന്ധം കൂടുതൽ ആഴത്തിൽ പരിശോധിക്കേണ്ടതുണ്ട്. അത്തരം പഠനങ്ങൾ സുസ്ഥിരമായ കാർഷിക നയങ്ങൾ രൂപപ്പെടുത്തുന്നതിനും തണ്ണീർത്തടങ്ങളുടെ സംരക്ഷണത്തിനും കർഷകരുടെ ദീർഘകാല ക്ഷേമം ഉറപ്പാക്കുന്നതിനും വിലപ്പെട്ട സംഭാവന നൽകുമെന്ന് പ്രതീക്ഷിക്കാം.

(പ്രധാന വാക്കുകൾ: ശേഷിസമീപനം, ആവാസവ്യവസ്ഥാ സേവനങ്ങൾ, നെൽകൃഷി, ട്രേഡ് ഓഫ്, ക്ഷേമം, തണ്ണീർത്തടങ്ങൾ)

Chapter I
Design of the Study

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DESIGN OF THE STUDY

1.1 Introduction

Wellbeing is an engine of human flourishing. It is not just feeling of good health and happiness among individuals, but is also the cornerstone of creating a more social progress, equity and resilient in a sustainable society. Among OECD countries, beyond GDP, wellbeing is measured across different dimensions such as housing, income, jobs, education, health community, life satisfaction, environment, safety and work life balance. In India, wellbeing emphasises on community resilience and rural livelihood which enable policies to linking farmer welfare to sustainability. Agricultural sustainability, food security and rural livelihood are directly depending on the wellbeing of the farmers. Wetland farming is a wellbeing strategy by linking ecological services with farmers livelihood.

Wetlands, particularly paddy wetlands, are both a food production hub and an ecosystem, which ensures wide range of services to support human wellbeing. These ecosystems are unique socioecological settings where natural resources, ecosystem functions and human wellbeing are interrelated. The paddy wetland ecosystem is not only valued in terms of traditional paddy production, but also their vital contributions in ecosystem services. Ecosystem services are the direct and indirect benefits obtained from ecosystem functions of nature. The circumstances and activities that take place in natural ecosystems are known as ecosystem functions (Daily, 1997) which are perceived to support human wellbeing (Costanza et al., 1997). Food, natural fibres, supply of clean water, pest and disease regulation, medicinal substances, recreation, and protection from natural hazards such as floods are examples of ecosystem services. These services are classified as provisioning, regulating, and cultural services (MEA, 2005) that directly affect the wellbeing of the people and supporting services needed for production and maintenance of other services (DeGroot et al., 2002). Such ecosystem services are indispensable to the wellbeing of the people everywhere. However, many of these marketed and non-marketed ecosystem services are neglected in agricultural policies that prioritised short term productivity than sustainability.

The ecosystem services approach is a multidimensional framework which evaluates the multiple benefits an ecosystem contributes to create an ecological link with socio economic wellbeing. This approach offers a framework for comprehending the intricate relations that between people and the natural world and emphasizes the necessity of sustainable resource

operation to guarantee the long-term viability of these benefits. By assessing the interlinkages between different ecosystem services including provisioning, regulating, supporting and cultural services, this approach highlights the role of wetland farming to support rural livelihoods. These wetland ecosystem services have been contributing significantly to sustainable agricultural practices and promoting environmental resilience and enhancing the overall wellbeing of the people.

Wetland ecosystems are the most productive ecosystems on Earth (Ghermandi et al., 2008), which give multiple services to society (Brink et al., 2012). The ecosystem services analogous as provision of drinking water, flood tide drift control, source of energy for water boiling, water for husbandry, can have a dramatic impact on the health and wealth to the people (Horwitz et al., 2012). India has wetlands with an aggregate swamp area of 15.3 m ha, counting for nearly 4.7 per cent of the total geographical area of the country (Murthy et al., 2013; National Wetland Atlas, 2013).

Wetland farming is a traditional agricultural system that has been practiced for centuries in the Kole wetland area of Kerala. This farming system is characterized by the cultivation of crops in the wetland areas, which are flooded during the rainy season and drained during the dry season. The ecosystem services approach provides a useful framework for understanding the benefits that this farming system provides to both the environment and the people who depend on it. Some of the key ecosystem services provided by Kole wetland farming include the provision of food and fibre, the regulation of water flows and nutrient cycling, and the maintenance of biodiversity and ecosystem stability. Additionally, this farming system provides important cultural and recreational benefits, as well as supporting local livelihoods and contributing to regional economic development.

However, in recent years, these wetlands have been facing increasing challenges such as conversion of land, climate variability, soil erosion and water scarcity. Over the past forty years, pollution, increased agricultural production, and urbanization have caused India to lose over one-third of its natural wetlands. We are losing wetlands at a rate of 2 to 3 per cent each year. The main causes of this decline are overfishing, agriculture, deforestation, invasive species, climate change, water drainage, land encroachment, and urban development. This problem became aggravated by the intensive farming practices of land.

Since the Green Revolution we adopted intensive farming practices which have been significantly contributed to increasing food production and rural livelihoods. The use of high

yielding varieties of seeds, irrigation, and chemical fertilizers have helped to increase agricultural productivity, and have made India largely self-sufficient in food production. Food grain production of India has increased from 50.8 million tonnes in 1950-51 to 303.3 million tonnes in 2019-20 (MOAFW, 2021). The adoption of these intensive farming practices has led to significant increases in income for farmers in India. The average income of farmers who adopted intensive farming practices increased by 49 per cent over a five-year period, compared to an increase of 20 per cent for farmers who did not adopt these practices (NABARD, 2018). The use of high yielding varieties and irrigation, has led to significant increase in crop yields in the state of Kerala. The average yield of paddy increased from 2,429 kg/ha in 1980-81 to 4,227 kg/ha in 2014-15 in Kerala (KSPB, 2016). However, the resource intensive ways of wetland farming have raised serious sustainability issues related to increasing stress on water resources, desertification and land degradation, climate change and biodiversity loss which pose major threats to farmers and local population living in and around the wetland. The excessive use of chemical fertilisers and pesticides in farming led to soil degradation and loss of fertility. The extent of depletion of soil fertility was estimated to be 33 per cent of the cultivated land in India and loses over 5.3 billion tonnes of soil every year due to soil erosion (SoER, 2019). The widespread use of pesticides and herbicides can have negative impacts on pollinators and other beneficial insects. The National Bureau of Soil Survey and Land Use Planning reported that India has lost 38 per cent of its natural habitats between 1980 and 2010. Intensive agriculture practices have negative impacts on biodiversity in Kerala, as they often involve the clearing of natural habitats for cultivation and the use of monoculture farming practices. High levels of water for irrigation in farming have led to the depletion of groundwater and reduced the availability of water for other uses. The excessive use of water in intensive farming creates water shortage in more than 60 per cent of districts in India (CGWB, 2013). Further, 32 per cent of the monitored river stretches in India were categorised as polluted due to excess nutrient and pesticide contamination (CPCB, 2018). The agricultural runoff is one of the major contributors to water pollution in the state, leading to eutrophication and algal blooms (Bijukumar, 2014). These pressures on wetlands threaten the ecosystem services and socio-economic stability of the farming households. The occurrence of trade-off between ecosystem services is very common in wetlands due to this intensified nature of farming. The increase in paddy crop, a provisioning service produced through intensive farming practices, has negative or positive impacts on other ecosystem services.

The ecosystem services contributed by wetlands either directly or indirectly contributed to different dimensions of wellbeing. Based on ecological or environmental perspective, wellbeing has several dimensions including basic materials for life, health, social relations, security and freedom of choice (MEA, 2005). For example, provisioning services like food products provide basic materials for the people directly and nutrients as health services indirectly. In the similar fashion, the ecosystem services provide many contributions to all these dimensions. Similarly different people receive benefits of ecosystem services differently. The extent to which individuals receive different benefits depends on their understanding of importance and access of ecosystem services. The understanding of such differences is attributed to their capabilities. Capabilities enable individuals to produce and access the ecosystem services and their benefits (Fisher & Eastwood, 2016). For example, according to Chaudhary et al. (2018), the accessibility of food crops is higher for arable land owners, which improves their wellbeing. The individual competencies or capabilities such as farming knowledge, ecological knowledge, and above all their basic capabilities such as age, ownership of land, house property and education, with varying degrees impact their wellbeing. Thus, the study of capabilities and their role of accessing ecosystem services to promote their wellbeing is significant in the context of wetland farming.

The Kole wetlands which form one of the rice granaries of Kerala are the important type of wetland settings in central Kerala, India. It is one of the largest unique wetland ecosystems in the state and is known for its traditional paddy farming practices. This wetland supports various types of livelihood activities which are sometimes in conflict with each other. However, with the increase in human population, intensified methods of farming and developmental activities, the Kole wetland ecosystem has been facing severe threats, which has led to the degradation of its ecosystem services. The present study explores the interlinkages between paddy farming and their impact on wellbeing of the farmers through an intermediate effect of ecosystem services. The understanding of the complex relationships between human societies and the natural environment in the realm of wellbeing can provide critical insights for designing the sustainable agricultural practices and policies in the region. The ecosystem service approach aims to identify the ecosystem services functions, assess the farmers perceptions on these services, and evaluate the impact of these services on wellbeing dimensions of farmers. This research seeks to contribute the nexus between farming, ecosystem and wellbeing in the context Kole wetland paddy farming.

1.2 Background of the study

Wetland paddy agroecosystem services are the important human made wetland systems which provide direct and indirect benefits to both wetlands and agriculture (Turner et al., 2000). Fish and fiber, food, water supply, water purification, climate regulation, flood control, coastal protection, recreational activities, and, increasingly, tourism are just a few of the many ecological services that these wetlands offer to enhance human wellbeing (MEA, 2005). Kole wetlands, located in Thrissur district, central Kerala, is a paddy farming ecosystem which ensure food security and rural livelihoods. Among wetlands, Kole wetlands are the part of Vembanad-Kol, a Ramsar site of international importance, is a multifunctioning productive ecosystem landscape which is located below the sea level of Kerala. This area supports provisioning services including extensive paddy production, local fisheries, livestock; regulating services including flood control, ground water recharge, and carbon sequestration; cultural services including aesthetic and recreational activities. However, environmental and socio-economic pressures resulting from population growth, urbanisation, land conversion, uncontrolled sand mining, and intensive farming practices have posed a major threat to the paddy cultivation and associated ecosystem services provided by the Kole wetlands.

To counteract these challenges and intension to continue the farmers in paddy cultivation to support ecological value of wetlands, state adopted several policies to prevent land conversions like Kerala Conservation of Paddy Land and Wetland Act of 2008 and even paid royalty payments of Rs. 2,000 per hectare to organic paddy landowners in 2020-21. Despite these interventions, to earn short term earnings from land as compensation to reduced paddy land holdings, farmers adopted intensive and over use of chemical inputs like fertilisers and pesticides in paddy cultivation to increase their productivity. The excessive use of chemical inputs not only leads to a decline in paddy yields over the years but also affects the ecosystem services due to decrease in soil quality, water pollution, damage aquatic ecosystems, and has an impact on human health and wellbeing. Furthermore, the paddy land conversion and the overdose of chemical inputs create an ecosystem services trade off – where the short-term increase in one service affects the long-term sustainability of other ecosystem services negatively. These interrelationship (trade off or synergy) of ecosystem services directly affects the wellbeing of the farmers because they heavily depend not only for their income and food security but for other ecological services like cultural and regulating services.

The ecosystem services approach provides a better understanding of the interrelationship between farming and the countervailing effects on ecosystem services trade off and wellbeing of farmers which is suitable for balancing agricultural productivity and ecosystem services resilience with sustainable livelihood. However, the assessment of economic or material dimensions of farmers livelihood is insufficient to express the wellbeing of the people. Instead, capability approach introduced by Amartya Sen is adopted to attain a broader perspective on wellbeing focusing on individual's real freedom and opportunities i.e., *what they are able to be and do*. This study integrates the ecosystem services approach with the capability approach and comprehensively assesses the impact of paddy farming on human wellbeing. The findings of this study will be crucial for guiding future agricultural policies, land use planning, and conservation initiatives in paddy farming regions.

1.3 Review of Literature

Kole wetlands are an important agricultural landscape in the Indian state of Kerala, where they provide a range of ecosystem services that are essential for human wellbeing. A review of the literature on wetland agroecosystem services examines the key details of the many facets of ecosystem services and how they relate to human welfare globally. Furthermore, a thorough analysis of these studies at the international, national, and state levels highlights the topic's scope and applicability as well as the areas that require further investigation. This literature review examines initially the studies on land use change and their impact on area, production, productivity of paddy crops and ecosystem services, followed by the interlinkages between farmers capabilities, Kole wetland farming and human wellbeing from an ecosystem services perspective.

1.3.1 Studies on Land Use Changes

The literature on land use changes has recognised the pattern of changes in lands, specifically wetlands and their impact on crop production and ecosystem services.

Assefa et al. (2021) investigated the effects of land use and land cover change on wetland ecosystem service in the peri urban and urban area of Bahir Dar city, Ethiopia by utilising Arc GIS input. This study examines the patterns of land-use/land-cover (LULC) change over a 35-year period (1984–2019) in order to assess its effects on the values of wetland ecosystem services. The study discovered that while built-up area increased, wetlands and water bodies in the city and its surroundings decreased. Since 1994, cultivated land has also gradually

decreased. The overall Ecosystem value had decreased as a result of changes in LULC. The poor community's way of life and the local climate are negatively impacted by the loss of ecosystem services value that leads to LULC changes.

Nedd et al. (2021) examined the reasons behind LULC changes by a meta study on definitions and challenges of land use/ land cover. The study result pointed out that rapid population growth, migration, and the conversion of rural to urban areas were the major factors of land use change.

Hasan et al. (2020) made a review of how different types of ecosystem services are affected by land use change and their consequences for human wellbeing. Due to discrepancies between agricultural production and hydrological systems, the study review looks at how land use change affects the supply of ecosystem services, supporting, and regulating services on cultural services. The study concluded that most of the literature accept the conclusion that there is a negative impact on ecosystem services by the changes in land use.

Land use change is a major determinant of ecosystem change because it affects the system's structures, processes, and functions (Chen et al., 2019). Anthropogenic land use activities contribute significantly to ecosystem degradation.

The land use changes due to urbanisation, population growth and high demand of food and fibre experiencing conversion, degradation and changing ecosystem (Fu et al., 2017) and hence ultimately affecting the provisioning services of ecosystem services (Rijal et al., 2018; Keeler et al., 2019).

Lee-Gammage (2018) pointed out that the conversion of a piece of land use by humans from one purpose to another is referred to as land use change. Land can be converted from cropland to grassland, or from wild land (for example, tropical forests) to human-specific land uses (e.g., palm oil plantations).

Fox et al. (2017) used a combination of remote sensing, quantitative surveys, and semi-structured interviews to examine changes in agricultural land use in Kerala between early 2000 and 2003. These mixed methods research consistently revealed a general decline in Kerala's agricultural sector. According to these two methodological approaches, the loss of wetland in all rice-growing regions was accompanied by a widespread increase in built surfaces in every panchayat, which was further suggested to be the most noticeable change. The most severely

impacted crops were rice, pepper, and cashew, with over 75 per cent of respondents either reducing production or giving up on cultivation altogether.

In their analysis of coastal land use changes in Bangladesh, Paul and Rashid (2017) presented both the current uses of coastal land and the temporal fluctuations of these changes. The way humans use land is referred to as "land use" in their study. It represents the economic and cultural activities that occur in a particular location. It is a process through which human actions alter the natural landscape. It refers to how land has been used and is often concerned with the essential role of land within economic activities. It was discovered that Land use change can be a nonlinear process and may cause feedback responses within a system, stress the conditions of life, and may render a person vulnerable.

Devi et al. (2017) examined the role of land use changes and hydrological aspect of ecosystem services to bring welfare. The study was based on primary data gathered through a structured pretested interview schedule from households residing within a distance of 1 5 0 0 metres from the Thrissur Kole ecosystem during December 2013 to May 2014. The land use changes in the ecosystem were assessed by employing the advanced GIS and Remote Sensing software for spatial data and word processing and database management software for non-spatial data. The study results reveal that the built-up area under Kole has steadily increased (5.4 per cent) in 2013. The conversion of Kole lands to the built-up area was intense in the Southern Kole due to the faster pace of urbanization in Thrissur compared to Malappuram. The eighties and nineties witnessed steady and fast shift from paddy cultivation due to social, economic and technical reasons. Over a span of 32 years, the area under paddy land has drastically declined (28.45 per cent decline), while the area of garden land and built-up area has increased subsequently. The study reveals that the declining trend was due to the changes in the tenant-peasant relationships and the changes in the structure of the family system. Shift from the joint family system to the 'nuclear' has increased demand for land for the housing purpose in parallel to the infra structural and industrial demand for land. Absence of effective monitoring mechanism and loop holes in the existing regulations have made it possible to do any kind of alteration to the land.

Pullanikkatil et al. (2016) investigated how changes in land use and land cover affected ecosystem services in Malawi's Likangala River catchment. According to the land use maps, there has been a decline in woodlands and wetlands since 1984 along with rising trends in agriculture. As a result, ecosystem services like those provided by forest products, wild animals

and fruits, and medicinal plants have also been declining over time. Additionally, there was evidence of illegal sand mining, waste disposal, deforestation, and farming on marginal lands degrading the catchment. This change in land use and land cover is a result of population growth, urbanisation, and the demand for agricultural lands. The study recommends using an integrated strategy that takes an ecosystems approach to address catchment degradation. In order to reduce ecosystem degradation in a sustainable manner, it is necessary to address both the immediate and underlying causes of land-use and land-cover change.

In order to create national level LULC maps for India at decadal intervals for 1985, 1995, and 2005, Roy et al. (2015) built a decadal land use and land cover data base for the country. They use satellite images to generate the maps, with a minimum mapping unit of 2.5 hectares. The study discovered a spatial correlation between cropping area and precipitation, which supports the nation's reliance on the monsoon for its agricultural system. Over the past few decades, India has undergone significant Land-Use and Land-Cover Change (LULCC).

Vimod and Kishore (2015) examine the impact of urban sprawl on Land Use in a small part of the Kole wetlands near Thrissur city, Kerala by using open data and open-source tools (satellite imagery) to do spatial analysis. The study focuses on the land use changes from 2005 to 2015 and determine the extent of paddy/wetland lost during this time. The study finds that the unique Kole wetland agroecosystem face severe pressures due to urbanization.

Polasky et al. (2011) identified that land use change is the transformation of the natural landscape as a result of direct human-induced land use such as settlements, commercial and economic uses, and forestry activities. Land use changes have a large impact on the world's ecosystems. Changes in forests, grasslands, wetlands, and other ecosystems, for example, have a substantial impact on ecosystem services, biodiversity conservation, and landowner returns.

Srinivasan (2011) studied land use changes in the Kole wetlands from 1981 to 2007 with the help of Survey of India toposheets and IRS imagery. The study finds that between 1981 and 2007, the extent of paddy fields in the southern Kole alone has decreased from 181.63 km² in 1981 to 135.85 km² in 2007. Most of this decrease in paddy fields is accounted for by a corresponding increase in mixed crop and built-up land, with a small but significant increase in water-logged areas indicating fallow land.

Mendoza et al. (2011) made a study on land use change processes in watershed level in the Lake Cuitzeo Watershed, Mexico over a 28-year time period (1975–2003). Multitemporal analyses were made to analyse the land use change (LUC) and opine that one of the major

forces influencing changes in human activity and the natural environment is land use change (LUC), which must be precisely quantified to comprehend the effects of such changes.

Altieri (2009) opined that the dynamic nature of human-managed landscapes, which experience changes at multiple scales and not always at the same time, makes measuring land-use/cover change (LUCC) challenging. This is particularly true of tropical landscapes in developing nations, where agricultural land holdings frequently have small sizes and a variety of agricultural practises. The selection of crops in these landscapes, which can be based on markets, available technologies, government incentives, pest prevalence, investment potential, and other factors, can range from subsistence to commercial in nature.

DeFries et al. (2007) examined the land use change in the protected area around the word and opined that significant indicator of how humans interact with the environment is changes in land use and cover, which have a variety of effects on ecosystems and human livelihoods. Protected areas throughout the world are key for conserving biodiversity, and land use is key for providing food, fibre, and other ecosystem services essential for human sustenance.

Kumar (2005) synthesised Kerala's shifting land use paradigms and changing situation. Kerala's agricultural land use changes over the past 50 years have been characterised by a first rise in total cropped area (26 per cent between 1960 and 1969), followed by abrupt changes in the coverage of specific crops. For instance, between 1975 and 2003, the area dedicated to the cultivation of rice fell by 60 per cent, whereas the areas dedicated to the cultivation of coconut, rubber, arecanuts, and banana (plantains) soared by 106, 62, 41, and 96 per cent, respectively, between 1955 and 2000. A paradigm shift in the state's land management is essential, as the study highlighted environmental degradation and the need to mitigate climate change.

Land use changes, according to the US-Environmental Protection Agency (EPA, 2022), occur at a variety of scales and have distinct and cumulative effects on air and water quality, watershed function, waste generation, wildlife habitat extent and quality, climate, and human health. Land development and agricultural uses are the two most important types of land use change. Land development creates impervious surfaces through the construction of roads, parking lots, and other structures, whereas agricultural land uses, such as crop types planted, tillage practices, and various irrigation practices, can affect the quality of water and watersheds, limiting the amount of water available for other uses. Grazing livestock in riparian areas can alter landscape conditions by reducing stream bank vegetation and increasing water temperatures,

sedimentation, and nutrient levels. Pesticide, fertiliser, and nutrient runoff from animal manure can also degrade water quality.

Westbrooks (1998) opined that overgrazing, land conversion, fertilisation, and the use of agricultural chemicals are agricultural land use practises that can promote the growth of invasive plants. These plants have the potential to alter fish and wildlife habitat, contribute to biodiversity loss, and pose health risks to livestock and humans.

Since the 1970s, Kerala has experienced rapid changes in its agricultural land use. Particularly, local land-use scholars have observed a shift away from traditional, species-rich home gardens and towards monoculture and conventional cash-crop agroforestry (Kumar, 2005; Peyre et al., 2006). The biodiversity of managed landscapes is impacted by changes in land use, particularly agricultural intensification. In fact, due to commercialization and fragmentation of land holdings, a significant portion of Kerala home gardens has been transformed into small-scale coconut and rubber plantations or cropping systems with fewer crops. The fundamental cultural significance of tropical agroforestry to rural Keralites would be at odds with a shift towards monoculture-style agriculture, even though it would be consistent with shifts seen in other developing regions (Kumar & Nair, 2004). Another significant change in land use has been the recent conversion of paddy land into straightforward agroforests and other agricultural crops, in addition to the purported shift from traditional to monoculture-style agriculture (Guillerme et al., 2011).

Turner et al. (1995) opine that at different scales, land use is influenced by economic, cultural, political, historical, and land tenure factors. Land cover, on the other hand, is one of the many biophysical attributes of the land that affect how ecosystems function.

In short, the reviewed literatures on land use change emphasised the massive conversion of agricultural land particularly paddy land for other non-agricultural purposes. This land use change affects the paddy production and the loss of ecosystem services provided by the agricultural ecosystem.

1.3.2 Studies on Economics of Paddy production

The reviewed literature about economics of paddy production has emphasised the role of land use changes on cropping pattern, production and productivity of paddy crops and the resource use efficiency in paddy production.

Kumar et al. (2023) investigated the impact of climate change, ecological impact, and carbon footprint on rice crop production in India between 1982 and 2016. These effects are examined using the fully modified ordinary least square (FMOLS), canonical cointegration regression (CCR), and autoregressive distributed lag (ARDL) models. According to this study, there is a long-term connection between climate change and rice production in India. According to the study, environmental impact and carbon footprint encourage long-term rice production. Despite rainfall boosts the productivity of rice crops has a negative long-term impact.

Krishnankutty et al. (2021) examine the sustainability of traditional rice cultivation in Kerala by employing a multinomial logit model and discriminant function analysis to extract the key factors determine marketing behaviour of farmers, and various cost calculations to study the economics of rice business. Traditional cultivators hold the key to sustainable paddy farming because they are packed with superior nutritional, environmental, and local qualities. Even though traditional rice farming was not found to be economically viable, it was profitable when costs for imputed personal labour and owned land were disregarded. According to the study, less educated and old traditional farmers, only use a less marketing channel. The majority of them, however, were content with their farm business. Traditional rice would probably gain momentum in important areas by streamlining the market support system and processing facilities.

Lekshmi and Venkataramana (2020) examined the growth and instability of area and production of paddy since the Kerala conservation of paddy land and wetland Act, 2008. According to the study, wetland paddy cultivation is well suited to Kerala's climate. A structural gap in area, production, and productivity during 2007–08 and 2009–10 was found using the Bai-Perron test, which may be related to the conservation act. It was discovered that both area and production experienced negative compound annual growth rates. For the entire time period, productivity showed a positive growth rate. While area instability remained largely unchanged before and after the break dates, production instability spiked after that date. An exponential growth model was used to forecast the future. The expected area and production showed a declining tendency until 2030. According to projected calculations, the area loss in another 12 years would be around 36,444 hectare and Production would also be lowered to 3,70,795 tonnes.

Biswas (2020) used the Bai-Perron multiple structural break analysis and attempted to comprehend the economic growth of West Bengal. The Bengal economy had two output growth breaks between 1960 and 2014. The first break happened in 1983 and, the second break

occurred in 1993. The first break affected from in the agriculture sector, which was triggered by a change in the political regime and policy prescriptions, while second break from a break in the service sector and a shift in policy paradigm within the same political dispensation. This research looked into the characteristics of distinct growth periods in terms of sectoral composition. The West Bengal economy had transitioned from a low to a medium to balanced growth period, followed by a high growth phase. The period of low growth is marked by agrarian stagnation, slowdown in industry, and political instability. On the other hand, the medium-growth phase was an era of unparalleled agrarian progress and political stability. The tertiary sector expanded rapidly during the second part of the period of high growth, while political instability increased.

Sunitha et al. (2018) investigated growth rate of rice by using time series data from 1986-87 to 2015-16. The data were separated into two periods of fifteen years each for the study, resulting in a total of thirty years of data. Compound growth rate (CGR) and linear growth rate (LGR) of rice crops of 10 Telangana districts were calculated using the exponential model $Y_t = \beta_0 \beta^t e^t$ and LGR was calculated using the linear model $Y_t = \beta_0 + \beta_1 t + e_t$. Growth rate of production was higher than area and productivity growth rates in the state.

Athira and Kumar (2016) made a scenario analysis of rice production in Kerala found that from 1980 onwards, the area under rice cultivation had decreased dramatically. Paddy fields in Kerala had been converted to other uses. Some of the major factors identified in the study for the decreasing trend in rice production and area are technological, economic, social or ecological, and political. One of the options suggested to overcome this deficiency is to promote climate resistant rice varieties.

Hari and Kumar (2016) investigated the evolving trends and factors influencing the shifting of rice cultivation in Kerala, particularly in the Palakkad district. The study found that although paddy only covers 12 per cent of Kerala's gross cropped area, rice is the state's primary food crop. In Kerala, the paddy fields are frequently transformed for other uses. From the 1980s onward, the area used for rice cultivation gradually decreased. The study also emphasizes that seasonal labour shortages, inadequate irrigation systems, and a lack of reliable input supplies are significant causes of shifting rice cultivation. The study also shows that the difference between supply and demand for rice, which was roughly 50 per cent until the middle of the 1970s, is getting wider every year as a result of the extensive conversion of paddy lands for growing other cash crops like coconut, rubber, bananas, etc. or for habitations. The likelihood

of rice yields declining is likely due to an increase in the frequency of droughts and floods as well as an increase in temperatures. According to the study, one strategy for surviving such conditions is to develop and encourage the spread of rice varieties that are less sensitive to such climatic changes.

Maneesh and Deepa (2016), in their study found that downward trend in paddy area, production, and productivity was a source of concern and became a threat to India's food security. Total area under food grains had decreased by 40 per cent since 2001-02. Similarly, area under paddy declined while production and productivity improved. The principal cause for the changing agricultural land is revealed to be the rising cost of cultivation, lack of labor, high cost for input, and so on. The study implies the importance to promote effective planning for cultivation at the village level.

Sreeja et al. (2015) examined the impact of historical trends in land use and climate on agricultural output in a tropical deltaic wetland paddy system in Kuttanad over the course of 48 years (1966-2014). The dramatic shifts in land use in the delta over the past forty years were discovered through supervised classification of Landsat images. The Maximum Likelihood method of supervised classification was adopted for image classification. The Mann-Kendall method is used to test the trends in output, productivity, and climate variables, and the Sen slope method is used to quantify them. The paddy area in the districts of Alappuzha and Kottayam was analysed over time and showed a consistent and statistically significant ($= 0.05$) decline from 1200 sq. km in 1966 to 508 sq. km by 2009. In the four decades, 1973-2014, a total of 100.6 sq.km of wetland paddy area was converted into uplands, either into coconut groves or into homesteads with a mixture of crops in the region. The rate of land conversion is the highest in the Lower Kuttanad region. This study found that in the short term, human-induced land use change influences the delta more significantly than the influence of climate change.

Rejula and Singh (2015) investigated changes in Kerala's land use patterns and cropping trends between 2001 and 2012. For the period (2001–2012), the compound annual growth rate and the Cuddy–Della Valle instability index were calculated to measure the growth and instability of the crops. Each year, the state's crop diversification index was calculated. The study found that areas of land that are considered cultivable waste, fallow other than current fallow, and current fallow experienced positive area growth. Additionally, it was discovered that rubber (1.07 per cent) and banana (1.53 per cent) exhibited the highest rates of positive area growth.

Rice (4.01 per cent), tapioca (3.83 per cent), and plantain (1.01 per cent) among food crops all showed negative area growth.

Leema (2015) studied the economics of paddy cultivation in Kole lands of Kerala. The study used Net Returns Approach to examine the average return per hectare in co-operative and non-cooperative Kole lands and revealed that net profit per hectare is higher in cooperative than non-cooperative farms in Kole lands. The resource efficient in paddy land is estimated by Cobb-Douglas production function and identified that labour, land and fertilisers are more efficient than seed in paddy production. Furthermore, study finds that inorganic fertilisers have made positive influence on paddy production.

Karunakaran (2014) conducted a study on paddy cultivation trends and factors, as well as their impacts on food security of Kerala. The exponential model was used to estimate compound growth rates for the area, production, and yield of paddy for the years 1960–1961 to 2009–2010. The study observed a declining trend in area, production, and yield of paddy in Kerala from 1960-61 to 2009-10 due to crop diversification in favour of non-food crops particularly rubber. Food security is a vital issue in Kerala with a shortage of rice about 40.12 per cent in 1960-61 and it is gradually increased by 83.45 per cent in 2009-10. This will enlarge the supply demand gap and bringing food insecurity in Kerala. The conversion of paddy fields over the past 50 years has reduced the paddy supply of Kerala and increased the gap between supply and demand. The environmental issues such as land degradation, ground water depletion, chemical pollution, etc. are responsible for such a mass conversion of lands towards nonfood crops. The study suggests that the way to improve the rice production situation in the state is to increase the yield. By implementing better technology with adequate, efficient, and effective inputs, yield can be increased. The revenue authorities should strictly enforce the various laws that already exist regarding land use patterns in the paddy sector.

Srinivasan (2012) investigated the rice productivity and economic and ecological sustainability of selected *Padasekharams* in Kole lands, using the Cobb Douglas production function to estimate the input use and yield level of rice, as well as the net returns from rice cultivation, and discovered that their production is subject to diminishing returns to scale, making it uneconomical for farmers. Paddy yields are kept high through judicious and excessive use of chemical inputs, which is greater than the national average. This posed a danger to paddy cultivation's long-term viability. Intensified agricultural practices, the transition from subsistence to commercial fishing, and infrastructure development have resulted in trade-offs in other aspects of wetland's ecosystems, negatively affecting farming's ecological sustainability

and facilitating land conversion for non-agricultural uses and mining, both of which have put a strain on wetland ecosystem services. This pattern results in a trade-off between the two. The research argued that new agricultural strategies with low input costs are needed.

Ahmad et al. (2011) studied the climate change and its potential effects on food production, water supply, biodiversity, and livelihoods. According to the study, the area under food grain, for example, fell from 126.18 m ha to 122.23 m ha between 1975-76 and 2008-09, while production increased from 121.03 Mt to 234.47 Mt during that time period. The study also found a large-scale fluctuation in the area under cultivation during the Kharif season. The area under Kharif crops cultivation grew from 78.21 million hectares in 1966–1967 to a maximum of 84.14 million hectares in 1983–1984, with some slight variations. However, the area under cultivation has continued to decline since then due to changes in the pattern of temperature and rain fall.

Rahman (2010) examines how changes in agricultural land use in Bangladesh over a 59-year period (1948–2006) have affected crop diversity, productivity, the availability of food, and the environment. The study pointed out that land use intensity has increased significantly over this time due primarily to the widespread adoption of a rice-based Green Revolution technology package starting in the early 1960. Another finding of the study shows that, contrary to expectations, crop diversity has also increased. Furthermore, despite significant increases in the absolute productivity of paddy farming, the decline in productivity caused by the high use of fertilizers and pesticides calls into question the sustainability of agricultural growth. Moreover, the study highlights that, despite crop diversity has increased, it has increased more slowly than expected. Additionally, despite rapid population growth, there has been an improvement in food accessibility, with a shift in dietary energy imbalance in recent years. Lastly, the production environment has suffered due to widespread soil nutrient depletion, which is seen in many agroecological regions. The study recommended that crop diversification as a growth strategy for agriculture in Bangladesh in order to increase resource economy, productivity, and farming efficiency.

Rajalakshmi (2006) conducted a study on economic analysis of the shifts in paddy production in Palakkad district of Kerala, and found that the profitability of paddy crops is relatively low compared to other crops, especially plantain crops. It was found that this low profitability and high input costs lead farmers to switch from paddy production to other crops. The net returns approach was used to calculate the economics of paddy production, and a log-linear regression method based on Cobb-Douglas production function was used to estimate the size-productivity relationship of paddy fields and identified an inverse relationship between size and productivity.

From the examination of other factors that caused the change in paddy production, it was found that several complex interrelated factors are responsible for the shift in paddy production.

Job and Nandamohan (2004) tried to investigate the growth pattern of paddy in Kerala in different seasons. The exponential growth model was used to estimate compound growth rates of area, production, and yield of paddy in the three crop seasons for the state. Rice production was estimated using a multiplicative model based on area and yield effects. The findings of the study revealed a substantial negative trend in rice area and production, as well as a considerable positive trend in productivity.

Kannan and Pushpangadhan (1988) conducted exploratory research of Kerala's agricultural deceleration, including two different phases of agricultural growth between 1962–1963 and 1985–1986. The 1960s and early 1970s saw an overall increase in the rate of expansion of area, production, and yield for all crops; however, the pace of growth of aggregate area, output, and land productivity nearly stagnated throughout the mid-70s to mid-80s.

The resource use efficiency of Thrissur Kole lands was studied by Muraleedharan (1987) by using the Cobb-Douglas production function by considering yield per hectare as dependent variable and farm size, human labour, bullock labour, fertilizers and manures as independent variables. The study identified that farmers have not been able to distribute the inputs well, and there appears to be a significant opportunity to increase Kole cultivation profit through the best possible use of inputs.

George and Mukherjee (1986) assessed the growing patterns of rice in Kerala region for time periods such as 1960-61 to 1974-75 as period I and 1975-76 to 1983-84 as period II. These changes were examined throughout the seasons of winter and summer. They covered rice farming areas of all the important districts. Compound growth rate and Regression technique was used to estimate the area and production. To determine the contribution of area and the yield on production changes during the period, an additive decomposition model had been utilised.

Pillai (1967), in his study observed the resource inefficiency in paddy cultivation in Kerala. This conclusion has been drawn from the Farm Management studies of 1962-63, 1963-64 and 1964-65. Cobb-Douglas production function was used to fit the resource efficiency of farm land, human labour, bullock labour and farmyard manure and fertilisers as independent variables.

Schultz (1964) in his work '*Transforming Traditional Agriculture*' presume that traditional

farmers are profit maximisers. With the aid of Cobb-Douglas production function, study chooses the output and input combination that maximizes profits in a given price of all inputs. Schulz's study deals with allocative efficiency rather than technical efficiency. He argues that traditional agriculture often allocates resources in an effective manner. The framework thus offers a foundational lens for evaluating agricultural modernization strategies, but this will not take place unless farmers have an incentive to do so. The central element of this theory focuses on the abilities of the farmers.

In summary, the reviewed studies on rice production and productivity show that rice production and profitability are lower than other crops, and therefore the extent of paddy land conversion is large. The reviewed studies show that input efficiency improves even as fertiliser use and costs increase. However, rice production operates under conditions of diminishing returns to scale.

1.3.3 Studies on Ecosystem Services and Agriculture

Ecosystem Services (ESS) are benefits that humans freely obtain from natural environments and ecosystems, which contribute to human wellbeing. The people obtain a variety of tangible and intangible benefits from ecosystems (MEA, 2005). The Millennium Ecosystem Assessment classified these benefits as provisioning services, regulating services, supporting services and cultural services (Alcamo et al., 2003). The economic, social, and ecological contributions of ecosystems to humans are referred to as Ecosystem Services (DeGroot et al., 2012; Müller & Burkhard, 2012).

Sustainable management system prefers the identification of various ESS and their beneficiaries (Chowdhury & Behera, 2021). The provisioning services of ecosystem services of traditional waterbodies are economically significant. They made an empirical study from West Bengal in India and emphasised that ESS promotes every aspect of human wellbeing and these services were the inputs for human wellbeing.

Hong et al. (2020) used a structural equation model (SEM) and a multiple linear regression model to experimentally build the ecosystem services bundle index by mapping 12 ecosystem services in Zhejiang Province between 2000 and 2015 at the district and county level. They also used Spearman's correlation to examine the link between ESS. Based on the calculation of Ecosystem Services Index, their study discovered that ecosystem services were geographically concentrated and that provisioning and regulatory services have synergy. On a temporal scale, the Ecosystem Services Benefit Index (ESBI) value is unevenly distributed.

The rainfed lowland paddy farming methods provide several ecological benefits in addition to food production (Chivenge et al. (2020). They observed that traditional rice farming strategies helped to regulate water throughout the terrain, as well as nutrient cycling, carbon sequestration, biodiversity preservation, and cultural traditions. Intensive agricultural techniques, on the other hand, are part of the green revolution, and they cause pollution, greenhouse gas emissions, and water contamination while improving output. Furthermore, many individuals in rural areas are affected by waterborne infections. The study concluded that agricultural operations must be managed to safeguard the ecosystem services offered by rain-fed low-land rice crops.

Nayak et al. (2019) evaluated rice farm ecosystem services in Eastern India by assessing the economic value of services in four rice fields chosen at random from each Agro-Climatic Zone (ACZ). The overall economic value of parts of the ESS varied from \$1238 to \$1688 hectare per year, according to a soil sample analysis of regulating, providing, and supporting services. The non-promoted ecosystem, on the other hand, would have a considerably higher value than the marketed one.

Berge et al. (2017) investigated the wetland ecosystem services for sustainable paddy cultivation in Vietnam's Mekong Delta using one-way analysis of variance (ANOVA) and Dunnett's post hoc test for multiple comparisons. The study demonstrates that integrated rice-fish farming and integrated pest management techniques provide sustainable alternatives to intensive paddy farming because of a more balanced use of multiple ecosystem services that are beneficial to the farmers' health, economics, and environment. The report emphasizes that although the Mekong Delta's increasing paddy production during the last 20 years has boosted agricultural earnings and decreased poverty, it has also had negative consequences on human health and the environment. The study found that although paddy was thought to be the most important ecosystem service from paddy fields and related wetlands, a number of other ecosystem services, such as water quality, aquatic animals, plants, habitats, and natural pest enemies, were also thought to be crucial to the wellbeing and means of subsistence to farmers. Furthermore, due to intensive rice farming over the past 15 years, there has been a general decline in all other ecosystem services, and this decline will continue. Most farmers agreed to slightly lower rice yields in exchange for better quality in other ecosystem services.

Langerwisch et al. (2017) used LPJmL's vegetation and hydrology model to analyse the combined impact of climate change and land use change on the delivery of ecosystem services in seven study areas in the Philippines and Vietnam. They discovered that not all services would

be provided in the same way going forward. Under current land use patterns, ecosystem services simulations predicted a decline in rice yields, carbon storage, and sequestration by the end of the century. But this was expected to result in more irrigation water being available. The findings also suggest that, at the expense of native vegetation, land-use change may partially offset the adverse effects of climate change in some regions. Additionally, they discovered consistent trade-offs between carbon storage and irrigation water supply under most scenarios, as well as synergies between rice production and carbon storage. Their findings demonstrate that, in order to manage rice agroecosystems sustainably under climate change, it is necessary to take into account not only the effects of climate change and land-use change alone but also their interactions.

Hoffmann et al. (2014) investigated Ecosystem Services in agricultural lands and found that the increased use of synthetic inputs and intensive farming practices quickly replaced ES, posing a threat to ES maintenance and delivery in agricultural regions. Provisioning service maximisation in agriculture might lead to trade-offs with other ES. At various scales, the loss of an ecological service is absorbed by society. The advantages of ES, on the other hand, frequently accrue to numerous stakeholders at different levels. As a result, long-term ecosystem management strategies are critical to balancing both intra- and intergenerational human needs for various ES.

Natuhara (2013) studied multifunctionality or ecosystem services of paddy rice cultivation in Japan. According to the study, rice fields provide ecosystem services such as groundwater recharge, the production of non-paddy foods, flood control, the prevention of soil erosion and landslides, the mitigation of climate change, water filtration, spatial cultures, and the support of ecosystems and biodiversity. Furthermore, paddy fields and the neighbourhood are home to more than 5000 different species. The relationship between paddy fields and the surrounding environment is crucial for maintaining biodiversity. Modernization and the end of farming have both had an impact on the ecosystem of paddy fields. The study suggests that current conservation initiatives need to be strengthened in order to promote paddy fields' ecosystem functions in line with economic demands of people and their need for a stable food supply.

The flow of ecosystem benefits helps to reduce rural poverty (Sukhdev, 2010). The conceptualisation, indication and quantification of ecosystem services potential, flows and demand are provided by Burkhard et al. (2014). The study estimated the ecosystem services

potential, supply and demand assessments and concluded that ecosystem service potentials of landscapes differ from supply, especially for provisioning ecosystem services.

Ecosystem services contribute to human society and are essential to civilization's survival. Clean water, erosion control, food, climate regulation, recreation, and natural beauty are all provided by the Earth's ecosystems (Daily et al., 1997).

To sum up, literatures showed that agriculture particularly paddy farms provide multifunctional ecosystem services. Qualitatively and quantitatively ecosystem services are estimated by the authors by using several statistical methods at the international and national level. The reviewed literature exposes the significance of ecosystem services to provide wellbeing of the people.

1.3.4 Studies on Ecosystem services Trade Off

Jiang et al. (2022) estimated the temporal trade off among ecosystem services using production possibility frontier. The study emphasised the significance of production possibility frontier to examine the quantification of temporal changes in four key ecosystem services, including water retention, soil conservation, carbon sequestration, and habitat improvement, in five-year periods from 1990 to 2020. The Integrated Valuation of Ecosystem Services and Trade-offs (InVEST) model has been used to assess the quantitative and visual model for ES estimation.

Zou et al. (2020) analysed the ecosystem services trade off within the Millennium Ecosystem services framework. Ecosystem Trade Off index (ETO) was calculated to classify and quantify the trade-offs between provisioning, regulating, cultural and supporting ecosystem services. The ETO ranges from negative infinity to positive infinity, where positive values mean that relative ES_a dominates the trade off, while a negative value means that relative ES_b dominates. The magnitude of trade off level depends on the absolute value of ETO.

In their research, Wang et al., (2019) used a framework in a watershed on China's Hainan Island to integrate Ecosystem Services synergies/trade offs and techniques such as win-win or ES substitutes to match ES supply and demand. Using the SWAT model, the study evaluated the ESSD for farmer human wellbeing without jeopardizing government and stakeholder advantages. Their research indicated that the local agricultural product supply was only 0.65, which was insufficient to fulfil demand. However, other services such as water resources, water purification, soil retention, and flood control, among others, had more supply than demand. Integrated techniques of win-win and ES replacement were used to enhance the supply-demand

ratio of agricultural product provision, and it was discovered that their provisions were improved along with a minor rise in other services.

Vallet et al. (2018) used an interdisciplinary approach to investigate the trade-off between ecosystem services from the landscape to stakeholders, and offered a framework for studying temporal variations in ES and relating socioeconomic determinants to ES demand at various scales. The research was carried out in Costa Rica's upper Reventazón watershed to uncover ES trade-offs. It also contrasted alternative methodologies for measuring ES trade-offs (correlations and production frontiers) and highlighted their importance for various decision settings. The trade-offs between stakeholders in the distribution of ES benefits and engagement in the governance of ES in the watershed region were found in the study.

The demand side of ecosystem services and their trade-offs were assessed (Turkelboom et al., 2018) using a socio-ecological framework, and it was demonstrated that stakeholders and their ecosystem use are at the heart of any trade off analysis. According to them, trade-offs are context-dependent, and one trade-off can trigger another, which is exacerbated when ecosystems are intensively used.

The understanding of complex relationships among ecosystem services such as trade off and synergy is required for sustainable ecosystem functions and resilience. A trade-off is an antagonistic situation in which one quality of something is sacrificed in exchange for another (Cord et al., 2017) whereas synergies are positive association between ecosystem services (Raudsepp-Hearne et al., 2010).

To comprehend the links among multiple ecosystem services, Bennett et al. (2009) suggested a typology of ESS relationships. Their research recognizes that trade-off studies take into account several ESS in the same system, necessitating a broader view of ESS than a single feeding of ESS. The interconnections between various ecosystem services were investigated (Bennett et al., 2015) using the principle of sustainable development to improve human wellbeing through ecosystem services and effectively assessed how benefits are distributed among individuals and stakeholders. The study discovered that the stakeholder's location, access rights, and decision-making access determine who wins and who loses. Human activity in one area influences the mismatch between supply and demand for ecosystem services in the same and nearby locations.

Trade off is a fundamental concept in economics that is particularly relevant in evolutionary contexts (Garland, 2014). In an economic context, a trade-off is typically defined as the opportunity cost, which is the preferred option when making an economic decision. This

concept stems from the notion that resources are scarce, meaning that an individual or group must collectively give up some amount of another scarce good in order to obtain more of one scarce resource (DeGroot et al., 2010). Ecosystem service trade-offs in relation to ecosystem services were considered in the Millennium Ecosystem Assessment Report to be decision-making in ecosystem management to deliberately change ecosystem services (MEA, 2005). On the other hand, The Economics of Ecosystems and Biodiversity (TEEB) considered ecosystem service trade-offs to be how a particular ecosystem service will change in response to changes occurring in another ecosystem service (Sukhdev, 2010).

Castro et al. (2014) examined geographic mismatches among ecosystem services on biophysical, sociocultural, and economic dimensions within a spatial unit and utilized correlation analysis to find trade-offs between ecosystem services on the supply and societal demand sides.

There are also some refined definitions of trade-offs, where interactions of ecosystem services are involved to enhance the supply of a particular ecosystem service at the cost of other ecosystem services (Haase et al., 2012). Trade-offs of ecosystem services are generally involved where human activities enhance the production of a particular ecosystem service at the cost of reduction of the production of another ecosystem service (DeGroot et al., 2010; Elmqvist et al., 2013).

Trade off analysis of ecosystem services helps to find the optimal decision points for balancing the cost benefits associated with different human usages of ecosystem services. The study done by Deng et al. (2016) has given significant light on trade off analysis of ecosystem services at different scales with regard to the perspective of land use. Natural ecosystem services are critical for human development and wellbeing. As a result, while some ecosystem services are prioritised, others are ignored and harmed (Deng et al., 2011).

Ecosystems differ significantly in terms of complexity as well as temporal and geographical variation across various ecological situations. In order to help both practical conservation and economic growth, Tallis et al. (2008) present an ecosystem services framework that identifies the particular trade-offs between various ecosystem service types at various scales. The report emphasizes the central idea of Millennium Ecosystem Assessment report that environmental conditions and human conditions are intimately intertwined. Although they are a noble objective, "win-win" initiatives that help the economy and conservation are challenging to implement.

Analysis of World Bank projects with a double aim of fighting poverty and conserving biodiversity (Haase et al., 2012) showed that only 16 per cent of projects achieved significant success in both areas. Failure to initiate a worldwide monitoring process may threaten the future of working collectively to promote ecosystem services and conservation as well as enhancing human well-being. It can also help scientists and policymakers understand the potential consequences of an unbalanced approach to ecosystem services (Haase et al., 2012).

Power (2010) studied the trade-offs and synergies of agroecosystem services and discovered that agricultural ecosystems contribute provisioning services which critical to human wellbeing. They also offer and consume a variety of different ecosystem services, including regulating and provisioning functions. Maximizing agroecosystem provisioning services can lead to trade-offs with other ecosystem services, but systematic agriculture management approaches can reduce the trade-off and maximise synergies.

Rodríguez et al. (2006) emphasized the need of considering trade-offs among ecosystem services in terms of regional scale, temporal scale, and reversibility. Trade-offs become increasingly unclear and difficult to control when the temporal or geographical scale grows. Chemical fertilisers have enhanced agricultural productivity, but they have the potential to degrade water quality and reduce shrimp and other local fisheries production on a larger scale. Increased agricultural output in one location may have an influence on the ESS of another location (space trade-off), and short-term societal requirements may have an impact on future generations or continue for a long time (time trade-off), and some are lost forever (irreversible). Spatial trade-offs can be simply defined as benefits here and costs there (Ring et al., 2010) which take place geographically between different landscapes. For example, an increase in water productivity due to increased agricultural inputs in the upstream will have an impact on water quality management services and result in expenses downstream (Pattanayak, 2004).

Rodríguez et al. (2006) observed that ecosystem service trade-offs among stakeholders imply that some stakeholders will benefit at the expense of; that is, one individual benefits from a specific ecosystem service at the expense of others. Similarly, United Kingdom National Ecosystem Assessment (UKNEA, 2011) noted that there could be a situation where a change in the quality or quantity of a particular ecosystem service available to some stakeholders could reduce the wellbeing of those stakeholders; that is, the use of the service could lead to a decrease in the wellbeing of the stakeholders.

An interdisciplinary methodological guide was provided (Mouchet et al., 2014) for quantifying ecosystem services associations. In order to quantifying these associations, combined ecological (supply) and socio economic (demand) aspects of ecosystem services relationships was used. The aforesaid combinations create three types of relationships: (1) Supply – Supply; (2) Supply—Demand; and (3) Demand—Demand.

Mengist et al. (2020) in their study perform a meta-analysis of ESS trade-offs and synergies between human and the natural environment. Their research found that provisioning of ESS and their relationship to human welfare are performed well, but that regulatory ESS receives less attention owing to its intangible and difficult-to-measure advantages.

Bennett and Balvanera (2007) observed from their study that in order to meet the growing demand for provisioning services, humans have drastically changed the Earth's surface over the past few decades. This has had a detrimental effect on biodiversity and the current and future generations of many regulating services. According to a related study by Kirchner et al. (2015), agricultural intensification and centralization related to providing ecosystem services for higher macroeconomic output typically reduce or damage other ecosystem services related to ecosystem regulation and maintenance as well as cultural services. This is the typical issue for agroecosystems.

Wang et al. (2015) measured the various ecosystem services in China's Sanjiang Plain between 1992 and 2012 and identified that there were substantial losses of ecosystem carbon stocks and natural habitats with grown food production as a result of widespread land conversion from natural wetlands to cultivated land. They highlight that although ecosystem services promote human wellbeing, it is challenging to balance supply and demand due to their intricate trade-offs or synergies. A paradigm for incorporating ES synergies/trade-offs and strategies ("win-win," "small loss-big gain," and "ES replacement") to enhance ES supply-demand matching is presented by Wang et al. (2019). In a watershed on China's Hainan Island, when local ES supply and demand were drastically out of balance, the architecture was put to the test. Combining the "win-win" strategy (planting rubber with intercropped medicinal plants) with the "ES replacement" strategy (converting some secondary forest into rubber intercropped with medicinal plants) could successfully improve the match between the supply and demand of agricultural product provision (its supply-demand ratio increased from 0.65 to 1.3).

Howe et al. (2014) performed a meta-analysis of the ESS trade-off and discovered that it synergized in the real world, resulting in trade-off win-win situations. According to the studies

examined, there is a trade-off between stakeholders. This trade-off occurred when one stakeholder acted locally and another acted regionally. Stakeholders' perceptions are also contradictory. The research focuses on three key indicators of stakeholder trade-off. First, there is private interest in one or more ecosystem services, particularly winners, while losers have public interest. Second, trade-offs exist between provisioning services, such as paddy, fish, and water, resulting from crop management systems, as well as between provisioning and non-provisioning services. Third, when one of the stakeholders—usually the winner—acted locally, trade-offs seemed to happen more frequently.

There are some studies, which specifically assessed trade-off relationships between ecosystem services, specifically for agroecosystem management. For instance, Swallow et al. (2009) assessed the trade-off between agricultural production and regulating services, such as sediment yield; carbon sequestration by Crossman et al. (2011); and valued agricultural production, and biological conservation at the landscape scale by Barraquand and Martinet (2011).

Dymond et al. (2012) examined the trade-offs between soil erosion control, clean water provision, and climate regulation associated with new *Pinus radiata* forests in New Zealand are investigated using national models. The study examined potential trade-offs between agricultural production and biodiversity benefits and discovered that the benefits of increased biodiversity outweighed the loss of agricultural production returns.

Bryan (2013) synthesises the complex linkages between incentives, land use and ecosystem services and pointed out that changes in agroecosystem service provision have been identified as major drivers of intensive land-use change and management. Changes in land use and management can have an impact on a variety of ecosystem services, with both co-benefits and trade-offs. Multiple incentives can motivate multiple changes in land use and management, and their effects on ecosystem services frequently interact with both synergies and tensions.

Haines-Young et al. (2012) discovered a trade-off between regulating ("habitat diversity") and provisioning ("crop-based production") services. Four ecosystem services—"crop-based production," "wildlife products," "habitat diversity," and "recreation"—are mapped and evaluated using these techniques. Correlation analysis of trade-offs based on mapping only finds interactions between pairs of ecosystem services, indicating that a more integrated perspective on service bundles is required for trade-off analysis among ecosystem services, even though trade-offs and synergies are more commonly found within service bundles.

Raudsepp-Hearne et al. (2010) used cluster analysis to determine the provision of all 12 ecosystem services and grouped the 137 municipalities into six data clusters in order to analyse interactions among ecosystem services. In addition, Haines-Young et al. (2012) used cluster analysis to investigate the trade-offs between the selected services, identifying seven spatially explicit clusters with distinct evolutionary trajectories of ecosystem services.

Nelson et al. (2009) applied stakeholder-defined scenarios of land-use/land-cover change in the Willamette Basin, Oregon, using a spatially explicit modeling tool called Integrated Valuation of Ecosystem Services and Trade-offs (InVEST). They discovered that humans are crucial to agroecosystem management; political practices, socioeconomic incentives, and technological advancements are likely to affect the quantity and quality of ecosystem services, influencing the direction of trade-offs. According to the study, there is little trade-off between ecosystem services and biodiversity protection because high biodiversity scores also had high ecosystem service scores. Commodity production values were greater in more development scenarios, while environmental services and biodiversity protection were lower. Payments for carbon sequestration, however, lessen this trade-off. Natural resource choices may be made more effective, efficient, and defensible by quantifying ecosystem services regionally and analyzing the trade-offs between them.

There are large number of studies reviewed on ecosystem services tradeoff concepts and their measurement. The reviewed literature suggests the existence of different drivers of ecosystem services trade-off or synergies and methods for assessing the ecosystem services association. The majority of the studies estimated the trade-off between different ecosystem services, while only a few studies examined the trade-off within each ecosystem services. Most of the studies used the correlation method, Regression analysis, Production Possibility Frontiers in InVest model and the ESS index to assess the trade-off.

1.3.5 Studies on Capabilities, Ecosystem Services and Human Wellbeing

The reviewed literature presented in this section emphasised the role of capabilities of farmers to achieve wellbeing through ecosystem services. A detailed reviews on capabilities, ecosystem services and wellbeing are presented in a separate Chapter II by incorporating historical background and theoretical framework of the study.

In China's environmentally vulnerable regions, Liu et al. (2024) investigate how individual capacities affect ecosystem services and farmers' wellbeing. The study created an objective and subjective wellbeing measure as well as an importance-accessibility index of environmental

services. By using structural equation model, study examined the relationship between the capabilities, ecosystem services and wellbeing of farmers. The results of the study indicated that capabilities on ecosystem services are directly significant to objective wellbeing but not significant to subjective wellbeing. Similarly, capabilities had significant indirect effect on objective and subjective wellbeing by influencing ecosystem services.

Zhang et al. (2021) conducted a study about linkages between demographic factors, land use, ecosystem services and human wellbeing in Uxin in Inner Mongolia, China. The study used Structural Equation Model to analyse the relationship between these variables. They collected the perceptions and satisfaction of the changes in ecosystem services over the period from 2007 to 2016 from the respondents by using 5-point Likert scale. The result of the study indicated that demographic factors influence the enhanced land use intensity which resulted the increase in provisioning services and a simultaneous decrease in regulating services. Furthermore, regulating services provide more to human wellbeing than provisioning services.

Balasubramanian and Sangha (2021) studied the integration of capabilities and ESS approaches to evaluate indigenous connections with nature in two tribal communities as biodiversity hotspot in India. They identified that the capacities and functions that people acquire from their tribal lands are linked to the wellbeing of two ancient tribal communities. Compared to the Soligas (30 per cent), these ties were significantly stronger for the Kattunayaka tribe (on average, 70 per cent of people agreed that forest ES play a key role in various aspects of their wellbeing). This is because the former are still closely linked to their traditional lifestyles and are appropriately referred to as "the chiefs of the forest."

Osorio-González et al. (2020) looked at the long-term viability of ecosystem services in terms of their ability to improve human wellbeing. They used accessible scientific literature to present a history of the ESS concept as well as a methodology for quantifying ecosystem services. They also talked about how ESS may help with human wellbeing and development goals.

Rendón et al. (2019) performed a case study in Saltmarsh to examine the relationship between ESS and human wellbeing and provided a framework that emphasizes the ESS approach's interconnectedness with nature and human wellbeing. The suggested paradigm established the interrelationship between Ecosystem Services and Dis Services, as well as their trade-offs and their implications for human wellbeing at various intergenerational scales.

Dawson and Martin (2015) used Sen's capability approach to human development to build a technique for measuring the complicated links between ESS and human welfare. Based on

disaggregated data, the study conducted an empirical case study in Western Rwanda. To understand the social complexity in ecosystem services research, different types of values; the differences between people; power relations and their influence on trade-offs; the importance of multiple land-use types in the landscape; and changes at multiple scales and their driving forces were explored.

In their essay "Beyond Benefits?" Polishchuk and Rauschmayer (2012) look at Ecosystem Services through the Capability Approach and provide a multidimensional framework of human wellbeing, opening up a richer debate on human dimensions of ESS in terms of different roles of providing goods and services, as conversion factors, and as elements of the environmental factor affecting personal and social wellbeing.

Daw et al. (2011) advocated for the disaggregation viewpoint of human welfare by applying the ecological service idea to poverty reduction. To investigate the relevance of ES to poverty reduction, the disaggregated analysis may be used geographically using social grouping and the stakeholder analysis and equity weights tools. However, combining ES and human wellbeing does not provide a better understanding of the wellbeing of impoverished and vulnerable people. Because distinct ES may contribute to different aspects of wellbeing, ES was disaggregated to investigate the trade-off.

1.3.6 Studies on Wetland Ecosystem Services in Kerala

Wetlands are highly productive ecosystems that provide a variety of goods and services to living beings. It is a sensitive and adaptable ecological system. They offer a variety of goods and services based on their location. They provide many ecological goods and services, but are under severe stress as a result of land use change, economic growth, urbanisation, agricultural intensification, and other factors (Biswas et al., 2022).

Panikkaveettil et al. (2020) performed research on local stakeholders' opinions on climate change in the Thrissur district Kole wetland and their readiness to pay to safeguard the environment using the contingent value technique. Climate change, as well as saline incursion owing to sea-level rise, were identified as important issues in Kole wetland farms, according to their research. Stakeholders in these domains are typically aware of climate change, although they are not all equally knowledgeable about it. Human involvement and wetlands conversion hurt a negative impact on the ecosystems of the Kole wetlands, which will exacerbate flood-related disasters in 2018. As a result, the government might take steps to mitigate climate change and protect people's lives and livelihoods. The majority of stakeholders are prepared to

pay a fee for the conservation of the Kole wetlands, based on their income levels. The research evaluated the value of ecosystem services but did not explain how the Kole wetland and its ecosystem services affect human wellbeing.

Aravindh et al. (2019) used the Contingent valuation approach to estimate WTP in a sample of 100 households to investigate stakeholders' perceptions of participatory conservation of the Kole wetland in the Thrissur district. The study discovered that stakeholders are aware of the ecological and economic importance of wetlands and are prepared to pay for the ecosystem preservation. Unsustainable agricultural methods, pollution, land reclamation, urbanisation, and climate change were also cited as important issues facing wetland farming. Stakeholder's WTP is mostly determined by their educational attainment, length of residency, income, and property ownership. The study concluded that assessing the value of Kole wetlands in different places is necessary.

In the Kole lands of Thrissur district, Mridula and Devi (2016) evaluated the farmer attitudes of automation in rice cultivation. Most farmers think that mechanisation in rice cultivation reduces labour shortages and high salaries, according to their opinions of the social, economic, and environmental impacts of mechanisation. Aside from that, automation saves time and money, allowing for more efficient and cost-effective production. Mechanization causes a variety of environmental issues such as air pollution, noise pollution, soil deterioration, and so on. However, according to the report, no one is aware of the environmental consequences of excessive automation in rice cultivation.

Agriculture is the primary cause of wetlands degradation, but healthy wetlands and their wise use are critical for long-term food production. Wetland losses are the result of negative impacts on wetlands' key functions. This will disproportionately affect poor families who rely on these bodies of water for domestic purposes, such as water supplies, irrigation, food, and fisheries. Rao (2018) investigated the drivers of ecosystem deterioration and institutional arrangements for their management in the Kuttanad wetland ecosystem of Kerala, discovering that Kuttanad wetlands are productive multiple-use and multiple-user ecosystems with ecological and economic value, providing paddy farming, fishing, tourism, and water to residents, all of which are essential to human wellbeing, health, livelihood, and survival. The study found that home sewage discharge and water pollution are direct drivers of ecosystem deterioration, whereas bad institutional management, such as the Kuttanad package (e.g., the closure of Thannermukkam bund), and the real estate market are indirect drivers.

Aktar et al. (2009) studied the benefits and hazards of pesticides use in agriculture. The study highlighted that pesticides are the quick and affordable solutions for eliminating all kinds of weeds and pests across urban landscapes. However, the pesticides residue in soil, air, surface and ground water contribute environmental contamination which significantly affected the beneficial soil microorganisms, insects, plants, fish and birds. Similarly, the heavy dose of herbicides also impacted negatively on environment. Their study suggested a safer and non-chemical pest control use is a remedy to reduce environmental contamination through pesticides and weedicides.

Using the DPSIR framework, Srinivasan (2010) investigated the environmental parameters of the Kole wetland and discovered the many applications of ecosystem services provided by the Kole wetland, as well as their agricultural interaction. Her study focuses on the characteristics and functions of the Kole wetlands. The Kole lands are part of the Vembanad-Kole wetland ecosystem, which covers 151250 acres and was designated as a Ramsar site in 2002 as one of Kerala's rice granaries. Many off-site and on-site goods and services are available on the Kole lands, some of which are promoted but many of which are not. Some non-marketed off-site activities, such as flood management, groundwater recharge, and nutrient retention, are classified as ecological services. Non-marked services on-site, such as recreational opportunities for locals, habitat and nesting sites for migratory birds, and support of plant and animal diversity, among others, play an important role as functions of the Kole wetlands. According to her, Kole wetlands are shown to assist stakeholders' livelihood activities, however, many households consider it as a wasteland rather than a source of income. As a result, the land is converted to intense agricultural, industrial, or residential usage.

Binilkumar (2010) used a discrete choice experiment to determine the economic worth of the Kole wetlands ecological and economic services. With a sample of 240 families, the study was conducted in the peri-urban region of Kole lands. The study employed logit models to assess stakeholders' preferences for various Kole wetlands qualities and discovered that there is significant variation in preferences for wetland attributes between and across stakeholder groups. According to the findings, stakeholders in the peri-urban region of the Kole wetlands are prepared to pay a significant positive value for the protection and maintenance of these areas on average. The availability of water and recreational activities are the most desired qualities of Kole wetlands, whereas organic farming and bird population are the least desired. He also assessed the change in welfare-based only on qualities, excluding the endowment effect.

1.4 Research Gap

Paddy wetland ecosystem particularly, Kole wetland ecosystem provides multiples of ecosystem services that sustain human livelihoods. Changes in land use patterns and anthropogenic pressures by intensive agricultural practices to increased production have led to tradeoffs between ecosystem services in Kole lands. Understanding of this tradeoff is inevitable for the assessment of wellbeing of the farmers living in and around the Kole wetland area. It is observed that existing studies on wetlands and their agricultural systems based on the net returns approach and the production function approach (Schultz, 1964) mainly focus on land use change, agricultural input efficiency, and the economics of paddy farming, but relatively less emphasis on role of intensive farming approaches, their ecological farming efficiency in wetlands and their resultant trade off. The present study will fill this research gap by analysing the changes in Kole wetland paddy farming practices and their resulting trade off on wetland ecosystem services by the use of quantitative model of Ecological Production Function approach and Ecosystem Services Trade off Index analysis.

Furthermore, most of the reviewed wellbeing assessment studies have used income based or quantitative measures of ecosystem services and wellbeing based on theories including theory of externalities (Pigou, 1920), the theory of sustainability (Brundtland Commission), social welfare theories (Samuelson, 1973), and the monetary valuation of Ecosystem Services (MEA, 2005; Costanza, 1995; and DeGroot, 1992). However, these studies often neglecting the multidimensional aspects of socio-economic wellbeing related to capabilities, freedom and farmers participation. The present study applies an integrated approach of socio-ecological and socio-economic aspects, linking ecosystem approach and the capability approach to study the impact of Kole Wetland paddy farming on the wellbeing of local farmers in relation to ecosystem services. Thus, the study aims to analyse a comprehensive framework of paddy farming, ecosystem trade off and wellbeing of the farmers by using a sound theoretical and methodological modelling.

1.5 Significance of the Study

India has witnessed rapid degradation and loss of wetlands over the decades. In fact, this loss is not merely an ecosystem service crisis, but a developmental crisis, which would lead to food, water and climate insecurity for society. The Kole wetlands are the dynamic socio ecological system which emphasizes the role of environmental and socio-economic aspects of human wellbeing. The existing studies about these wetlands do not cover the role of their ecosystem

services to contribute wellbeing dimensions based on capabilities of the farmers. This study bridges this gap by integrating ecosystem services approach and capability approach among Kole wetland paddy farmers. The integrated approach allows a more comprehensive evaluation of environmental resources of wetlands and their ecological and economic functions to maintain sustainable livelihood. Furthermore, this approach helps the policy makers and wetland managers to link the ecological sustainability and human development. The present study of the interrelationship between paddy farming, ecosystem services and wellbeing with an integrated approach provides an opportunity of multidisciplinary research connecting environmental economics, development economics and sustainability.

1.6 Statement of the Problem

The Kole wetland is the ecologically rich and economically vital and most productive multiple use wetland agroecosystem in Kerala. The farmers and local populations particularly those living near Kole wetlands are highly dependent on these services for their wellbeing. Because of the current state of urbanisation and population growth, these paddy fields have been converted for other agricultural and non-agricultural purposes. This unending conversion of land reduced paddy production had a significant impact on the nation's food security. To increase paddy production and productivity, intensive farming practices such as modern ploughing techniques, chemical fertilisers and insecticides, and high yielding varieties of seeds are used. The inputs, processes and output associated with these intensive farming practises initially increased paddy production but eventually had a significant impact on the ecosystem services provided by paddy lands due to land degradation. The exploitative and unsustainable nature of farming may damage the regulation services which in turn reduce the flow of the provisioning services provided by the ecosystems. The external human pressures may impact the nature of the ecosystems to such a degree that ecosystems can lose its resilience entirely. Such trade-off between ecosystem services has implications on wellbeing of farmers.

The scope of the existing studies was focused to biophysical and economic aspects of Kole wetlands. There were only limited recognitions given to the importance of ecosystem services contributions and their resultant trade off to achieve sustainable livelihoods. Moreover, existing studies failed to recognise the socio-economic dimensions of farmers wellbeing based on their capabilities. If the role of ecosystem services and their trade off remain unrecovered and continues in unsustainable farming, the ecosystem imbalances widen and reduce the overall resilience of the wetland ecosystem which directly and indirectly affect livelihood aspects of

the Kole wetland regions. The narrow perspective of material or monetary nature of wellbeing failed to capture the multidimensional aspect of wellbeing within socio-ecological perspective. Hence, there are pressing needs to assess the interlinkages between paddy farming, capabilities, ecosystem services and wellbeing of farmers in wetland regions. The present study employs an integrated approach of ecosystem and capabilities with the use of Ecological Production Function and Structural Equation Modelling (SEM) to address the sustainable wetland management strategies to achieve ecological balance and wellbeing.

1.7 Objectives

1. To examine the dynamics of Paddy land use in Kerala with special reference to Kole Paddy wetland agroecosystem in Thrissur.
2. To analyse the paddy farming practices and their impact on wetland agroecosystem services in the study area.
3. To discern the wellbeing of the farmers in terms of their capabilities and agroecosystem services contributed by Kole paddy wetland.

1.8 Research Hypothesis

If farmers use their ability, skills, knowledge, and equal opportunities to access resources (capabilities) in farming, then paddy farmers will achieve their wellbeing. However, the intensive farming practices adopted in farming affect the wetland ecosystem services and farm yields, which in turn affect the wellbeing of farmers. Therefore, it is significantly stated that the wellbeing of the farmers depends on their capabilities and the intermediary effect of wetland ecosystem services.

1.9 Methodology of the Study

The study relies on mixed method of research with analytical and theoretical in nature. The multidisciplinary combinations of research methodology at different scales to obtain data and answering the research questions and testing the hypothesis. A pilot survey was conducted to check the suitability of questionnaire. The questionnaire was tested on 50 households selected from South Kole and North Kole area and data were analysed. Based on this experience some modifications were made.

1.9.1 Data Source and Sampling Methodology

The study is based on both primary and secondary data. The relevant secondary data for the analysis of dynamics of land use have been collected from various published sources including Economic Review, reports from Directorate of Economics and Statistics, Kerala, Farm guide, reports from Kerala Civil Supplies Corporation, and other published articles and journals. Additionally, various working papers, annual reports, books and websites have been used for the study.

The primary data were collected from paddy farmers in Thrissur Kule lands of Kerala by using a structured questionnaire. The Kule lands cover around 13,632 hectares in the Thrissur and Malappuram districts of Kerala. Multi stage systematic random sampling method was followed in drawing the sample of farmers for the study. Thrissur Kule lands are found in the Anthikkad, Chavakkad, Cherpu, Chowannur, Irinjalakkuda, Mullassery, Puzhakkal, and Vellangallur block panchayaths. The Ponnani Kule lands are situated in the Perumpadappu and Ponnani block panchayaths of Malappuram district. As a first stage selection, Thrissur Kule lands area was selected from the entire Kule lands of Kerala because it has the largest concentration of Kule lands (71 per cent). The Thrissur Kule ecosystem, which is spread over an area of approximately 54,000 hectares within a 1.5 km radius of the Thrissur Kule land area of 10,152 hectares, has been selected for this study. There are six block panchayaths in this Thrissur Kule land area (Atlas of Kule Lands, 2024). In the second stage of sample selection, Thrissur Kule area is divided into North Kule and South Kule. The North Kule consists of three block panchayaths including Puzhakkal, Mullassery and Anthikkad and South Kule consists of three block panchayaths such as Cherpu, Irinjalakuda and Vellangallur. At this level, it was found that there were 20,658 registered farmers in 10,152 hectares of paddy land in six block panchayaths. Using a Cochran's formula based on the number of known farmers, it was found that 385 were required ($385+8=393$ collected). To obtain more variation and an adequate proportion of all size groups of farmers, samples were randomly selected from the "*Padasekharams*", which are an organised institutional arrangement for paddy cultivation on the Kule land. As reported by the Zilla Kule Karshaka Samiti, there are 122 registered Kule "*padavus*" or "*padasekharams*" in the Thrissur Kule area. Based on the area or size, these *padasekharams* are arbitrarily divided into large (more than 1000 acres), medium (500 to less than 1000 acres), and small (less than 500 acres). From the 18 Krishi bhavans in six Block panchayaths, 18 *padsekharams* were selected in proportion to the size classification of the *padasekharams*. Sample farmers were selected from one large *padasekharam*, 4 medium size *padasekharams*, and 14 small

padasekhrams for the study. In the final stage, based on probability based proportionate sampling method, 393 farmers were selected from the *padasekharms* at random (Table 1.1). Out of the total sample, 252 farmers from North Kole and 141 farmers were from South Kole.

Figure 1.1

Sample Design

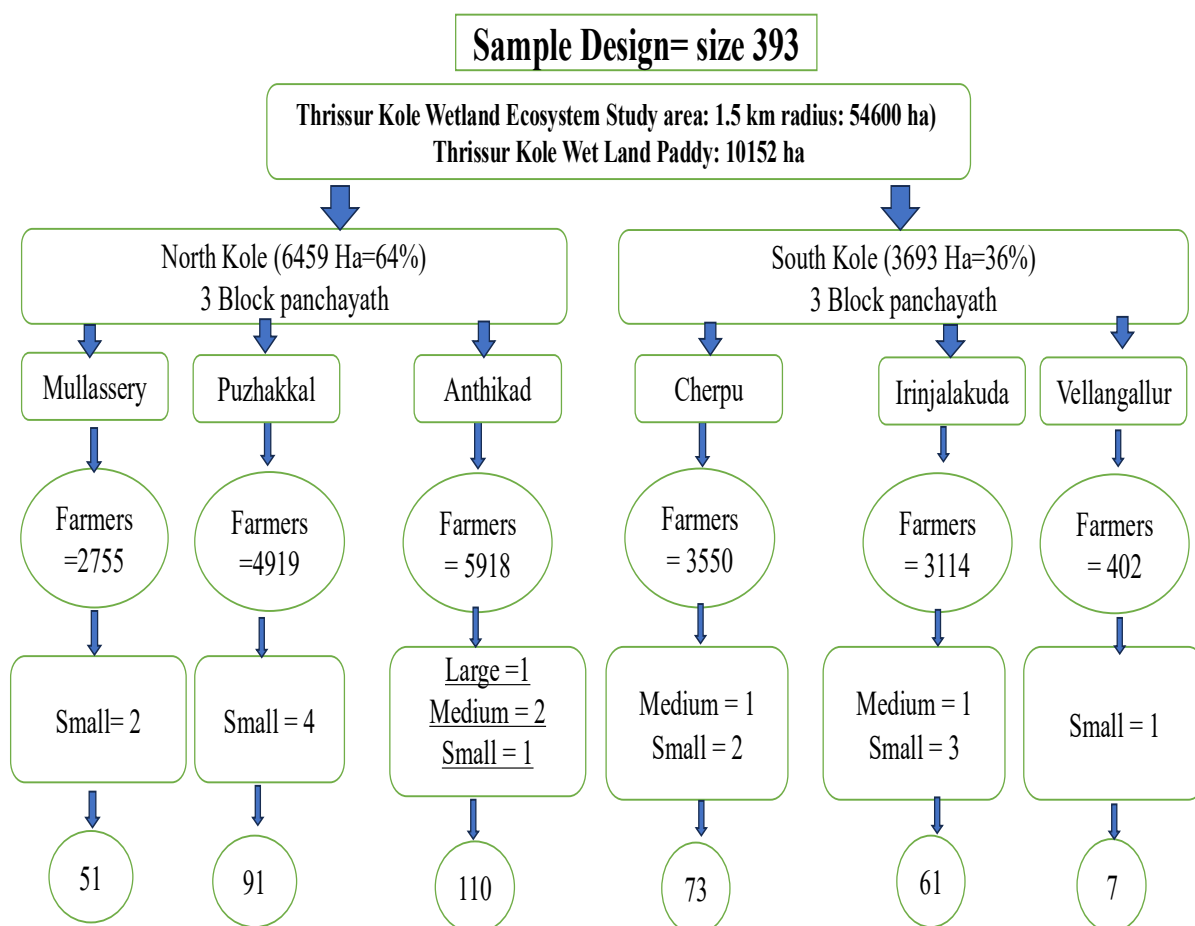


Table 1.1
Distribution of Sample Households

Kole	Block Panchayath	Panchayath/ KrishiBhavan	Padasekharam Name	Area (Ha)	Farmers	Size of Padavu	Sample
North	Mullassery	Mullassery	Madhukkara Thekkumpuram Kole Karshagha Sangham	1255	2755	Small	26
		Venkidangu	Ponnamutha			Small	25
	Puzhakkal	Adat	Onpathumuri	2343	4919	Small	15
		Ayyanthole	Maninadan			Small	12
		Tholur	Sangham Kole South Padavu			Small	40
		Kaiparambu	Mundurthazham			Small	24
	Anthikad	Anthikad	Anthikad Kole Padavu Padasekhara Samithi	2861	5918	Large	53
		Arimpur	Chaladi Pazham Padam			Medium	17
		Chazhur	Variyam Kole			Small	7
		Manalur	Manalurthazham			Medium	33
South	Cherpu	Cherpu	Jubilee Thevarpadavu Padasekhara Samithi	1473	3550	Medium	59
		Paralam	Pandaram Kole Padavu			Small	7
		Koorkanchery	Madamathope Nelkathir			Small	7
	Irinjalakuda	Porathissery	Thekkepadam	1693	3114	Small	7
		Muriyad	Muriyad Kayal Cheppadam			Small	7
		Karalam	Chemmanda Puliyapadam			Medium	40
		Parappukkara	Thamarachal			Small	7
	Vellangallur	Poomangalam	Panchekkal Chira Kakkulam Padam	527	402	Small	7
Total				10152	20658		393

Source: Computed from Kole Land Atlas, 2024 & KLDC, Thrissur

1.9.2 Methods Used

The dynamics of land use pattern were examined by identifying the structural break during the 40 years of farming. Bai - Peron test was conducted to identify the structural break period. The trend, pattern and performance of land use and cropping pattern and the degree of variability within the break period in Kerala and Thrissur were assessed by using the Compound Annual Growth Rate, percentage variation, Coefficient of Variation and Cuddy Della Valle Index.

The economics of paddy farming was assessed by the method of Cost Benefit Ratio and the relationship of output and bio physical and ecological inputs were examined by using the Ecological Production Function which is a modified version of Cobb Douglas Production

Function. Multiple Regression analysis has been used to assess the relationship between ecological services and farm inputs. The Ecosystem Services associations like tradeoff or synergy were estimated by correlation and the method ESS Tradeoff Index.

To assess the level of capabilities, understanding the access of ecosystem services and wellbeing achievements, 10-point Likert scale type opinion or satisfaction measurement was used. The interrelationship between capabilities, ecosystem services and wellbeing was assessed by Structural Equation Model by the use of Smart PLS.

1.10 Concepts and working Definitions Used

1.10.1 Dynamics of Paddy Land Use

Dynamics of paddy land use refers to the changing patterns and trends of paddy fields over the period of time. It identifies the changes in land use and cropping patterns.

1.10.2 Farming Practices

Farming Practices or agricultural practices are the set of systems or methods of input mix to cultivate crops. These practices include: land preparation, sowing, adding manure and fertilizers, irrigation, removing weeds, harvesting, storage, and transportation.

1.10.3 Ecosystem Services

Ecosystem services are the direct and indirect benefits obtained from nature. Ecosystem services included in the study are provisioning services, regulating services, and cultural services (MEA, 2005). Provisioning services include material benefits from Kole wetland ecosystems like paddy, duck, fish, vegetables and livestock. Regulating services are the processes important for human functioning, such as erosion prevention, climate regulation, flood mitigation, soil nutrients regulation, carbon sequestration and moderation of extreme events. Cultural services include aesthetic beauty, recreation, spiritual and religious values, and educational information.

1.10.4 Wellbeing

Wellbeing is “what is ultimately good for a person” (Standard Encyclopaedia of Philosophy) and as good or satisfactory condition of existence; a state characterised by a state of health, happiness and prosperity; and welfare (Dictionary.com). Millennium Ecosystem Assessment (MEA) identifies human wellbeing as a multi-dimensional perspective consisting of basic material for a good life, health, security, good social relations, and freedom of choice and action.

The basic material includes food, shelter, clothing, and access to goods. Health involves feeling well and having a healthy physical environment. Security involves access to resources, personal safety, and protection from disasters. Good social relations involve mutual respect, social cohesion, and helping others. These constituents of human wellbeing in relation to ecosystem services were classified as four categories i.e. provisioning services, regulating services, supporting services, and cultural services.

1.10.5 Trade off/Synergy

Trade off as an antagonistic situation that involves losing one quality of something in return for a gaining another. Trade-off means the negative relation between different ecosystem services provided by Kole wetlands. Synergy means positive relations between different ecosystem services which have impact on human wellbeing. For instance, production of paddy may either increase or decrease duck, and fish. Similarly, their production may negatively or positively affect soil quality, water retention or aesthetic or recreational capacity of the land.

1.10.6 Capability Approach

There are two normative demands in Amartya Sen's Capability Approach, namely the capability to achieve wellbeing and the demand that wellbeing be described in terms of the capability and achieve the functionings. Functioning refers to "doings and beings," that is, the various states of human beings and activities achieved by the person. Capability refers to the true opportunity available to achieve the "doings and beings."

1.11 Organization of the Study

The composition of this study comprises seven chapters. The present introductory chapter deals with the design of the study including review of the existing studies related to the problem under study in different subsections, research gap, statement of the problem under study, methodology and data source, and the limitations of the study.

The second chapter provides a theoretical and analytical frame work of the study. It includes the reviews on theoretical background and the building of a conceptual model based on existing theories of MEA, and Capability approach.

Third chapter provides a comparative analysis of trend and pattern of land use, particularly paddy land use in Kerala and Thrissur. This chapter also explains an overview of the significance of ecosystem services of Kole paddy wetlands in Kerala.

An overview of the Kole Wetland Agroecosystem in Thrissur is given in the fourth chapter. Also, a brief description of the study area and the socio-economic conditions of the sample respondents were included in this chapter.

Chapter five examines the economics of paddy farming in relation to farming practices and net returns from paddy. This chapter includes the impact of farming practice on ecosystem services and the extent of their associations like tradeoff or synergy of ecosystem services.

The sixth chapter discusses the capabilities of the farmers and their role of achieving wellbeing in relation to ecosystem services provided by the Kole wetlands. The structural Equation model is used to examine the complex interrelationship between these potential variables in the study.

Finally, chapter seven elaborates an overall summary of finding of the study, important implications, suggestions and conclusions, followed by references in the study.

1.12 Limitations of the Study

The scope of the study is limited to explore the interlinkages between farming and wellbeing of the farmers. The time series data collected to assess the area, production and productivity of paddy in Kole lands are limited to 2013 to 2023 due to non-availability of data. The evaluation of capabilities, ecosystem services and their impact on wellbeing is primarily based on the perceptions of farmers which are qualitative in nature. The knowledge and perceptions about capabilities and different dimensions of wellbeing involve chance of biasedness among farmers. The weightage given to each ecosystem services can influence the wellbeing and their interlinkage among different groups and individuals is in different ways. This may lead to the generalization of interlinkages. Moreover, definitions of capabilities and wellbeing used in the study are debatable among economists. In spite of all these limitations, the present study is a remarkable attempt to assess the wellbeing of the farmers in the context of ecosystem services of wetlands.

Chapter II

Theoretical and Analytical Background

CHAPTER II

THEORETICAL AND ANALYTICAL BACKGROUND

2.1 Introduction

The present study is designed to examine the role of wetland paddy agroecosystem to provide wellbeing to the society particularly paddy farmers in Thrissur Kole area. In addition, the other problems proposed to study are the changes in land use pattern and cropping pattern, the impact of excessive chemical input and their effects on ecosystem services and their trade off. Some of these problems have been studied globally and nationally by some researchers. This chapter is an attempt to review the historical background and methodological reviews and issues of the existing studies under following heads: -

- a) Studies on Ecosystem services – a historical background
- b) Studies on Wellbeing and Ecosystem Services Approach
- c) Studies on Wellbeing, Ecosystem Services and Capability Approach

2.2 Theoretical approach

The ecosystem services-based approach can provide a theoretical foundation for the study by conceptualising the direct and indirect benefits or value that Kole wetlands provide to human wellbeing. This framework recognises the importance of various services provided by ecosystems, such as food production, water regulation, climatic regulation and cultural services. This study examines how the wellbeing of the farmer community affects the access to and use of ecosystem services contributed by Kole wetland agroecosystem. For that, the study examines the multi-dimensional aspect of wellbeing in relation to Ecosystem services in Kole wetlands in Kerala. The core subject of the study is to analyse the interrelationship between ecosystem services and wellbeing of the farmers using Capability Approach¹. The study applied the Millennium Ecosystem Assessment framework to evaluate the linkage between Ecosystem services and wellbeing on the basis of capabilities and functioning perspective given by Amartya Sen.

¹ “The capability approach has two normative assertions: first, that freedom to attain wellbeing is of pre-eminent moral importance, and second, that wellbeing must be defined in terms of individuals' capability and functioning.” (Stanford Encyclopaedia of Philosophy).

2.2.1 Historical background of the Theoretical framework

The theoretical foundation of the ecosystem services approach was based on Malthusian² perspectives on "general" resource scarcity and how it affects the long-term material well-being of humanity. In their theoretical assertion, Thomas Malthus (1766-1834) and David Ricardo (1772-1823) explained that natural resources are limited and will ultimately impede the advancement of the human economy. Malthus (1798) believed that the major determinant of biophysical limits is exponential population growth, whereas Ricardo (1926) believed that the major attribute of biophysical limits is gradual decrease in land fertility. Recent Malthusian followers (Ehrlich-Commoner model³) regard population, technology, and per capita consumption as the primary determinants of environmental degradation and, ultimately, economic growth limits. However, Hussen (2018) contends that because technical advancement is vulnerable to decreasing returns and malicious technologies are the primary cause of the current environmental disaster, Malthusians are sceptical about technology's capacity to overcome biophysical boundaries.

Modern thinking about importance of environment relate to Optimum use principle of natural resources. The two promising modern theories related to environment were Harrold Hotelling's theory⁴ of optimal use of exhaustible resources (1931) and Arrow's (1974) notion of externalities and their impact on welfare. The environmental economist developed a policy of internalisation of externalities⁵ and use the non-market valuation methods to assess ecosystem services. Finally, the human nature interactions and sustainability are addressed by natural resource economics and ecological economics and use the term 'ecosystem services' to discuss the broad set of contribution of nature to human wellbeing.

Neoclassical economists acknowledge the limitation of natural resources, but they do not think that this reality limits economic expansion. However, they believed that technology will increase the efficiency of resource use and discover a new replacement for natural resources.

² English economist and clergyman Thomas Robert Malthus who proposed the theory of Population.

³ The Ehrlich-Commoner model is a debate-based framework that uses the IPAT where $I=P \times A \times T$. equation relate Environmental Impact (I) to Population (P), Affluence (A), and Technology (T). The model is a debate between Barry Commoner, who emphasized the role of technology, and Paul Ehrlich and John Holdren, who highlighted population and affluence.

⁴ Hotelling's theory is also known as Hotelling rule is an economic framework that predicts how the price of an exhaustible resource determines with an unanticipated discovery of additional resource stock in a perfectly competitive market. The rule that price of a non-renewable resource should increase at a rate equal to the rate of return on any other capital asset.

⁵ Externalities make pricing became impossible with market intervention.

They contend that "specific" or relative scarcity of resources, rather than "general" or absolute scarcity, is crucial and does not restrict growth because of the potential for factor substitution. Neo-classicists, in stark contrast to Malthusians, think that economic expansion is a superior way to address population and environmental issues. It is through understanding that human technological advancement is a prerequisite for overcoming biophysical constraints. The neoclassical growth paradigms stated that human made capital and natural capital were substitutes and will continue the growth process in to the future as the pace of technological progress follows past trends. The extent to which the resource substitution is possible, the exhaustion of resource is not a major alarm (Solow, 1974) and the limits to growth is less meaningful under technological innovation (Rosenberg, 1973).

Unfortunately, historical patterns of technological advancement might not hold true in the future. The technical capabilities were deceptive and even hazardous when taking into account the limitations of energy availability and/or the resilience of natural ecosystems (Georgescu-Raegan, 1986; Arrow et al., 1995).

Ecological Economics⁶, ardent critiques of mainstream economics, criticises the neoclassical growth paradigm of substitutability of human and natural capital as narrow and incomplete perspective of material and immaterial reality. This neoclassical 'growthmania' does not consider neither the biophysical limits nor the intra and intergenerational equities. According to Arrow et al. (1995), ecological systems are finite, which is a resource base of all economic activities that produce a variety of services. But their unwise use irreversibly reduces the capacity to produce goods in the future.

Barbier et al. (1994) opined that the carrying capacity of nature is determined by technology, desires, and production and consumption patterns. They are also dependent on the constantly changing state of interaction between physical and biological settings. Thus, carrying capacity is essential for the sustainable and resilience of the life-supporting ecosystems. These ecosystems produce ecological services which are critical for human wellbeing. The loss of the ecosystem equilibrium reduces the biological productivity and their capacity to support human life. Ecosystems provide renewable resources and provide ecological services that safeguard

⁶ Ecological economics is a multidisciplinary field that integrates ecology and economics which viewed on human economy as a subsystem of larger earth ecosystem. It addresses issues like sustainability, climate change, and species extinction by emphasizing the preservation of natural capital and considering the intrinsic value of nature. Their main focus is on full ecological and social dimensions of economic activity.

human activities and influence human wellbeing. Atmospheric composition maintenance, climate stabilization and improvement, water purification and flood control, waste absorption, nutrient recycling, soil formation, crop pollination, food production, species preservation, and the upkeep of recreational areas, scenic landscapes, and aesthetic and amenity values are all part of these ecosystem services (DeGroot, 1992; Ehrlich & Mooney, 1983).

According to Ehrlich and Ehrlich (1992), Ecosystem services are treated as a 'factor of production' and always been a prerequisite for human wellbeing and economic development. Ehrlich and Mooney (1983) believed to have coined the phrase "ecosystem services". The wellbeing of the local people certainly depends upon the nature or ecosystem embedded with their lives (Dodson, 1997). The concept of ecosystem provides a bridge between people and their environment.

2.2.2 Wellbeing Dimensions of Ecosystem Services Approach

The theoretical framework of the study is based on the understanding of livelihoods and wellbeing in the context of ecosystem approach. To achieve locally relevant wellbeing, this approach necessitates a participatory place-based analysis. This approach examines how sustainable development is achieved with social and environmental resilience. The concept of an ecosystem provides a bridge the gap between people and their environment As a result, the Ecosystem Services method is a plan for the fair and sustainable management of all resources, including land, water, and life. Organizations such as the Convention on Biological Diversity (CBD) and the Millennium Ecosystem Assessment (MEA) have both given their stamp of approval to the ecological strategy.

Developed nations saw a shift in their perspectives on resource usage and environmental quality throughout the 1960s and 1970s. The Club of Rome's Limits to Growth (Meadows et al., 1972) and the release of the book "Silent Spring" (Carson, 1962) have drawn significant attention to the topic of ecosystem health and the issue of agricultural practices. The United Nations Conference on Human Development in Stockholm in 1972 and the United Nations Commission on the Environment and the Economy, which produced the seminal document 'Our Common Future' (WCED, 1987), were prompted by the environmental effects of pollution as well as the crucial role of technology and population growth. In order to highlight the significance of striking a balance between economic development and environmental quality, the commission popularized the phrase "sustainable development," describing it as the way by which society improves conditions without compromising chances for future generations. The focus of

sustainable development has been on livelihoods and wellbeing in relation to the ecosystem services that nature provides and their care.

Costanza et al. (1997) calculated the average annual value of ecosystem services since the late 1990s to be \$33 trillion in 1995 (\$46 trillion in 2007 \$US). Additionally, they offer an updated estimate based on land use change projections from 1997 to 2011 and revised unit ecosystem service values. In 2011, the projected annual value of all global ecosystem services was \$145 trillion (assuming just unit values changed) and \$125 trillion (assuming updated unit values plus changes to biome areas). Depending on the unit of measurement, an estimated \$4.3–20.2 trillion in ecosystem services were lost between 1997 and 2011 as a result of changes in land use. A straightforward benefit transfer approach served as the foundation for our estimate. Despite the fact that wellbeing was undervalued, it greatly increased interest in the subject of ecosystem services.

Ecosystem services (ESS) definitions can be divided into two main variations: one focusing on the ecological dimension and the other describing ESS as an economic category. Daily, (1997) provide a definition based on ecological dimensions of ecosystem services which encompassing ecosystem goods, functions like water purification and climate stabilization, and aesthetic and cultural benefits. This approach involves various aspects of human life and the sustainability of natural ecosystems.

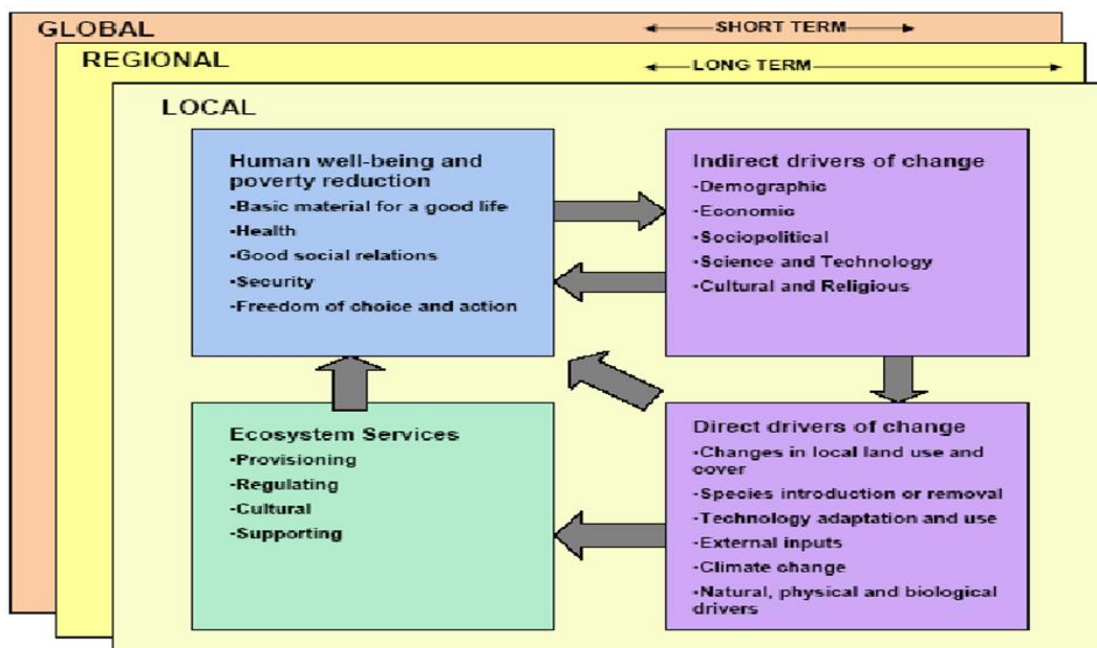
The Millennium Ecosystem Assessment (MEA, 2003) proposes an economic definition of ESS, categorised into provisioning, regulating, cultural, and supporting services, which links to various elements of wellbeing. According to MEA, the ecosystem services are the “benefits people obtain from ecosystems”. Based on economic perspective, ecosystem services are classified into the categories of provisioning, regulating, cultural and supporting services. The MEA was unique in that it was carried out on several scales, ranging from local to regional to global. The MEA multiscale nature recognises that people and ecosystems interact across many temporal and geographical domains, as depicted in the MEA conceptual framework (Fig. 2.1). The conceptual framework links human wellbeing, indirect and direct drivers of change, and ecological services (Millennium Ecosystem Assessment Report, 2003).

According to the Millennium Ecosystem Assessment (MEA, 2005), modifications to the direct and indirect drivers of wetlands may have an impact on the relationship of ecosystem services, which may then have an impact on human wellbeing. The components or factors that determine wellbeing were either directly or indirectly contributed by ecosystem services. Basic material

necessities for a happy life, freedom and choice, health, pleasant social interactions, and personal security are some of the essential elements that make up human wellbeing. Happiness and sadness are, in fact, location-dependent and contextual, indicating local social and individual elements including geography, environment, age, gender, and cultural background (Prescott-Allen 2001). Ecosystems are critical to human wellbeing because they provide provisioning, regulating, cultural, and supporting services. Security, basic needs, health, and social and cultural interactions are all impacted by changes in these services, which have an effect on human wellbeing. People's choices and freedoms have an impact on these aspects of wellbeing (Duraiappah, 2002; MEA, 2005). Freedoms include participatory freedom, economic facilities, social possibilities, guarantees of transparency, protective security (Jordan, 1996; Sen, 1999), and ecological security (MEA, 2005). There are present and future ramifications to the relationship between ecological changes and human wellbeing. Overuse of ecosystems may momentarily reduce poverty and improve material wellbeing, but it may not be sustainable.

Fig:2.1

Millennium Ecosystem Assessment Framework on Ecosystem Services and wellbeing



Source: Adapted from MEA, 2005

Multifunctional ecosystem services contribute to human wellbeing in a variety of ways. The MEA framework identifies five components of wellbeing: basic material for a good life, good social relationships, security, and the freedom of choice and action (MEA, 2005).

The ecosystem service approach is a comprehensive framework for understanding human-nature interactions and imagining sustainable development paths (Bennet et al., 2015). The economic, environmental, and social outcomes of sustainable development pathways determine desirability of human being (Howe et al., 2014). These outcomes are highly competitive in terms of ecosystem service relationships. Ecosystem service relationships (Cord et al., 2017) describe the synergistic (or positive associations) or antagonistic (or “trade off” as negative associations) joint variation of ecosystem services among bundles of multiple ecosystem services, including provisioning, regulating and cultural services (MEA, 2005).

Synergy and trade-offs are biophysical and stakeholder-centric. It occurs when the provision of one ecosystem service is reduced due to increased use of another ecological service, or when one stakeholder receives more of a particular ecosystem service at the expense of others (Rodriguez et al., 2006). Examining the connection between ecosystem service trade-offs or synergies and their final effect on human wellbeing is at the heart of the ecosystem service approach research (Howe et al., 2014). A person's sense of security, independence, control over their destiny, and positive social relationships are the few numerous aspects of quality of life that are integrated into wellbeing in a changing environment (MEA, 2005).

The wellbeing of the local communities greatly depends on the ecosystem services. The Millennium Ecosystem Assessment (2003) developed a methodological as well as conceptual guide for the assessment of interlinkage between ecosystem services and human wellbeing. The practical application of Ecosystem services concept has got momentum in policy decision by the implementation of Payment Ecosystem Services (PES)⁷ schemes in developing and developed countries. The study made by TEEB (2010) embraces the monetary and non-monetary value of biodiversity conservation to support the provisioning of ecosystem services. Similarly, IPBES report (2020) proposed a similar approach by using a new terminology of “Nature contribution to People”. All the above reviewed studies describe the objective aspect of benefits or valuation of ESS by the commodification of ecosystem services through a price tag. The ESS studies mostly investigated the objective aspects like resources or social attributes to highlight the monetary value of ecosystem services. But, in reality, Ecosystem Services is being played a wider role in the realm of wellbeing beyond monetisation.

⁷ Payment Ecosystem Services are incentives to compensate and encourage land owners, or companies to manage their land with clean water, carbon sequestration, and biodiversity.

2.2.3 Capability Approach

The literature has discussed long about the relationship between economic growth and development. Economic growth is often measured quantitatively through indicators like per capita income or Gross National Product (GNP), but development is an inherently normative dimensions with welfare enhancement and human rights. An increase in income alone does not necessarily signify original development. Sen (1999) argues that individuals positive experiences and opportunities of the individuals should be prioritised in development. This perspective acknowledges the limitations of growth oriented economic models and emphasised the role of individual opportunities. Contrary to the traditional development strategies based on economic indicators like growth, income, and consumption, the Capability Approach shifts the focus of development towards individual freedoms, choices, and the ability to pursue a good life. This capability framework integrates multiple dimensions of wellbeing, including education, health, and political freedom, and making to evaluate development not merely by resources or outcomes, but by the real capabilities people possess. This approach has significantly influenced composite indices like the Human Development Index (HDI), which incorporates key indicators of life expectancy, educational attainment, and income.

Development is not merely an economic growth or material achievements, but it is about expanding the freedoms and capabilities of individuals to lead lives they value. Amartya Sen's perspective of development involves enhancing people's access to education, healthcare, and opportunities for meaningful participation in decision making processes. This perspective emphasis that development is a process of empowering people to realise their potential and exercise their agency. By shifting the focus from economic growth to individual's freedom and wellbeing, Amartya Sen's capability approach has been deeply influenced human development theory. Sen defines development as the expansion of individuals' capabilities — their real opportunities to achieve valued functioning, or states of being and doing. This framework distinguishes between functionings (what a person manages to do or to be), capabilities (the freedom to achieve those functionings), and agency (the ability to pursue meaningful goals). Rather than offering a prescriptive theory of poverty or inequality, the capability approach provides a normative lens for assessing wellbeing, social arrangements, and policy design.

2.2.4 Capability Approach on Ecosystem Services and Wellbeing

The MA-ES⁸ and IPBES-NCP⁹ approach provide a multidimensional perspective of linking ecosystem services and human wellbeing. However, both these studies failed to describe explicitly the association of ESS and wellbeing based on people's capabilities. In fact, wellbeing is both objective and subjective (OECD, 2011). The objective aspect of wellbeing assessed the wealth, resources and environmental quality in terms of monetary units, while subjective aspect of wellbeing measured in terms of life satisfaction, happiness and freedom. Such a multidimensional aspect of wellbeing of the people is assessed in terms of capabilities of the people. Amartya Sen, an ardent critique of standard welfare economics, rejects the notion of monetary and utilitarian views on wellbeing and advocated the capability approach based on "achieved functioning" (Robeyns, 2005a; Sen, 1999).

The quality of life that people can truly attain is the main focus of the capability approach (Sen, 1999). According to Sen, the functioning and capabilities are the two set of concepts in analysing wellbeing under capability approach. While capabilities are the actual, or substantive, opportunity that a person has to accomplish these doings and beings, functioning are states of "doings and beings" of human beings and activities that a person has attained, such as being well-nourished, getting married, being educated, and traveling. Robeyns (2005b), argues that, in a Capability approach, goods and services can be converted as set of capabilities based on three groups of conversion factors: personal, social and environmental. Based on her physical and mental capabilities, the set of personal conversion factors transforms commodities and services into a predetermined capability. But the social conversion factor covers such factors as social practices, gender roles, caste relationships etc., finally, environmental conversion factors enhance capabilities through geographic location, climate, clean air, extreme natural events etc.

Sen's analysis of capability approach did not signify the role of environment and ecological dimensions of wellbeing (Sneddon et al., 2006). Though, recently, some of the studies (Ballet et al., 2012; Scholtes, 2010; Holland, 2008) expanded their work to nature and capability approach, but does not address the role of nature's contribution to individual wellbeing within capability approach. The UNEP report on "Human Well-Being, Poverty & Ecosystem Services", Duraiappah (2004) identified the ways in which Ecosystem services contributed to wellbeing. The report explicitly connected the Ecosystem services and ten wellbeing

⁸ Millennium Assessment- Ecosystem Services Approach

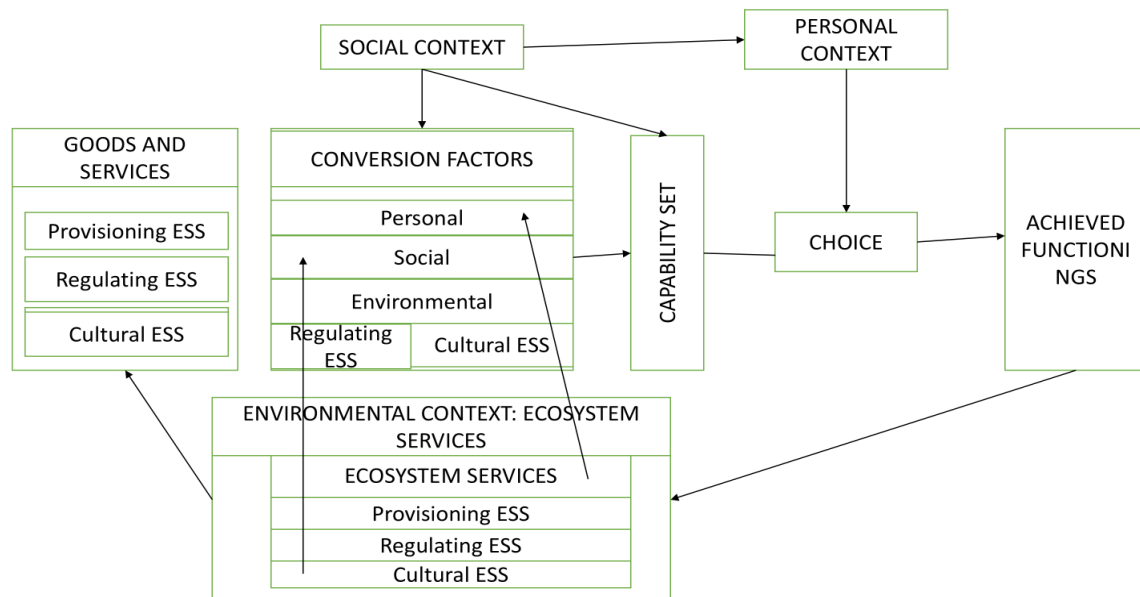
⁹ IPBES -Nature's Contribution to People Approach

constituents or determinants similar to concept of functioning's and capabilities of Amartya Sen (1993). The study report also adopted the Millennium Ecosystem Assessment (MEA) definition of ecosystems and ecosystem services. The report added "being able to" before each ingredient and determinant of wellbeing to account for the core features of capabilities—agency, value, and choice. These 10 constituents of wellbeing are: (1) being able to get enough food. (2) being able to avoid preventable illness. (3) being able to access secure and hygienic place to reside. (4) being able to access to sufficient and pure drinking water. (5) being able to access to pure air. (6) being able to have enough energy to cook and stay warm. (7) being able to access conventional medicine. (8) being able to maintaining traditional, cultural and spiritual activities that make use of natural materials present in ecosystems. (9) being able to handle severe natural disasters including landslides, floods, and tropical storms. (10) being able to make sustainable management choices that allow for the creation of a sustainable revenue stream while also respecting natural resources. The report synthesised that, although, there are potential trade-off between three ecosystem services, the potential synergy also resulted from ecosystem services to human wellbeing.

A comprehensive framework of capability approach was given by Polishchuk and Rouschmayer (2012), within the sphere of ecosystem services and wellbeing, rejecting the 'benefit' or 'monetisation' approach of Millennium Ecosystem Assessment (2005). According to them, all the three Ecosystem services – Provisioning, regulating and cultural ecosystem services – are treated as goods and services which directly and indirectly influence people's capabilities. In fact, these ecosystem services are not just goods and services but it serves as a conversion factor. The provisioning services are tangible goods and resources such as food, water, fibre, medicinal plants etc which act as a conversion factor, stem from their potential ability to translate natural ecosystem into direct benefit for human wellbeing. The regulating services such as soil erosion, flood regulation etc. served as an environmental conversion factor which translated into actual capabilities. Also, cultural services like jogging, swimming etc provide a space for socialisation and converted as wellbeing element of social cohesion. Apart from above direct influence, Ecosystem services provide some indirect social conversion factors such as health and education to influence on capability formation. Based on the above approach, they presented a theoretical incorporation of Ecosystem Services concept into capabilities and illuminated their implications on human wellbeing. Fig.2.2 graphically summarises the role of Ecosystem Services and their conversion factors on human wellbeing based on Capability approach.

Figure: 2.2

Person's capability set formation focussed on the contribution of ESS



Source: Adapted from Polishchuk and Roschmayer, 2012

Sangha et al. (2015) assessed the role of Ecosystem Services in the wellbeing of indigenous people in Australia based on the holistic integrated MEA and capability approach. The study focused on how natural resources are associated with indigenous peoples' capabilities for attaining wellbeing. They reviewed and analysed the results from three case studies across Queensland, Australia based on a socio-economic-ecological perspective. According to them, indigenous people are stakeholders who are defined as "Any group or individual who can affect or is affected by ecosystem services". These stakeholders have different entitlements (Sen, 1984) to access ecosystem benefits. These entitlements are the multiple commodity bundles that a person may acquire in a community through exercising all of their accessible rights and opportunities (Sen, 1984). As a result, entitlements are a set of abilities for functioning or achievement, as well as the freedom to achieve human wellbeing. The study suggests that indigenous people's ability to use and value natural resources, as well as their security and freedom to do so, can positively impact their wellbeing and inform policy decisions (Sangha et al., 2018). Balasubramanian and Sangha (2021) conducted another study using the same integrated Ecosystem Services and Capability approach to assess the contribution of nature to the wellbeing of indigenous and local communities in two tribal communities, Soliga and Kattunayaka, situated in a global biodiversity hotspot in Western Ghats in India. The study

clearly demonstrated that people's capabilities - knowledge and skill for using the natural resources, are critical for achieving functioning - nutritious food, clean air and water, income, managing land to be safe from ecological shocks, and so on.

Liu et al. (2024) made an explorative study on the impact of individual capabilities on Ecosystem Services and farmers' wellbeing in an ecologically fragile area of China, Loess Plateau. The study assessed the objective and subjective wellbeing of the farmers' and discovered that capabilities directly influence objective wellbeing by ecosystem services but not influence on subjective wellbeing. Farmers' capabilities, on the other hand, had a significant indirect impact on objective wellbeing by influencing ecosystem services but no indirect impact on subjective wellbeing. The study quantitatively expressed the Nussbaum's list of capabilities (2016) by considering the characteristics of local farmers and their wellbeing was assessed in terms of Human's Needs Theory by the use of Structural Equation Model.

2.3 Conceptual Model

Based on the reviewed theoretical framework, the present study constructs an analytical model to investigate how capabilities of the farmers in relation to paddy farming affects their wellbeing through the influence of agroecosystem services in Kole Wetlands. Kole Wetland Paddy farming is a significant source of income as well as a producer and consumer of ecosystem services. These Kole wetlands are the most productive manmade ecosystems, used for paddy production, fish farming, and as a reservoir of water. Paddy farming in Kole wetlands is a classic example of an agroecosystem that contributes directly and indirectly to the livelihood of the local community and human wellbeing in general. The source of livelihood and wellbeing of the farmers depends upon the ecosystem services provided by the Kole wetlands such as provisioning, regulating, cultural and supporting services.

According to the theory of Capability approach, capabilities are peoples' abilities to do/achieve something (i.e. doings & beings) which are important in wellbeing of an individual. The Kole wetland paddy farmers have complete freedom to choose or opportunity to access all the ecosystem services and have the ability to do farming independently, as their entitlements or capabilities. The entitlements are set of abilities for functionings or achievements as well as freedom to obtain human wellbeing. Differences in benefits received from ecosystem services individually depend on differences in attributed capabilities. That is the conditions enable individual to produce or access ecosystem services benefits from them. Through long term paddy production experiences, farmers have developed many capabilities that are useful for

accessing ecosystem services (Liu et al., 2024). The Kole wetland paddy farmers as an individual have basic capabilities such as income, ownership of land, house property, family size, age composition and education. Along with these basic capabilities, farmers have acquired skill and knowledge about how to employ farm inputs in right way and in right time from paddy farming experience (Farming Knowledge treated as capability). Furthermore, the paddy farmers have knowledge about ecosystem services (Ecological knowledge as capability) which act as an environmental conversion factor to achieve set of capabilities. Thus, farmers basic capabilities, farming knowledge and ecological knowledge are the abilities to do/ achieve their wellbeing dimensions.

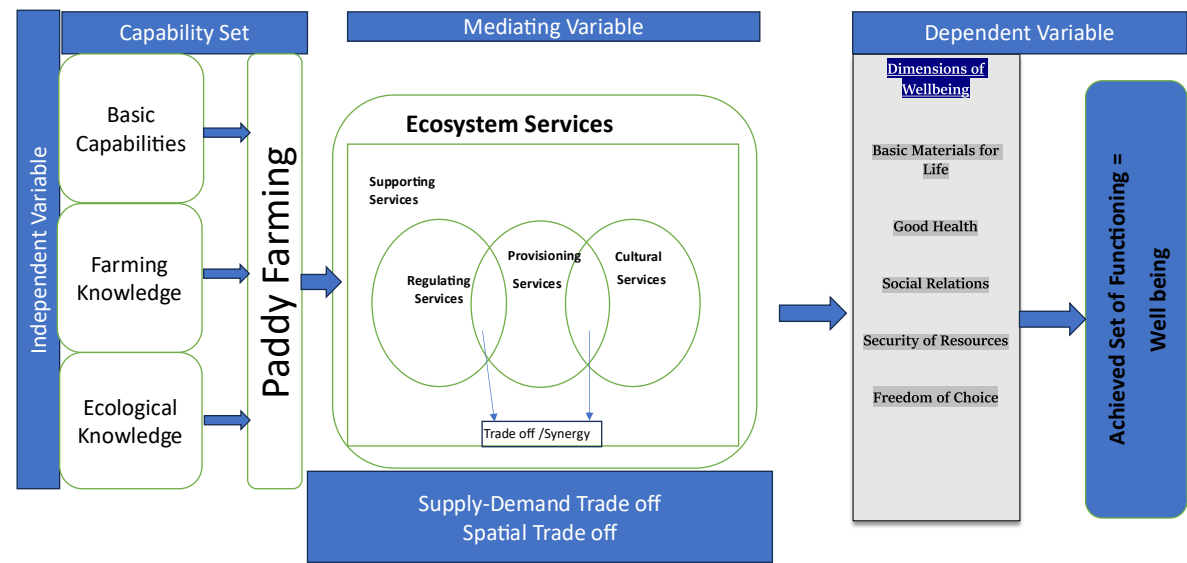
To achieve highest amount of wellbeing, farmers employed the intensive paddy farming practices like the adoption of land preparation, irrigation system, chemical plant protection, chemical fertiliser usage, cropping systems, ploughing frequency etc. This method of farming drastically impacts the supply and demand of ecosystem services provided by the Kole wet lands. Indeed, changes in supply and use of ecosystem services have an impact on several domains of human wellbeing. The ecosystem services provided by the Kole wetland farming are highly correlated among each other to provide human wellbeing and ecological sustainability. These relationships are synergetic or antagonistic (trade off) which are critical for managing ecosystem services and achieving maximum human wellbeing (Cord et al., 2017). A trade-off occurs when one service increases while another decreases, whereas synergy occurs when both services increase or decrease at the same time. For example, increases in paddy production as provisioning services may either decrease or increase regulating services like soil erosion, carbon sequestration, water recharge etc. Similarly, it affects the cultural services like aesthetic beauty, recreation as well. Conversely, changes in regulating services affect positively or negatively the cultural and provisioning services. These associations of ecosystem services were classified as supply trade-off and demand trade off. The supply trade-off is ecological in nature, while the demand trade-off is socioeconomic in nature. A unified typology given by Mouchat et al. (2014) as combinations of these two types of trade off were classified as (i) supply-supply: which considers ecosystem services delivery; (ii) supply-demand, which describes the locational differences in ecosystem services (spatial) or temporal lag between ES supply and stakeholder centred social benefits; and (iii) demand-demand, which refers to the conflict between different ecosystem services in terms of benefits.

The overall impact of the dynamic nature of ecosystem services and their associations provided by the Kole wetlands is strongly linked to the major domains of the people's long-term

wellbeing. Basic materials for a good life, health, good social relations, security, and freedom of choice are the highest constituents of wellbeing (MEA, 2003). The agroecosystem services provided by the Kole wetlands directly and indirectly depend on these wellbeing dimensions. Thus, farmer’s wellbeing depends not only on the achievable set of capabilities but also on ecosystem services from Kole wetlands.

The analytical model design of the research study is presented below in Figure 2.3

Figure 2.3
Analytical Design of Research Framework



Source: Compiled from MEA, Mauchet et al., Sen, Duraiappah

In short, the research model analyses how paddy farming in Kole wetlands and farmer’s capabilities translated into an achieved set of functioning or wellbeing through mediating effect of ecosystem services.

2.4 Conclusion

The historical evolution of the concept of ecosystem services approach and capability approach discussed in this chapter have offered a theoretical framework for understand and assess the wellbeing dimensions of farmers. The early classical political thinkers like Malthus and Ricardo laid a foundation for the integration of ecosystem services and capability approach as a theoretical framework by recognising the biophysical limits of nature and their role in

production. Later, Ehrlich – Commoner model has emphasised the ecological limits of environment for economic growth. The optimal exhaustible resource use of Hotelling and Arrow's theory of externalities emphasises the role of the environment in shaping sustainable development and wellbeing. Although the Neoclassical 'growthmania' creates a gap between people and nature, Ecological Economics bridges the gap with the introduction of ecosystem services. The book 'Silent Spring', Limits to growth of Club of Rome, and 'Our Common Future' by WCED emphasise and popularise the role of environmental quality and sustainable development. The emergence of the term 'Ecosystem Services' advanced by Ehrlich and Mooney, Daly, DeGroot, Coztanza, MEA and others highlight the multiple benefits of nature to humans and discourses the foundation of wellbeing.

Meanwhile, studies by Cord, Rodríguez, Bennett, Mouchet, Dowe, and others have identified trade-offs or synergies between ecosystem services and wellbeing. While the MEA, TEEB, and IPBES reports propose objective aspects of different wellbeing dimensions, Amartya Sen has reframed wellbeing in terms of human capabilities and achieved set of functioning's. Based on this, studies of Duraiappah, Polishchuk and Roschmeyer, Balasubramanian and Sangha, and finally, Liu et al. provide an integrated analytical lens for assessing wellbeing within the biophysical boundaries of ecosystem services and the socio-economic components of capabilities. Thus, this study uses a conceptual framework built on an integrated theoretical approach to assess how the multifaceted relationship between capabilities and wetland ecosystem services shapes farmer's wellbeing.

Chapter III
Dynamics of Paddy Land Use and Ecosystem Services in
Kerala

CHAPTER III

DYNAMICS OF PADDY LAND USE AND ECOSYSTEM SERVICES IN KERALA

3.1 Introduction

Based on the theoretical foundations of ecosystem services and wellbeing outlined in the previous chapter, the present chapter examines changes in land use patterns at the international, national, and local levels. This chapter also examines how changes in paddy land use patterns impact ecosystem services as a key determinant of capabilities of the farmers and their resulting wellbeing. Land is a vital natural resource with a wide range of applications in the social, economic, and ecological spheres. According to the Food and Agricultural Organisation (FAO, 1976) of the United Nations, land is defined as an area of the earth's surface whose characteristics include reasonably stable, or predictable cyclic features of the biosphere, as well as of the atmosphere, soil, and undergoing geology, hydrology, plant and animal populations, and the outcomes of past and present human activity. This highlights that the land serves as a fundamental component of production, providing a foundation for all other economic endeavours that support the process of production. The anthropogenic activities on land, including those for residential, commercial, industrial, agricultural, recreational, and conservation reasons, are referred to as land use. In order to satisfy their material, social, and cultural requirements, humans use of land and its resources exploitatively result a negative impact on the environment and human wellbeing (Briassoulis, 2000). For instance, the rising demands for food due to rapid population increase impose heavy human pressures on land and other natural resources which lead to overstrains on the land as an ecosystem.

Land has been used for forestry, business, residential, industrial, and agricultural uses, as well as other natural resource uses. The agro-related land fosters a close relationship between humans and the environment. It supports food, wood, natural resources, urban areas, recreational spaces, transit corridors, and the foundation for energy sources across world. Moreover, land as natural ecosystems assist to prevent pollution, manage soil erosion, and maintain the amount and quality of water. More specifically, land use is the way in which ecosystems are managed to produce part of human requirements (Karpagam, 1991).

The patterns, procedures, and variables that propel transition of land over time from one kind of land use to another are referred to as the dynamics of land use change. Land use change is a

crucial component of urbanisation, agriculture, environmental preservation, and regional growth. These land use changes affect the economic and ecological balance of the economy. The water quality (Yesuph et al., 2019) and the availability of ecosystem services (Lawler et al., 2014; Woldeyohannes et al., 2020) depends on these changes in land use. Therefore, it is pertinent to study the pattern and trend of land use change at international, national and regional level to understand the significance of land as an ecosystem particularly paddy land to maintain ecological balance. To explore the mediating role of ecosystem services in achieving the wellbeing of paddy farmers in the Kole wetlands, it is of great importance to examine dynamic land use patterns, especially land use changes in the Kole paddy fields of Thrissur, Kerala. The following sections under this chapter examine the overall trend and pattern of land use changes particularly paddy land and highlights the significance of ecosystem services contributed by the Kole wetlands in Kerala.

3.2 Land Use Pattern at the International Level

Globally, agriculture occupies half of the habitable land. According to Food and Agricultural Organisation (FAO, 2020), internationally, glaciers comprise 10 per cent of the land surface, while barren land makes up 19 per cent, leaving just 37 per cent for forests, 11 per cent for shrubs and grasslands, 1 per cent for freshwater coverage, and 1 per cent for built-up urban areas. The agricultural land is 4.8 billion hectares in 2019, accounting for around one-third of total land area and the remaining two-thirds being permanent meadows and grasslands utilised for cattle (3.2 billion hectares). Cropland area increased by 5 per cent over agricultural land during the years 1990 and 2019, whereas permanent meadows and pastures fell by 4 per cent. The increase in farmland area was mostly attributable to the spread of permanent crops. In 2019, the two basic components of farmland were 170 million hectares for permanent crops (perennials and tree crops) and 1.4 billion hectares for arable land (mostly annual crops). Since 1990, acreage under permanent crops has increased by 50 per cent, but arable land has remained steady. In 2019, per capita agricultural land area was only 0.6 hectares, with a 30 per cent decrease from 1990, suggesting effective land use for population growth. Forest land area (4.1 billion hectares) decreased by 4 per cent, irrigated area (340 million hectares) increased by 30 per cent, and organic agriculture covered 70 million hectares, three times hike from 2004. Asia and Africa have the most agricultural land (approximately 1.7 billion and 1.1 billion hectares, respectively). Following this pattern, Asia had the most agriculture, with 600 million hectares, followed by India, which had approximately 170 million hectares (FAO, 2022). However, from 1990 to 2019, India's farmland acreage stayed stable or exhibited minimal fluctuation.

In comparison to arable farming, animal grazing takes up the majority of land. Most nations devote less than 20 per cent of their land to food production, with several allocating less than 10 per cent. However, arable farming accounts for a sizable portion of land in South Asia and Europe. In 2015, India, Bangladesh, Ukraine, and Denmark each allocated more than half of their entire land area to farming (Ritchie & Roser, 2019). Cereal farming takes up the vast bulk of our arable land (720 million hectares). The overall land area utilised for coarse grains has been relatively steady over the last 50 years, and it is the second greatest consumer of arable land. Similarly, out of the total arable land, 11 to 12 per cent land utilised for paddy production which is approximately 165 to 170 million hectares annually (FAO, 2022). Out of the total paddy area, India ranks first in area under paddy production followed by China.

3.3 Land use pattern at the National Level

In India, land is primarily utilised for agricultural purposes and contributes lion share of world food products. India has a diverse range of land resources, including arable land, forests, and minerals. About 58 per cent of the land in India is arable land which is the mainstay of an economy. Out of the geographical area of India, 42 per cent currently used for cultivation of food and non-food crops which is one of the highest in the world. Among the states of India, Haryana and Punjab top with highest land available for agriculture purposes with 90.74 and 83.98 percent respectively, while the lowest land available for agriculture purposes in the union territory of Andaman & Nicobar Islands and in the state Arunachal Pradesh with 3.89 and 6.02 percent respectively. In Kerala, around 60 per cent of the land available for agricultural purposes. Forest area in India, covering 23.49 per cent of its land, provide timber, fuelwood, water cycle regulation, and soil erosion protection, ensuring a diverse flora and fauna. Area under Barren land during 1950-51 was 13.42 per cent and Forest was 14.24 per cent respectively, but barren land reduced to 5.4 per cent and area under forest increased to 23.49 per cent during 2022-23.

The net sown area in India accounts for about 54.58 per cent of the total geographical area i.e. 141.58 million hectares as against the world average of 32 per cent with a cropping intensity of 155.4 per cent (MoSPI, 2023). These cropped land area from the total available Agricultural/cultivable Land increased from 68.25 to 85.68 during the period 1950-51 to 2022-23. However, the per capita cultivated area decreased substantially during this period due to increased population in the country. Among these cultivated areas, the highest percentage share of area under non-food crops reported in Kerala with 64.53 per cent followed by Gujarat with

57.06 and Rajasthan with 41.6 per cent. Area under foodgrains (cereals and pulses) has decreased by 1.67 per cent from 138629 thousand hectares in 2021-22 to 136309 thousand hectares in 2022-23 (MoAFW, 2023).

The pattern of land use change in India discussed in this section has marked a larger transition from agrarian economy to an urban oriented structure at the cost of ecological resilience and livelihood aspects of the economy. The remarkable land use pattern identified in different states of India including Kerala showed a need for a better land use policy to ensuring sustaining ecological integrity.

3.4 Land Use Pattern in Kerala

The examination of land use pattern of Kerala is essential to understand the socio-economic dynamics and ecological sustainability of the state. The performance of agriculture sector depends on the pattern of land utilisation changes occurred overtime. The economic development leads to the structural transformation of land which leads to the changes in cropping pattern and shifts of land for non-agricultural purposes. Apart from Land Reforms Act 1963, population pressures, urbanisation, and foreign remittance augmented the diversion of land for non-agricultural purposes. Kerala is recognised as the most rapidly urbanising state. The urban population was only 82.66 lakhs in 2001, but it has grown to 1.59 crores (47.7 per cent of the total population) by 2011. Over a decade, between 2001 and 2011, the urban population in Kerala increased by 92.72 per cent (KSPB, 2017).

The economy of Kerala is sustained on eco-centric agriculture. Out of the total geographic area, 59.94 per cent accounts as arable land, 27.83 per cent as forest area, and just 12 per cent going towards non-agricultural uses. The terrain and physiological characteristics of the farming region primarily influence crop choices and the quantity of crops grown. Kerala accounts 1.8 per cent of the total land area and 2.76 per cent of the total population of the country. The differences in the land use pattern indicate the excessive pressure of population growth on the available land. The percentage of arable land is only 59.94 per cent of the total geographical area of Kerala in 2021-22. The land used for Net Area Sown was decreased from 56.10 per cent to 52.21 per cent during the period of 1980-81 to 2021-22 (KSPB, 2022). On the other hand, land used for non-agricultural purposes increased at gradual rate from 6.94 per cent to 11.98 per cent during the same period. The recent trend and pattern of land use in Kerala is a big challenge to food security and sustainable environmental habit of the Kerala economy.

3.4.1 Land use trends and status in Kerala

The trend and pattern of land use are calculated on the basis of secondary data. The secondary data on land use pattern of Kerala were collected from government reports published by the Department of Economics and Statistics (DES), and the Economic Review of the Kerala State Planning Board for all the districts for the period of 42 years from 1980-81 to 2021-22. Statistics on land use pattern were collected for Kerala state in the form of nine-fold classification. They are Area under Forest (FA), Land put to Non-Agricultural use (NAU), Barren and uncultivable land (BL), Permanent pastures and other grazing land (PP), Land under miscellaneous tree crops (MTC), Cultivable waste (CW), Fallow other than current fallow (OF), Current fallow (CF) and Net Area Sown (NAS). The data on Arable land (AL) and Uncultivable land (UCL) are measured by the researcher based on the land use pattern.

During the last few decades, Kerala economy experiences a massive structural shift in land use pattern particularly paddy land use towards non-agricultural purposes. To assess the structural break of land use pattern during the period between 1980-81 to 2021-22, Bai and Perron test (2002) is conducted. The reasons for structural break may include policy changes, economic crisis, institutional changes, and the speed of urbanization. Previous research has considered only one break point in the entire period of time as identified by the Chow test. However, there can be more than one break or multiple breaks in a time series data for several reasons. Bai and Perron test, employed in this study, detects four breaks in the data with no prior information.

Based on the test, the present study identified four break points or years in land use pattern of Kerala such as 1987-88, 1997-98, 2007-08, and 2012-13. The entire study period is divided into five periods based on these break points as follows: -

Period I: 1980-81 to 1987-88

Period II: 1988-89 to 1997-98

Period III: 1998-99 to 2007-08

Period IV: 2009-10 to 2012-13

Period V: 2013-14 to 2021-22

The analysis of paddy land use dynamics in Kerala discussed in this chapter is based on the identified structural intervals.

Table 3.1
Trends in land use pattern in Kerala: 1980-81 to 2021-22

Land Use Classes	Break Point Periods				
	I	II	III	IV	V
Total Geographical area	3885497	3886287	3886287	3886287	3886287
Forest area	1081509 (27.83)	1081509 (27.83)	1081509 (27.83)	1081509 (27.83)	1081509 (27.83)
Non-agricultural use	284802 (7.33)	320307 (8.24)	371558 (9.56)	402577 (10.36)	465561 (11.98)
Barren and uncultivable land	72491 (1.87)	38934 (1.00)	25527 (0.66)	16354 (0.42)	9784 (0.25)
Permanent pastures and other grazing land	3089 (0.08)	825 (0.02)	216 (0.01)	118 (0.0)	0
Land under miscellaneous tree crops	40606 (1.05)	22028 (0.57)	6397 (0.16)	2799 (0.07)	2267 (0.06)
Cultivable waste	115342 (2.97)	65072 (1.67)	92764 (2.39)	96596 (2.49)	88499 (2.28)
Fallow other than current fallow	28779 (0.74)	27730 (0.71)	45214 (1.16)	55835 (1.44)	49420 (1.27)
Current fallow	47605 (1.23)	58499 (1.51)	82953 (2.13)	76744 (1.97)	53914 (1.39)
Marshy land	NA	NA	349 (0.01)	189 (0.00)	12 (0.0003)
Still water	NA	NA	84829 (2.18)	99789 (2.57)	100316 (2.58)
Water logged area	NA	NA	2780 (0.07)	2840 (0.07)	2937 (0.08)
Social forestry	NA	NA	3162 (0.08)	2828 (0.07)	2700 (0.07)
Net area sown	2211274 (56.91)	2270593 (58.43)	2089029 (53.75)	2048109 (52.70)	2029368 (52.22)
Area sown more than once	688581 (17.72)	698409 (17.97)	672065 (17.29)	543625 (13.99)	493646 (12.70)
Gross cropped area	2899855 (74.63)	2969002 (76.40)	2761094 (71.05)	2591734 (66.69)	2523014 (64.92)
Arable Land	2443606 (62.89)	2443922 (62.89)	2324524 (59.81)	2385729 (61.39)	2329433 (59.94)
Total Uncultivable Land	1441891 (37.11)	1441575 (37.09)	1478810 (38.05)	1500558 (38.61)	1556854 (40.06)

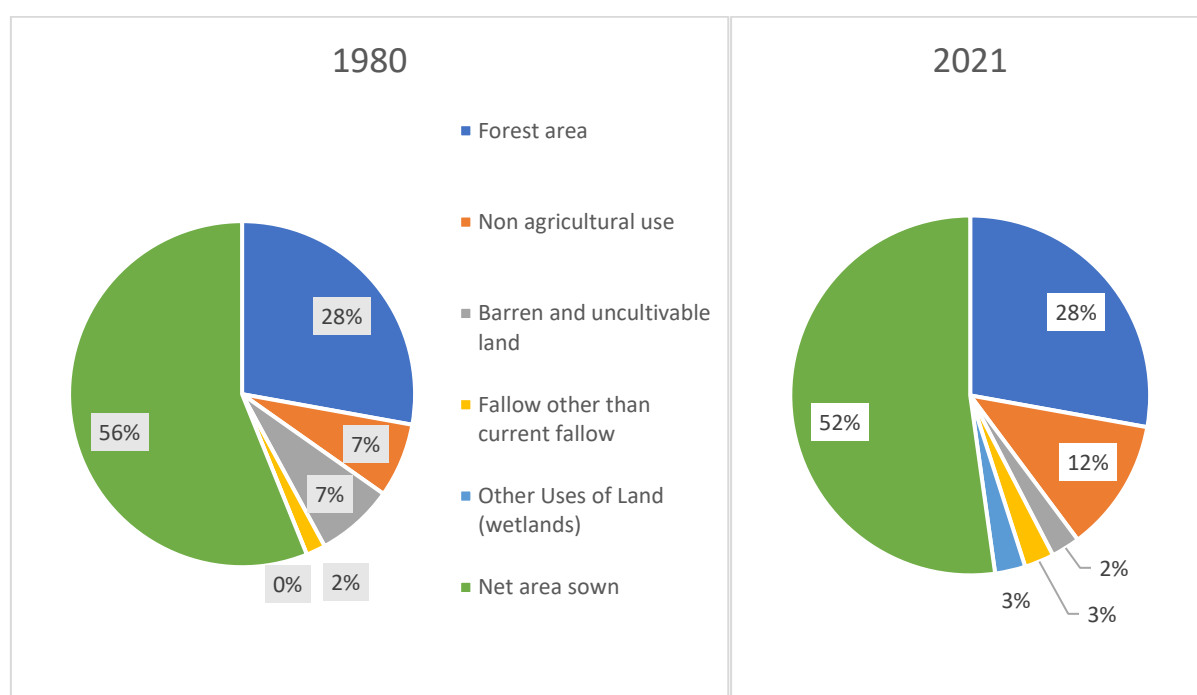
Note: Figures in parenthesis are percentage of Total geographical area

Source: Department of Economics and Statistics, Thiruvananthapuram, GOK

The total Arable land (AL) or cultivable land increases from 2399.38 lakh hectares (61.75 per cent of TGA) to 2443.60 lakh hectares during Period I which was 62.89 per cent of the total geographical area. But this percentage area remains same in the Period II. The Period III, noticed a gradual decrease in arable land (59.81 per cent) but a slight improvement in Period IV (61.39 per cent). The total Arable Land again decreased to 59.94 percentage during Period V. It was estimated that about 69,950 hectares of total arable land (1665 ha/ year) lost during the period of 1980-81 to 2021-22. Following the declining pattern of arable land, Net area sown also decreased from 22,11,274 hectare (56.91 per cent of TGA) in Period I to 2029.36 lakh hectares (52.22 per cent of TGA) in Period V. However, the NAS during Period II increased to 58.43 per cent, but it was decreased over the Period III, IV and V gradually to 53.75 per cent, 52.70 per cent, 52.22 per cent respectively. The total decrease of NAS over the period I to V was 1.82 lakh hectare (4.69 per cent of TGA), which was much higher than that of the decrease of AL is presented in the Figure 3.1 and Table 3.1. Thus, it was estimated that NAS lost per year was 4331 hectares during the period.

Figure 3.1

Percentage distribution of Net Area Sown in Kerala 1980 and 2021



Source: Computed from Department of Economics and Statistics, GOK, 1980 & 2021

On the contrary, it has been seen that the land area used for non-agriculture purposes increased drastically over each break point period. It was seen that the 99.36 per cent of the Net area sown

lost during this period was converted to non-agriculture purposes. The land area for non-agriculture uses increased from 6.94 per cent of the TGA to 11.98 per cent of TGA during 1980-81 to 2021-22 period. In 1980-81, the per cent area for non-agriculture purposes was 6.94 per cent, gradually increased to 7.33 per cent in the Period I. It was identified that there was a remarkable increase happened in each break points period. In the Period II, it was again increased to 8.24 per cent and later on non-agriculture use of land steadily increased to 9.56 per cent, 10.36 per cent and 11.98 per cent during Period III, IV and V respectively. On the other hand, per cent of land for barren and uncultivable land, and permanent pastures and other grazing land had declined marginally over the entire break point periods. The decline of barren and uncultivable land was substantial during the overall period from 2.21 per cent to 0.25 per cent. On the contrary, forest land area (27.83 per cent of the TGA) was remained constant over the entire period.

The area under cultivable waste and land under miscellaneous tree crops declined marginally over the break point periods. On the contrary, proportions of land other than current fallow, current fallow and other lands, such as marshy land, still water, water logged area and social forestry augmented marginally during the entire period of study. The area under current fallow increased marginally from 1.12 per cent to 1.39 per cent and land other than fallow from 0.69 per cent to 1.25 per cent during the period from 1980-81 to 2021-22. The shortage of labour, low profitability from agriculture and increase in foreign remittances leads to the increase of share of fallow land in agriculture. During the first break point period, the proportion of gross cropped area remains 74.63 per cent of TGA but improved to 76.48 per cent at the Period II and gradually declined to 71.05 per cent during the Period III. But it was estimated that, during the Period IV, the gross cropped area steadily decreased to 66.69 per cent and to 64.92 per cent during the Period V.

3.4.2 Performance of different Land use pattern of Kerala

The performance of land use pattern in Kerala over the different break periods has been assessed in terms of Compound Annual Growth Rate (CAGR) and is presented in Table 3.2 and their instability index of different land uses has been estimated by using Coefficient of Variation (CV) and Cuddy Della Valle Index (CDVI) and is presented in Table 3.3.

Table 3.2

Compound Annual Growth Rate of different Land uses classes in Kerala

Land Use Classes	I	II	III	IV	V	Overall Period
	1980-81 to 1987-88	1988-89 to 1997-98	1998-99 to 2007-08	2008-09 to 2012-13	2013-14 to 2021-22	1980-81 to 2021-22
Forest area	0.00	0.00	0.00	0.00	0.00	0.00
Non-agricultural use	0.42	1.42	0.72	2.11	1.61	1.44
Barren and uncultivable land	-1.76	-6.29	-1.37	-10.16	-4.58	-5.66
Permanent pastures and other grazing land	-7.69	-13.31	-3.40	-20.65	NA	NA
Land under miscellaneous tree crops	-5.04	-6.16	-10.82	-16.46	-2.11	-9.12
Cultivable waste	-1.08	-7.17	4.58	-0.18	-1.03	-0.57
Fallow other than current fallow	0.83	0.79	4.92	6.49	-3.05	2.11
Current fallow	0.57	2.77	1.02	2.54	-3.73	1.30
Marshy land	NA	NA	NA	-6.91	-35.32	NA
Still water	NA	NA	NA	2.00	0.02	NA
Water logged area	NA	NA	NA	4.27	-1.63	NA
Social forestry	NA	NA	NA	0.18	-0.29	NA
Net area sown	0.19	0.22	-0.82	-0.58	-0.07	-0.27
Area sown more than once	-0.66	-0.38	0.62	-1.64	-1.67	-0.78
Gross cropped area	-0.02	0.08	-0.46	-0.80	-0.41	-0.38
Arable Land	5.17	-0.06	-0.19	-0.25	-0.27	0.21
Total Uncultivable Land	-4.93	0.04	0.15	0.40	0.42	-0.22

Source: Computed from Department of Economics and Statistics, GoK, (various reports)

The compound annual growth rate of different break period is used to analyse the growth rate of various land use classes in Kerala during the period 1980-81 to 2021-22. During the entire period of study, since there was no change in the area under forest, the annual rate of growth of forest area remains observed to be zero. The area under non agriculture uses exhibited an annual growth rate of 1.44 per cent during the overall period. The land put to non-agriculture uses increased at an annual growth rate of 0.42 per cent during Period I, 1.42 per cent during Period II, and 0.72 per cent during Period III. Despite the Kerala Conservation of Paddy Land and Wetland Act 2008 was implemented, conversion of paddy area continued and hence land area was massively converted to non-agriculture uses at an annual growth rate of 2.11 per cent during the Period of IV (2008-09 to 2012-13), by utilising the loopholes in the Act 2008, which was much higher than that of the previous two periods. Due to the political parties' protest against the loopholes in the Act during the year 2008, and the implementation of Wetlands (conservation and Management) Rules, 2017 restrict the conversion of paddy wetland to non-agricultural purposes. Hence, the annual growth rate of this category was increasing only at a lower rate (1.62 per cent) during the Period V (2013-14 to 2021-22) than the previous period.

The compound growth rate of barren and uncultivable land, permanent pastures and other grazing land and land under miscellaneous trees was showing declining trend over the all-break point period and overall period under study. The above land uses declined at an annual growth rate of -5.66 per cent, -0.65 per cent and -9.12 per cent respectively during the overall period from 1980-81 to 2021-22.

The area under cultivable waste has declined at an annual growth of -1.08 per cent during the first period but declined at a higher rate of -7.18 per cent during the second period. During this period, both net area sown and non-agriculture uses of land exhibited a positive annual growth rate. The higher rate of decline in cultivable waste land was due to the reclamation of paddy by the innovation of improved farming technology in agriculture sector. But in the third period, cultivable waste land increased by 4.58 per cent per annum due to the diversion of agriculture land to non-agriculture purpose. This diversion was due to low profitability and high cost of cultivation of paddy and other agriculture crops. In the subsequent fourth and fifth period, annual compound growth rate of cultivable waste land was negative (-0.18 per cent and -1.03 per cent respectively).

The land under fallow other than current fallow exhibited highest annual growth rate during the Period III and IV viz a viz 4.92 per cent and 6.49 per cent growth rate per annum in the

respective periods. But during the first and second period showed only a moderate positive growth rate. The growth rate of overall period of this land type was 2.11 per cent. The shortage of labour and the high cost of cultivation with low profitability compel the farmers to kept their land as fallow. The current fallow land, noticed a positive growth rate in the first four periods but in the last or fifth period exhibited a negative growth rate (-3.73 per cent) per annum. However, the reduction in fallow land did not lead to an increase in the percentage of net area sown or non-agricultural uses. Instead, cultivable waste land exhibited a greater rate of increase throughout this time period.

In the case of Net Area Sown (NAS), compound annual growth rate increased marginally during Period I (0.19 per cent) and Period II (0.22 per cent) but subsequently, growth rate per annum decreased marginally over the remaining period. In the overall period, the CAGR of NAS was negative (-0.27 per cent).

Table 3.3

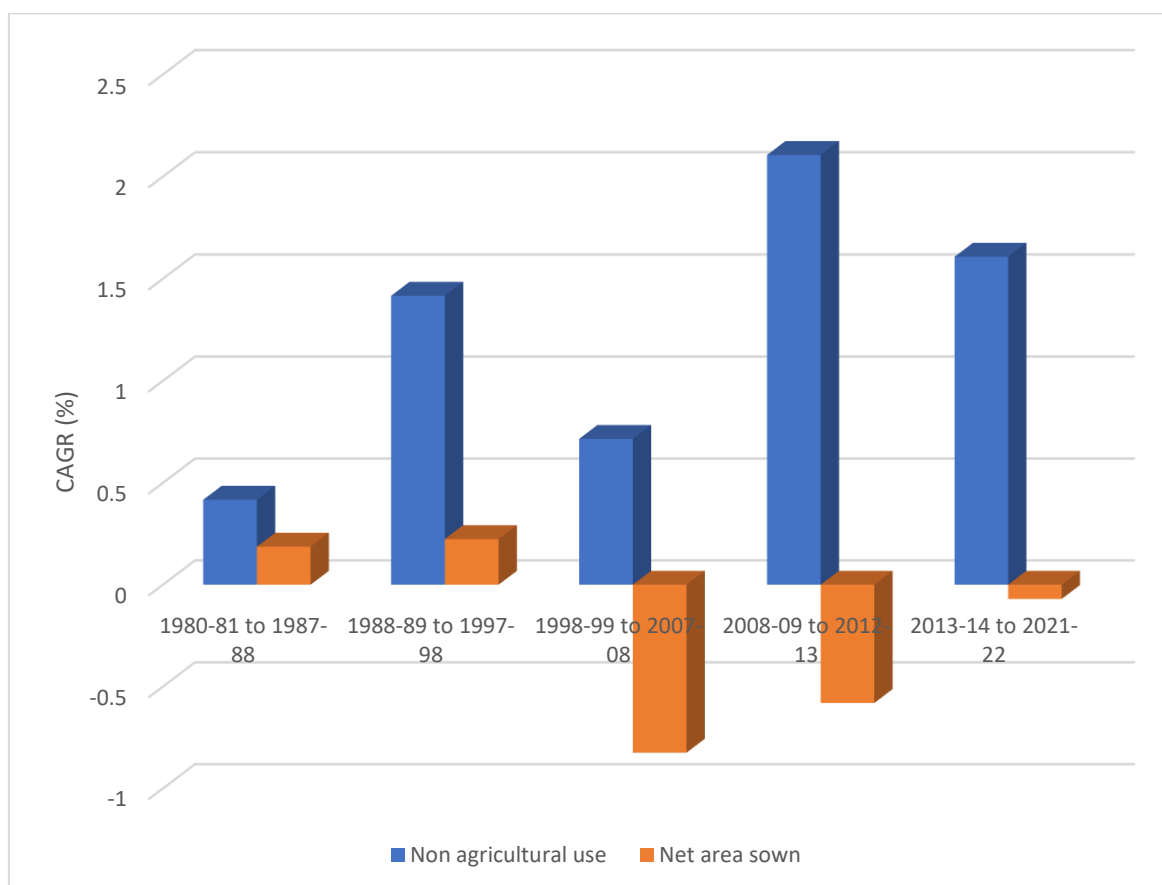
Compound Annual Growth Rate and Instability Index of important Land use in Kerala (In percentages)

Kerala-Land Use	Annual Growth and Instability Index	1980-81 to 1987-88	1988-89 to 1997-98	1998-99 to 2007-08	2008-09 to 2012-13	2013-14 to 2021-22	1980-81 to 2021-22
Non-Agricultural Use	CAGR	0.42	1.42	0.72	2.11	1.61	1.44
	CV	2.51	4.27	6.73	3.41	3.20	17.77
	CDVI	2.50	1.57	6.82	1.30	0.83	4.90
Waste Land	CAGR	-5.04	-6.16	-10.82	-16.46	-2.11	-9.12
	CV	6.12	21.04	6.78	4.08	6.95	40.06
	CDVI	15.38	6.27	6.18	2.27	4.29	21.24
Fallow land	CAGR	0.57	2.77	1.02	2.54	-3.73	1.30
	CV	2.85	7.39	7.78	5.50	9.76	22.88
	CDVI	2.56	4.56	4.21	3.89	5.78	13.27
Other Use of Land	CAGR	NA	NA	NA	2.00	0.02	NA
	CV	NA	NA	193.31	4.09	0.73	127.17
	CDVI	NA	NA	144.02	4.03	0.78	87.36
Net area sown	CAGR	0.19	0.22	-0.82	-0.58	-0.07	-0.27
	CV	0.53	0.75	2.42	0.86	0.42	3.97
	CDVI	0.33	0.42	0.51	0.49	0.45	1.45

Source: Computed from Department of Economics and Statistics, GoK, (various reports)

Figure 3.2

Trend of NAS and NAU in Kerala over different break periods



Source: Department of Economics and Statistics, GoK, (various reports)

The overall growth of arable land was positive (0.27 per cent) during the period of study, although the different periods except Period I exhibited negative trend. In the Period I the growth rate was 5.17 per cent. On the contrary, overall growth rate of total uncultivable land was negative (-0.22 per cent). In the Period I, the arable land grew at a rate of 5.71 per cent annually but net area sown grown only at 0.19 per cent per annum. Instead of increasing net area sown, increased arable land was kept as current fallow or fallow other than current fallow during this period. In the subsequent period a negative growth rate was observed in arable land (-0.06 per cent) but net area sown maintained a positive growth rate of (0.22 per cent). But the succeeding period showed a negative annual growth of net area sown presented in the Figure 3.2. It was estimated that net area sown lost was 10,051 hectare per year during the last 25 years. The area lost from agriculture was converted to non-agriculture uses. The instability index of different land use showed (Table 3.3) that over the break periods, the land use pattern

is stable or low level of instability except other land uses such as marshy land and water-logged lands in Kerala.

In short, the total area of agricultural land in Kerala has decreased over all periods, while the amount of land converted to non-agricultural purposes has increased significantly. The growth of land use for non-agricultural purposes showed a steady positive rate, but the net sown area showed a steady negative growth. Moreover, the growth of waste land and fallow land showed a stable positive growth. This massive conversion of agricultural land for other purposes seriously affects the agriculture sector particularly paddy sector in Kerala. This becomes a serious challenge in relation to food security and ecological resilience of the region. Section 3.5 examines the extent and change in use of paddy land in Kerala in line with the decline in the area of agricultural land.

3.5 Dynamics of Paddy Land use in Kerala

In Kerala, paddy fields are primarily wetlands which are highly productive ecosystem. They provide multiple direct and indirect benefits to the people. These economic and ecological benefits derived from paddy fields support the livelihood and overall wellbeing of the rural farming community (Srinivasan, 2012). But these paddy lands are initially converted to coconut plantation and later on converted to non-agricultural purposes due to the uneconomic farming. In fact, paddy cultivation is not an attractive sector in terms of source of earning and as a prestigious profession. Even though paddy fields generally provide ecological and economic benefits to the people, but it is realised that the economic return from paddy cultivation is not attractive to the farmers to continue in this sector or to conserve the paddy fields for future. Most of the farmers are unaware about the ecological significance of these paddy wetlands. In fact, they treated these lands either as a status symbol or as a real estate business (Muraleedharan, 1984). Therefore, the economic rationale for the farmers is better to convert paddy lands for non-agricultural purposes. The transformation of land as an asset in the form of buildings and residence leads to the collapse of ecological balance of the land. Kerala produces only 16 per cent of the total requirement of paddy for consumption (KSPB, 2017). The balance requirement is met through import of rice from other neighbouring states. In this situation, the conversion of paddy fields creates a big challenge to the food security of the state. Therefore, it is essential to understand the paddy land use change in terms of their performance, cropping pattern and the changes in area production and productivity of paddy crops.

3.5.1 Performance of area under Paddy in relation to different land uses

The performance of area under paddy was analysed by comparing the area used for other land uses in Kerala during the period of study. The area under paddy declined from 8.01 lakh hectare in 1980-81 to 1.94 lakh hectare in 2021-22, which was estimated as the three fourth of the paddy area. This showed that paddy occupies only one fourth positions among Kerala's agricultural crops with respect to area under cultivation. Conversely, the land area used for non-agriculture purpose increased around three fourth and fallow other than current fallow increased about more than 80 per cent during the period. The percentage variation in area under paddy showed a steep fall in each break point period (Table 3.4). During the first period, the per cent variation was (-24.65 per cent) but in the subsequent second and third period showed a big fall of (-35.92 per cent) and (-40.87 per cent) respectively. However, in the fourth period, since 2012-13, the use of land area under paddy was declined only at a lesser extent (-3.82 per cent). This remarkable improvement in area under paddy since 2008-09 period was mainly due to the enactment of The Kerala Conservation of Paddy Land and Wetland Act, 2008 and their subsequent amendment Act. On the other hand, net area sown during the Period I and II showed a positive variation but in the succeeding Period III, IV and V exhibited a negative variation.

The percentage variation of NAS during the Period V was only (-0.92 per cent). Conversely, the land put to non-agricultural use showed a positive variation of 5.55 per cent in the Period I and subsequently 12.47 per cent variation was exhibited in the Period II. The extent of variation in the Period III was much bigger (16 per cent) than the previous period but it was lower (8.35 per cent) during the Period IV. Again, the variation during the Period V was also much higher (15.65 per cent). The area under paddy and the land put to non-agriculture use were indirectly related. Surprisingly, the relationship between the net area sown and area under paddy was not significant. The percentage negative variation under paddy area were not compatible with the percentage increase in non-agriculture uses during each break point periods. This showed that paddy lands are not fully converted to non-agriculture uses but initially converted to plantation crops like rubber and coconut, subsequently banana and plantain and finally partly converted to non-agriculture purposes.

Table 3.4

Percentage variation in area under Paddy in relation to different land uses

Break Period	Arable Land	Net area sown	Non-agricultural use	Cultivable waste	Fallow other than current fallow	Current fallow	Area under Paddy	Gross Cropped Area
I	1.84	1.45	5.55	-10.61	7.04	9.24	-24.65	0.52
II	0.01	2.68	12.47	-43.58	-3.65	22.88	-35.92	2.38
III	-4.89	-8.00	16.00	42.56	63.05	41.80	-40.87	-7.00
IV	2.63	-1.96	8.35	4.13	23.49	-7.48	-13.82	-6.13
V	-2.36	-0.92	15.65	-8.38	-11.49	-29.75	-1.69	-2.65
Over all (1980-81 to 2021-22)	-2.92	-6.89	72.54	-31.41	83.81	23.72	-75.81	-12.54

Source: Computed from Department of Economics and Statistics, GoK, (various reports)

3.5.2 Performance of area under paddy in relation to other important crops in Kerala (Changes in cropping Pattern)

A change in cropping pattern, therefore, means a change in the ratio of land under different crops. In fact, the cropping pattern of Kerala state is very different from that of other states because of climatic and other topographic factors of Kerala state. Since its formation in 1956, state showed a persistent shift of paddy crops to garden crops like coconut and cashew and plantations crops like rubber, tea and coffee. In 1955-56, the land area under paddy cultivation was 7.59 lakh hectares and it was reached a record maximum of 8.81 lakh hectares in 1974-75. In the second half of 1970's, the area of paddy cultivated got much attention but by 1980's showed a reverse trend. In 1980's, the area under paddy cultivation reached the highest level in 1981-82, i.e. 8.06 lakh hectares. In the year 1988-89, showed a lowest area of paddy cultivation i.e. 5.77 lakh hectares only.

Over the last four decades, the paddy crops showed a sharp decline, while other crops, particularly cash crops exhibited a stable or better growth in area (Table 3.5). The area under paddy cultivation in Kerala which was 27.79 per cent of the total cropped area in 1980-81 was sharply declined to 7.75 per cent during 2021-22 period. Essentially, paddy area lost during this period was estimated more than 6 lakh hectares. Conversely, during the same period, the area gained by coconut was 1.14 lakh hectares, rubber by 3.13 lakh, banana and plantain by 0.51

lakh hectares and Arecanut by more than 0.31lakh hectares. The area of the perennial crops gradually increased over the years and these crops dominated the gross cropped area of the state (Figure 3.3).

Table 3.5

Proportion of area under important crops in relation to Gross Cropped Area (In Hectares)

Break Point Period	Gross Cropped Area	Paddy	Coconut	Tapioca	Banana & Plantain	Arecanut	Rubber
I (1980-81 to 1987-88)	2899855 (100)	604082 (20.83)	775365 (26.73)	172908 (5.96)	56909 (1.96)	60535 (2.08)	358957 (12.37)
II (1988-89 to 1997-98)	2969002 (100)	387122 (13.03)	884344 (29.78)	121389 (4.08)	80640 (2.71)	73351 (2.47)	465282 (15.67)
III (1998-99 to 2007-08)	2761094 (100)	228938 (8.29)	818812 (29.65)	83990 (3.04)	110708 (4.00)	99787 (3.61)	512045 (18.54)
IV (2008-09 to 2012-13)	2591734 (100)	197277 (7.61)	798162 (30.79)	69586 (2.68)	109870 (4.24)	101775 (3.92)	539565 (20.82)
V (2013-14 to 2021-22)	2523014 (100)	195734 (7.75)	765435 (30.34)	55664 (2.21)	100921 (4.00)	93968 (3.72)	551030 (21.84)

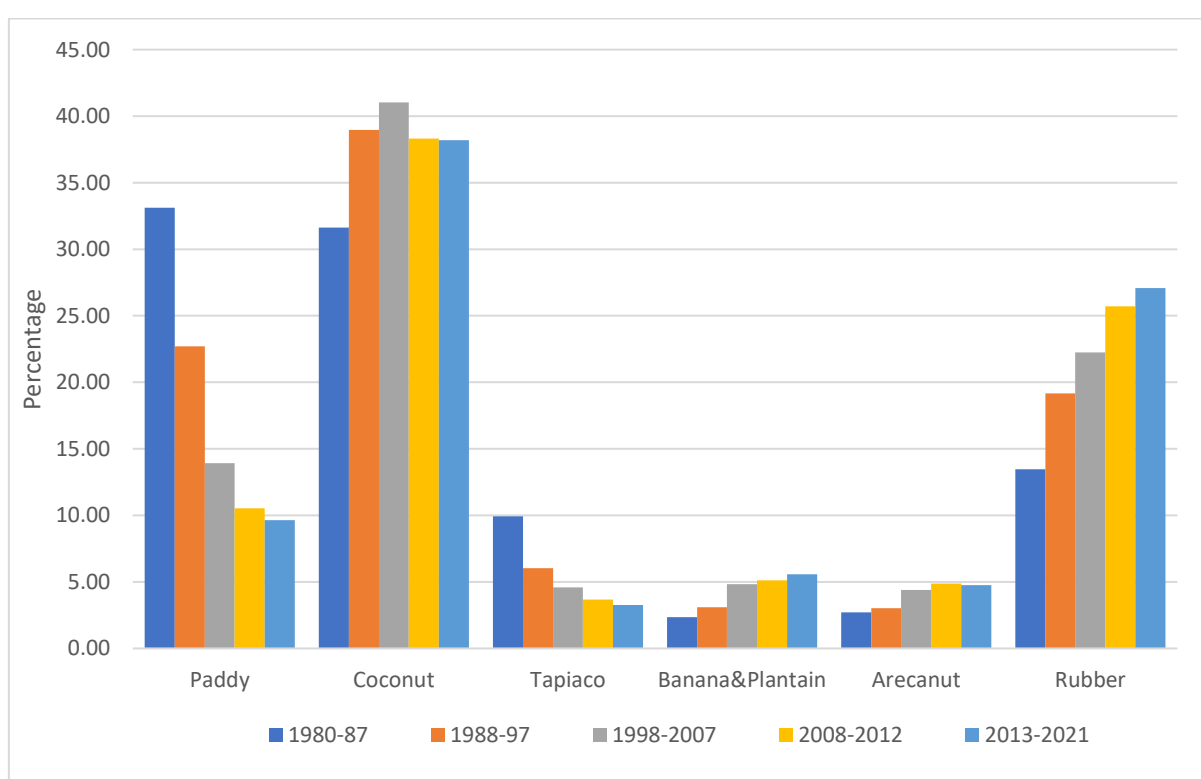
Note: Figures in parenthesis are percentage of gross cropped area

Source: Computed from Department of Economics and Statistics, GoK, (various reports)

The area under important crops given in Table 3.4, except paddy and tapioca was increasing over the decades. The area of paddy cultivated in the year 1980-81 was 8.01 lakh hectares, but it declined to 6.04 lakh hectares (20.83 per cent of the GCA) during Break Period I. It was about loss of 60,000 paddy area during the break period year. Again, during the preceding year of Break Period II (1996-97), paddy cultivated area was 4.31lakh hectares but it declined to 3.87 lakhs hectares (13.03 per cent of the GCA) Period II which was estimated as a loss of 43,704 hectares. However, in the year 2006-07, the area cultivated for paddy was 2.63 lakh hectares which declined sharply to 2.29 lakh hectares in the year 2007-08 (Break Period III). It

was estimated as 8.29 per cent of the gross cropped area of paddy. On the contrary, after a long period of continuous decline, area under paddy increased to 2.34 lakh hectares in 2008-09 but it declined to 1.97 lakh hectares in the Period IV. But again, the trend reversed and in the year 2021-22, the area under paddy was declined only marginally to 1.96 lakh hectares. The proportion of paddy to GCA slightly improved over these years from 7.61 per cent in 2012-13 to 7.75 per cent in the year 2021-22. The positive trend towards increased area of paddy cultivation was due to effective implementation of Kerala Wetland Paddy Act 2008 and their successive amendments.

Figure 3.3
Percentage distribution of area under important crops in Kerala



Source: Department of Economics and Statistics, GoK, (various reports)

The total area under perennial crops started to increase from latter half of the eighties. Among the perennial crops, coconut occupies a predominant position over the decades and accounted 30.34 per cent of the GCA in the year 2021-22. However, the share of coconut area to GCA and actual area cultivated increased simultaneously over the Period III. Although, the relative share of coconut area to GCA increased, the absolute share of area of coconut cultivated decreased marginally in the subsequent break point period.

Another annual crop, Tapioca, a staple food crop, showed a declining trend over the last five decades. During each break points, the absolute and relative area of Tapioca cultivated decreased marginally. The area under Tapioca (it is normally cultivated in mid and highlands) was also suitable for Rubber plantations fell short from 2.45 lakh hectares in 1980-81 to 5.57 lakh hectares in 2021-22. The share of Arecanut to GCA increased marginally from 2.12 per cent in the year 1980-81 to 3.72 per cent in the year 2012-22. The same positive trend was reported in all break point periods.

The area under Banana and Plantain and Rubber showed an increasing trend over the years. The area under Banana and Plantain increased from 49262 hectares in 1980-81 to 1 lakh hectares in 2021-22. The relative share of these crops showed marginal jump of 1.96 per cent, 2.71 per cent, 4.00 per cent and 4.24 per cent respectively in each break point period. On the other hand, the area under Rubber showed a substantial increase in proportion to the decline of paddy from 2.38 lakh hectares (8.24 per cent of GCA) in 1980-81 to 5.51 lakh hectares (21.84 per cent of GCA) in 2021-22.

The cropping pattern of main crops in Kerala demonstrated a clear trade-off between Paddy and Coconut on the one hand, and Tapioca and Rubber on the other. The growing pattern of land usage among different crops revealed that the desire to replace seasonal/annual crops such as Paddy and Tapioca with permanent crops such as Arecanut, Coconut, and Rubber remains strong. Subsistence crops are gradually being replaced by very profitable cash crops over the course of decades.

3.5.3 Season wise trends in area, production and productivity of Paddy crops

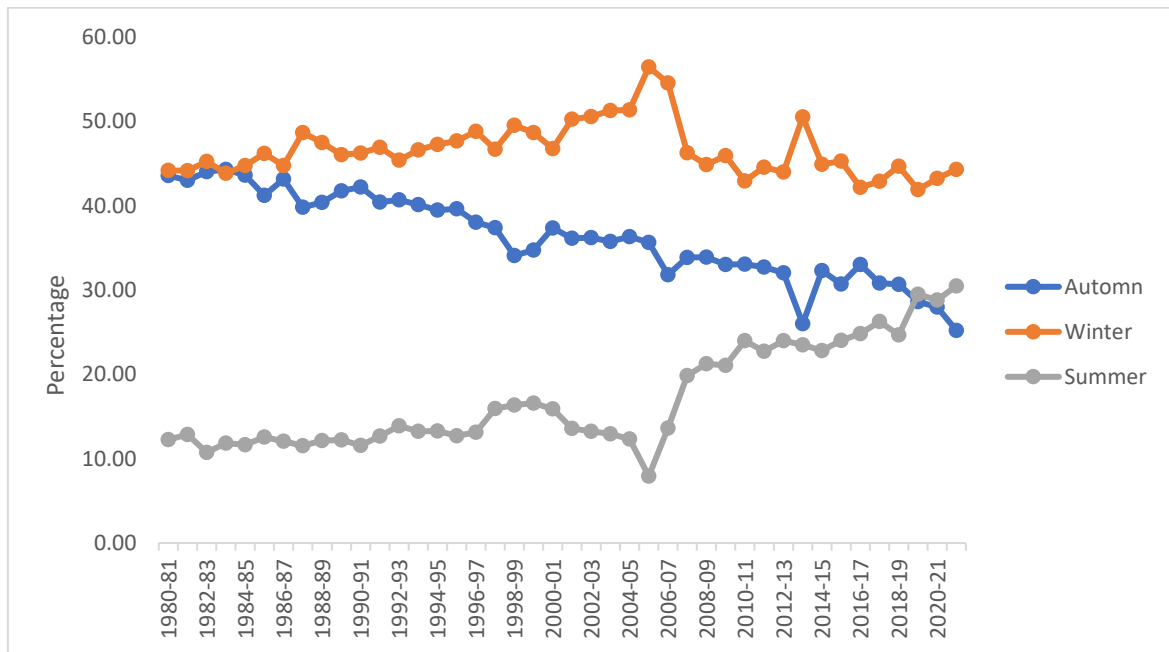
The season wise trend of area, production and productivity of paddy in Kerala is analysed with percentage variation in area (Section 3.5.3.1) and the estimation of their CAGR (3.5.3.2).

3.5.3.1 Variation in share of Paddy area in different seasons

In Kerala, paddy is cultivated during three seasons in a year viz autumn or “virippu” (April-May to august-September), winter or “Mundakan” (September-October to December-January) and summer or “Punja” (December-January to March-April). The percentage share of paddy area cultivated during autumn or “virippu” declined steadily over the years while share of summer or “Punja” increased at substantial rate but winter or “Mundakan” maintained a stable share.

Figure 3.4

Percentage share of paddy area in Kerala under Autumn, Winter and Summer



Source: Department of Economics and Statistics, GoK, (various reports)

The percentage share of autumn paddy area decreased steadily from 43.56 per cent in 1980-81 to 25.21 per cent in 2021-22, but winter paddy area maintained a share of 44 per cent with high amount of volatility during the overall period. However, the summer paddy area increased at alarming share from 12.26 per cent in 1980-81 to 30.48 per cent in 2021-22. In the year 2005-06, the winter paddy area showed a highest share (56.44 per cent) and the summer area showed a lowest share (7.93 per cent) in the same year. Up to the year 2006-07, share of summer paddy area witnessed a stable low rate but after that the share exhibited an increasing rate. The increase in the share of summer paddy area only by replace of the autumn paddy area over the years.

3.5.3.2 Compound Annual Growth Rate of Season wise Area, production and Productivity of paddy crops

The trend of area under paddy has been explained with the help of CAGR under different break point periods of all seasons. There was a significant decline of area under paddy across all seasons. The overall growth rate of paddy area showed a negative growth of (-3.99 per cent) per annum across all seasons. All the break point periods except period V showed negative growth rate per year.

During the first period (1980-81 to 1987-88), the paddy area showed a negative growth at a rate of (-3.95 per cent) per year. The area under paddy cultivation across autumn, winter and summer season together declined sharply at the rate of -4.89 per cent, -3.00 per cent and -4.27 per cent respectively during the period I. The production of paddy cultivation declined significantly across all seasons particularly at the negative growth rate of -7.12 per cent in summer season. Conversely, productivity of the paddy in the first break period showed a marginal positive growth during autumn (0.68 per cent) and winter (0.53 per cent) but decreased in the summer season (-2.98 per cent).

Table 3.6

Season wise Compound Annual Growth Rate of Area, Production and Productivity of Kerala

Break Point Period	Area				Production				Productivity			
	Autumn (virippu)	Winter (Mudakann)	Summer (Puncha)	Total	Autumn (virippu)	Winter (Mudakan)	Summer (Puncha)	Total	Autumn (virippu)	Winter (Mudakan)	Summer (Puncha)	Total
I	-4.89	-3.00	-4.27	-3.95	-4.24	-2.48	-7.12	-3.02	0.68	0.53	-2.98	0.97
II	-5.08	-3.80	-2.01	-4.07	-4.44	-2.75	-1.57	-3.22	0.67	1.10	0.45	0.89
III	-4.92	-3.70	-6.36	-4.40	-3.57	-2.15	-6.10	-2.87	1.42	1.61	0.28	1.59
IV	-5.64	-5.18	-1.42	-4.50	-4.60	-4.02	-0.87	-3.43	1.10	1.23	0.56	1.12
V	-1.23	-1.18	3.68	0.04	-2.21	1.03	4.99	1.24	-0.99	2.23	1.26	1.20
Over all	-5.07	-4.05	-1.72	-3.99	-3.84	-2.53	0.97	-2.49	1.30	1.58	2.74	1.56

Source: Computed from Department of Economics and Statistics, GoK, (various reports)

During the second break point period, the area decline continued at a steepest rate of (-4.07 per cent) per year during all seasons with particularly negative rate of (-5.08 per cent) for autumn crops and steepest negative rate (-3.8 per cent) for winter season. The production of paddy also showed a declining negative trend at a lower rate during the same period II with slightly better performance of winter paddy production. The productivity exhibited a slightly improving trend (0.89 per cent) per year over all season specifically a higher rate of CAGR (1.10 per cent) for winter season. The accelerated decline of paddy area and production during this period was

because of labour shortage in agriculture with gulf outmigration and continued significance and government promotion policy towards rubber and coconut. By mid 1990s, the import of rice from neighbouring states started and this reduced the interest of the farmers to grow more paddy.

The paddy area consistently declined in all seasons (-4.40 per cent) during the third break period especially with ever highest negative growth of summer season (-6.36 per cent) per annum. During this phase, the decline of paddy production marked a lowest negative growth of (-2.87 per cent) along with a highest negative growth in summer season (-6.10 per cent). The decline in paddy production in summer season is compatible with decline in paddy area. The productivity of paddy continued to improve with annual growth rate (1.59 per cent) in all seasons especially winter (1.61 per cent) and autumn (1.42 per cent). The Kerala government had made several initiatives for the improvement of paddy productivity by providing subsidies for seeds, fertilisers and irrigation during this break point period. Moreover, the Integrated Rice Development Programme (IRDP) for improving irrigation infrastructure and watershed management programme for addressing water scarcity. However, the area under paddy cultivation still declined due to urbanisation with a slow pace of increasing productivity.

The declining trend of paddy area worsened in the fourth phase also. The fourth phase of the break point period showed that the paddy area of autumn and winter season declined negatively (growth rate of -5.64 per cent and -5.18 per cent per year respectively). The production per year in the overall period also declined but the rate of decline was slowdown particularly in summer season (-0.87 per cent). The productivity continued to grow during this phase. The Kerala Conservation of Paddy land and Wetland Act (2008) was implemented during this phase to stop the rapid conversion of paddy land to non-agricultural purposes. But the weak implementation of these acts may help to continue the illegal conversion of paddy area which reduces the area under paddy during this period. The shortage of labour in paddy farming due to the implementation of MGNREG programme also leads to the shifting of area under paddy crops to non-agriculture purposes. However, during this period, a new organic farming culture was started in paddy crops which helped to increase the productivity by improving soil quality. The positive trend of productivity during this period, in fact, was due to the increased subsidy to inputs such as seeds and fertilisers, effective application of mechanisation, and introduction of high yielding seeds, especially during winter and summer season.

In the break point Period V (2012-13 to 2021-22), the area, production and productivity of all seasons showed a positive compound annual growth. The area under paddy showed only a modest decline for autumn (-1.23 per cent) and winter (-1.18 per cent) while a positive annual growth trend showed in summer season (3.68 per cent). The annual growth of production increased in the summer and winter season by 4.99 per cent and 1.03 per cent respectively but a negative growth noticed in the autumn season (-2.21 per cent). The negative growth of production caused a negative annual growth of productivity of paddy in autumn season. However, the productivity of all season (1.2 per cent) especially summer and winter showed a better positive growth. In fact, the period V exhibited a moderate stability in paddy area and a steady rise in productivity. This improvement in paddy cultivation was mainly by the support given by National Food Security Mission (NFSM) through better seeds, fertiliser and technology in summer season. Moreover, Kerala government support farmers, by offering subsidies for equipment like paddy transplanters and harvesters.

Recently, the Kerala State Agricultural Development Policy (2021) promoted farmers to return to Paddy production by providing financial incentives, better irrigation infrastructure, and climate-resistant paddy varieties. The government worked to adapt rice production to climate change by developing new, robust rice varieties that can endure droughts, floods, and unpredictable monsoon patterns. The state has also taken initiatives to restore abandoned paddy fields and wetlands, by providing incentives for farmers to resume rice cultivation in these regions.

The decline in paddy land and subsequent drop in paddy output has resulted in food insecurity, as well as some environmental and ecological issues in Kerala. The paddy growing wetland environment produces wide varieties of both direct and indirect products and services. These services contributed food security and sustainability. But the conversion of paddy fields to other commercial and perennial crops and non-agriculture purposes had undergone wide range of socioeconomic and ecological consequences. State food security suffers when paddy output fall. Kerala has a food production shortage of more than 90 per cent. Furthermore, it contributes to increased unemployment and poverty, reduced ground water recharge, and extended water logging in settlements. It also destroyed the wetland paddy ecosystem services like food and fibre production, fish production, soil nutrition and retention, water recharge, climate resilience, aesthetic and recreational activities and so on.

3.5.4 District Wise Paddy Land Use Change in Kerala

The inter district variations in the share and performance of paddy cultivation was calculated by estimating the compound growth rate of area, production and productivity of paddy at district level.

3.5.4.1 District Wise Share of Paddy Area in Kerala

In all districts, except Alappuzha, Palakkad and Kottayam, the area under paddy has been shrinking (Table 6). 80 per cent of the paddy area cultivated in Kerala concentrated in four districts such as Palakkad, Alappuzha, Thrissur and Kottayam. The percentage share of paddy area in Palakkad district, which is known as the “rice bowl” of Kerala, increased substantially from 22.91 per cent in 1980-81 to 39.09 per cent in 2021-22. However, the total area cultivated during this period declined from 1.83 lakh hectare to 0.76 lakh hectare. The share of Alappuzha also increased from 10.29 per cent to 18.66 per cent, but the area cultivated declined from 0.82 lakh hectare to 0.37 lakh hectare during the same period. Though the share of paddy area in Kottayam also increased from 3.99 per cent to 9.48 per cent, but there was a substantial contraction in total area cultivated. Conversely, the share of paddy area in Thrissur has remained relatively stable between 10.59 per cent (1997-98) and 13.93 per cent (1987-88), with a current share of 12.09 per cent in 2021-22. But, one of the major contributing districts of paddy in Kerala, Thrissur, too witnessed a decline of total paddy area from 1.10 lakh hectare to 0.24 lakh hectare. Even so, only Thrissur district showed a relatively stable per cent share of paddy area over the years. This was sometimes due to the implementation of Conservation of Paddy Wetland Act 2008. The share of paddy area of all other districts shrank over the period. Thiruvananthapuram, Kollam, Ernakulam and Kozhikode districts exhibited a higher shrink of the share of paddy area over the years. The steady decline of paddy shares in Thiruvananthapuram from 4.06 per cent in 1980-81 to 0.94 per cent in 2021-22 was due to the heavy urbanisation in capital city of Kerala. The share of Kollam and Ernakulam paddy area showed a similar pattern of steady decline from 6.24 per cent and 12.79 per cent in 1980-81 to 0.97 per cent and 2.41 per cent in 2021-22 respectively. The extent of urbanisation and industrialisation was very high in those districts. The share of Kozhikode fell from 5.67 per cent to 0.94 per cent during the period from 1980-81 to 2021-22.

The extent of paddy area in Kerala has significantly shrunk throughout the decades since 1980s (Table 3.7). The comprehensive reduction of paddy acreage in several districts exhibited the changes in cropping pattern, the extent of urbanisation, industrialisation and attitude of farmers

towards paddy cultivation. The table revealed the dominance of Palakkad district in paddy cultivation. The steady and stable share of Thrissur district in paddy cultivation in Kerala is also highlighted here.

Table 3.7

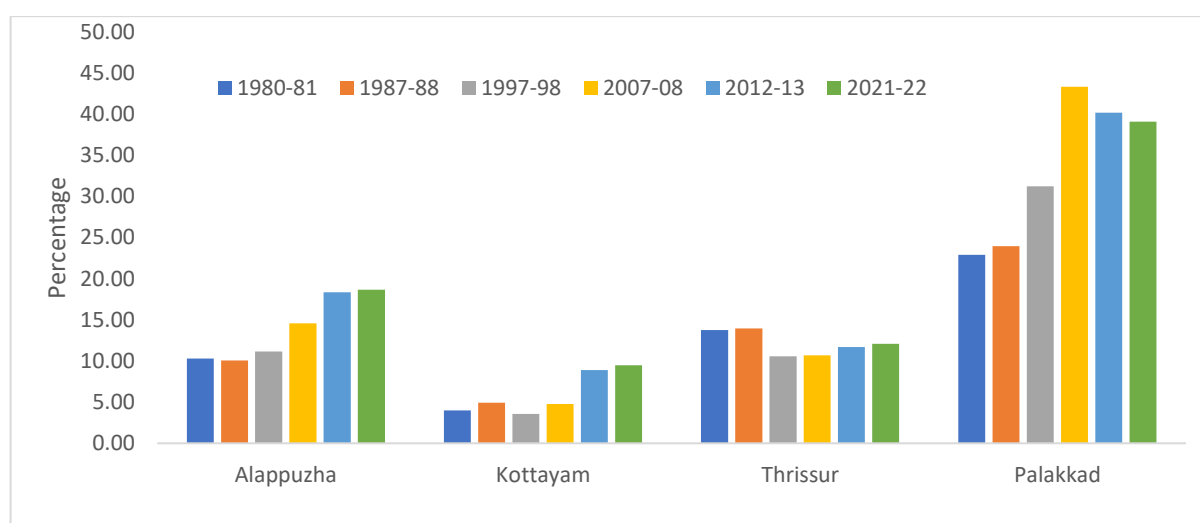
District wise percentage share of paddy area in Kerala

District	1980-81	1987-88	1997-98	2007-08	2012-13	2021-22
TVM	4.06	3.86	2.94	1.25	0.92	0.94
KLM	6.24	5.00	5.17	1.55	0.70	0.97
PTA	0.00	2.33	2.14	0.87	1.16	1.80
APA	10.29	10.06	11.16	14.56	18.35	18.66
KTM	3.99	4.94	3.55	4.79	8.91	9.48
IDK	1.16	0.89	1.05	0.96	0.60	0.25
EKM	12.79	13.21	11.92	5.39	2.00	2.41
TSR	13.76	13.93	10.59	10.67	11.71	12.09
PKD	22.91	23.95	31.21	43.32	40.15	39.09
MPM	9.98	9.35	7.47	4.15	3.38	5.01
KDE	5.67	2.58	2.06	1.66	1.78	0.94
WND	0.00	3.53	4.63	5.42	5.19	4.16
KNR	9.16	3.73	4.04	3.16	3.39	2.68
KGD	0.00	2.64	2.06	2.26	1.78	1.52
KERALA	100	100	100	100	100	100

Source: Computed from Department of Economics and Statistics, GoK, (various reports)

Figure 3.5

Percentage share of area of paddy among four paddy producing districts in Kerala



Source: Department of Economics and Statistics, GoK, (various reports)

The area under paddy showed a wide variation in major paddy producing districts in Kerala over 42 years. During the first break point period a steady share of positive trend in all four districts has been observed. However, in the period II, Palakkad and Alappuzha showed a positive trend in share but Thrissur and Kottayam showed a decline trend in percentage share of paddy area. Conversely, during the third break point period, all the four major rice producing districts exhibited a positive trend in their share. During the fourth and fifth break point period, Alappuzha, Kottayam and Thrissur showed a positive trend while Palakkad showed a significant decline of share of paddy area. The analysis of the trend of area under paddy showed that the share of Thrissur district remains stable over the years compared with other districts in Kerala.

3.5.4.2 District Wise CAGR of Paddy Area, Production and Productivity in Kerala

To gain a comprehensive understanding of rice cultivation variations, it is crucial to analyse changes in area, production, and productivity across districts. The analysis uses district-level data from 1980s. The district level analysis has been conducted from 1980-81 to 2021-22 for all districts except Pathanamthitta, Wayanad, and Kasaragod, which were recently constituted. The selected period for these districts was 1983-84 to 2021-22; 1981-82 to 2021-22; and 1986-87 to 2021-22, respectively. The district-wise cumulative growth rate of area under paddy for the period 1980-81 to 2021-22 was given in Table 3.8. The overall cumulative growth rate of paddy area in Kerala showed a moderate negative trend (-3.99 per cent) across the state, although with significant variations across districts and time period.

During the period 1980-81 to 1987-88 (Period I), the major paddy growing district, Palakkad, showed a negative growth rate of -3.14 per cent, slightly lower than the state average (-3.95 per cent). The other two important districts, viz, Alappuzha (-5.35 per cent) and Thrissur (-4.13 per cent) noticed a slightly higher negative growth rate than state average. Kannur districts showed a highest negative growth rate (-14.22 per cent) followed by Kozhikode (-11.85 per cent) respectively during this period. While, Kottayam and Ernakulam showed a lowest negative growth rate of -1.10 and -3.74 per cent.

During the second period, Palakkad district showed a lowest negative growth (-1.76 per cent), followed by Idukki (-1.61 per cent) and Wayanad (-1.23 per cent). The highest negative growth rate was observed in Malappuram, followed by Kozhikode and Kasargod. The major paddy growing areas like Alappuzha (-4.92 per cent) and Thrissur (-5.84 per cent) also showed a negative growth rate which was slightly more than the state average (-4.07 per cent).

Table 3.8
District Wise CAGR of Paddy Area in Kerala

District	1980-81 to 1987-88	1988-89 to 1997-98	1998-99 to 2007- 08	2008-09 to 2012- 13	2013-14 to 2021- 22	Over all (1980-81 to 2021-22)
TVM	-4.23	-5.97	-10.85	-11.36	-0.22	-8.14
KLM	-7.77	-4.15	-15.09	-22.47	7.82	-9.31
PTA	-7.30	-4.77	-12.64	-3.83	5.79	-5.60
APA	-5.35	-4.92	-1.65	1.99	1.90	-2.08
KTM	-1.10	-5.59	-3.17	13.55	2.67	-1.95
IDK	-6.10	-1.61	-5.13	-16.34	-2.41	-6.60
EKM	-3.74	-3.86	-11.33	-23.78	0.41	-8.61
TSR	-4.13	-5.84	-5.16	-5.48	0.17	-4.52
PKD	-3.14	-1.76	-4.80	-5.52	-0.81	-2.40
MPM	-4.87	-6.73	-8.46	-10.97	2.72	-6.59
KDE	-11.85	-6.46	-6.42	-3.87	-2.27	-6.52
WND	-3.72	-1.23	-3.86	-7.76	-3.90	-3.55
KNR	-14.22	-3.56	-5.77	-4.75	2.37	-6.01
KGD	---	-6.16	-5.97	-7.98	-3.38	-5.98
KERALA	-3.95	-4.07	-4.40	-4.50	0.04	-3.99

Source: Computed from Department of Economics and Statistics, GOK

During Period III (1998-99 to 2007-08), the Kollam district had the highest negative growth followed by Ernakulam, Pathanamthitta and Thiruvananthapuram districts which were much lower than state average. Only Alappuzha, Kottayam and Wayanad had area growth rate higher than the state average.

During the Period IV, since the inception of Conservation of Wetland Paddy Act 2008, a sharp decline of paddy area for most of districts particularly Kollam, Ernakulam, Idukki and Thiruvananthapuram have been noticed. However, Kottayam district experienced an increased trend with a highest positive growth rate of 13.55 per cent and Alappuzha exhibited a positive growth rate of 1.99 per cent of paddy area.

The period 2013-14 to 2021-22, having a positive growth rate for most of the districts, had much higher growth rate than the state average (0.04 per cent). Surprisingly, even Ernakulam and Kollam, showed a highest negative growth rate in the previous period, exhibited a positive

growth rate in this period, but Palakkad district, ‘Rice bowl of Kerala’, had a negative growth rate (-0.83 per cent). Thrissur district also showed the positive growth rate similar to state average.

The overall (1980-81 to 2021-22) period showed a negative compound annual growth rate for all districts and the state average. Paddy land area shrank in all areas, including major rice-producing districts. While all districts and the state average showed a negative growth rate with substantial instability over time, the Thrissur district mostly follows the state pattern with a constant negative growth throughout, but its overall rate is slightly lower than the state average. The district wise compound annual growth rate of paddy production is illustrated in Table 3.9.

Table 3.9
District Wise CAGR of Paddy Production in Kerala

District	1980-81 to 1987-88	1988-89 to 1997-98	1998-99 to 2007-08	2008-09 to 2012-13	2013-14 to 2021-22	Over all (1980-81 to 2021-22)
TVM	-1.70	-5.84	-8.19	-12.69	-0.85	-6.75
KLM	-7.03	-3.46	-13.50	-22.84	6.59	-8.60
PTA	-2.10	-4.83	-13.75	-2.52	4.33	-4.52
APA	-14.68	-3.90	-3.34	1.41	1.28	-0.41
KTM	-0.04	-6.17	-3.01	15.04	1.22	-0.97
IDK	-3.93	-2.20	-3.79	-16.17	-5.37	-5.98
EKM	-2.21	-3.73	-10.06	-21.80	1.03	-7.58
TSR	-1.47	-3.27	-2.99	-1.48	1.51	-2.30
PKD	-4.96	-1.34	0.29	-6.27	1.33	-1.33
MPM	-3.20	-5.12	-5.86	-8.58	6.23	-4.49
KDE	-12.02	-5.72	-5.17	-1.11	-4.64	-5.87
WND	-5.08	-0.05	-2.74	-6.94	-3.09	-2.37
KNR	-12.55	-3.15	-3.93	-0.43	1.58	-4.77
KGD	----	-5.51	-4.31	-6.71	-4.41	-5.07
KERALA	-3.02	-3.22	-2.87	-3.43	1.24	-2.49

Source: Computed from Department of Economics and Statistics, GoK, (various reports)

The overall interdistrict variations of paddy production showed a negative annual compound growth rate in all districts. During the overall period, the state level production declined from 12.72 lakh tonnes to 5.62 lakh tonnes. This decline was witnessed as an average -2.49 per cent

per year during this period (Table 3.9). During this period, the important rice growing districts, paddy production in Palakkad declined from 3.74 lakh tonne to 2.43 lakh tonne (negative compound growth rate of 1.33 per cent) and Alappuzha witnessed a decline from 1.45 lakh tonne to 0.93 lakh tonne (negative CAGR of 0.41 per cent). The third important paddy growing district, Thrissur, witnessed a sharp decline of paddy production from 1.48 lakh tonne to 0.72 lakh tonne during this period. Similar to state average, the average decline of paddy production per year in Thrissur was negative (2.30 per cent).

All break point periods showed a negative CAGR between 2.87 per cent to 3.34 per cent in Kerala, except break point period V. During the period V (2013-14 to 2021-22), the paddy production in Kerala showed a positive growth rate of 1.24 per cent. In fact, the reason for the positive growth rate in paddy production during this period was probably due to the positive area growth rate (0.04 per cent). Only Thrissur district showed a pattern of growth rate similar to state average in paddy production during all breakpoint periods. All other districts showed a higher volatility in all break period points compared to state average. The average compound annual growth rate of paddy production in Thrissur district during the period 2013-14 to 2021-22 was 1.51 per cent. All other break point periods showed a negative growth rate between 1.47 per cent to 3.27 per cent in Thrissur district (Table 3.9).

The district wise compound annual growth rate of paddy productivity is presented in Table 3.10. In the year 1980-81, the productivity of paddy in major rice producing districts viz, Palakkad, Alappuzha and Thrissur exhibited 2036 kg, 1757 kg, and 1338 kg per hectare respectively. This was higher than the state productivity of 1557kg/ha. The districts like Kottayam, Ernakulam and Idukki also showed a higher productivity than state (DES, 2017). The paddy promotion activities of last 40 decades have led to the enhanced productivity of paddy in Kerala. In Palakkad the productivity increased to 3181kg/Ha. Though the productivity of Alappuzha district also increased to 2551 kg/ha, it was lower than state productivity (2870 kg/ha) in 2021-22 period. Thrissur district showed highest productivity than all other districts and stood at a level of 3063 kg/ha in 2021-22 and it was 3663 kg/ha in the year 2020-21. In Alappuzha and Palakkad, paddy productivity increased by 45 per cent and 56 per cent, respectively, between 1980-81 and 2021-22. However, Thrissur district had a 129 per cent rise in paddy productivity over this time span. In addition, the compound annual growth rate of productivity also showed highest positive growth rate of 2.33 per cent in Thrissur, which was much higher than all other districts and state average (1.57 per cent). In fact, only Thrissur district exhibited a better positive growth rate of paddy productivity in all break periods

compared with other districts. Even though, Ernakulam, Malappuram and Wynand showed a positive growth in all break periods, but the growth rate of Thrissur was not comparable with those districts.

Table 3.10
District Wise CAGR of Paddy Productivity in Kerala

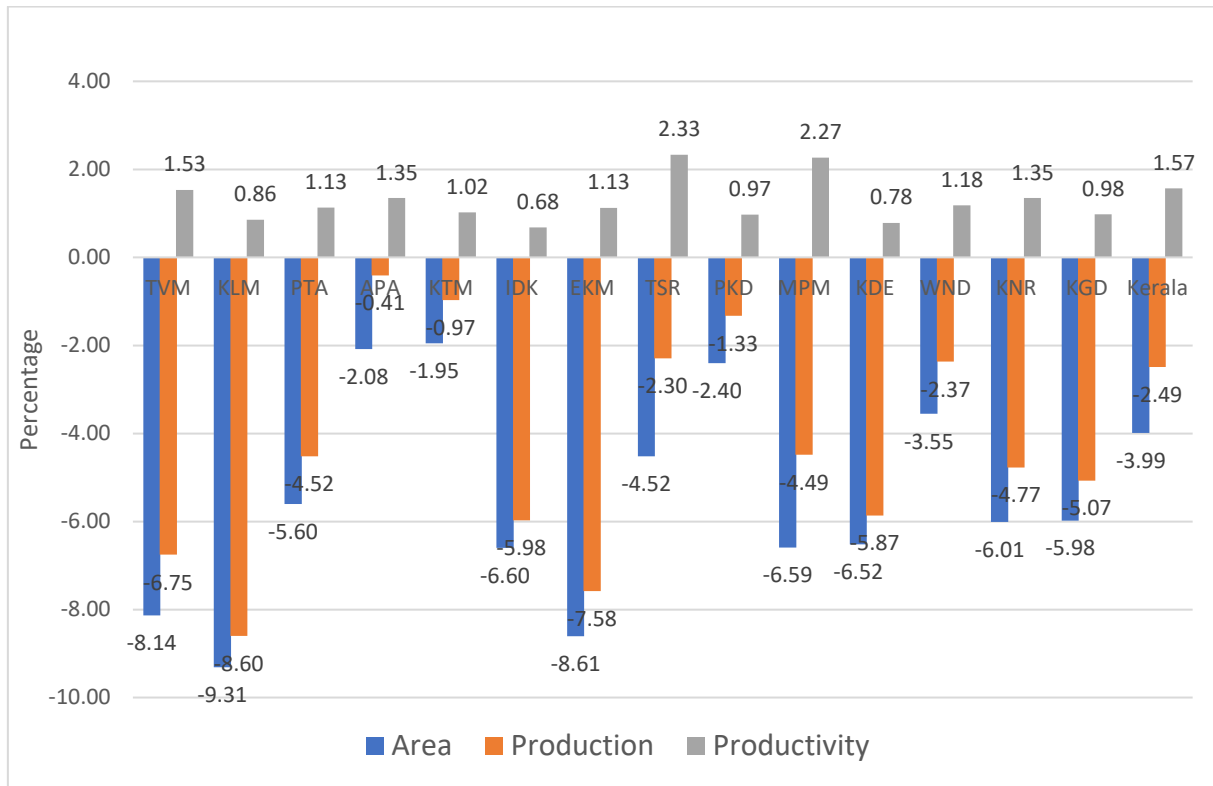
District	Period I	Period II	Period III	Period IV	Period V	Over all Period
TVM	2.49	0.14	2.98	-1.51	-0.48	1.53
KLM	0.81	0.72	1.88	-0.47	-0.85	0.86
PTA	5.60	-0.06	-1.27	1.36	-1.36	1.13
APA	0.87	1.07	-1.73	-0.57	-0.05	1.35
KTM	1.07	-0.62	0.17	1.33	-1.20	1.02
IDK	2.30	-0.61	1.42	0.21	-2.93	0.68
EKM	1.59	0.14	1.42	2.60	0.63	1.13
TSR	2.77	2.73	2.29	4.23	1.37	2.33
PKD	-1.88	0.43	1.02	-0.79	2.17	0.97
MPM	1.76	1.74	2.84	2.69	3.51	2.27
KDE	-0.18	0.79	1.33	2.88	-1.92	0.78
WND	0.16	1.26	1.17	0.88	0.86	1.18
KNR	2.14	0.42	1.95	4.53	-0.46	1.35
KGD	----	0.69	1.77	1.38	-0.96	0.98
KERALA	0.97	0.89	1.6	1.12	1.2	1.57

Source: Computed from Department of Economics and Statistics, GoK, (various reports)

The district wise examination of paddy land use change in Kerala identified that area, production and yield per hectare of Thrissur district produced a noticeable result compared with other districts. In tune with state average, the negative growth of paddy area in all districts are higher than the growth of production of paddy. Hence the productivity is positive in of all districts and state average (Figure 3.6). A significant contribution is being made by the highly productive Kole wetlands in this district for the attainment of highest positive paddy production and productivity in Thrissur compared with other districts in Kerala. Hence, the examination of Kole paddy land use change and their contribution in the field of paddy production is very relevant for the study of role of ecosystem services in achieving farmers welfare.

Figure 3.6

District wise CAGR of paddy area, production and productivity in Kerala



Source: Department of Economics and Statistics, GoK, (various reports)

The decline in area and production is due to the resultant fragmented land holdings of land reforms policy implemented effectively on 1980s in Kerala, which fragmented farms into small sizes, that would become inefficient. Moreover, mechanisation became difficult in these small holdings made farmers largely relied on labour intensive farming which makes paddy cultivation unprofitable. Thus, farmers substituted high return oriented commercial crops against highly labour-intensive and less remunerative paddy crops.

The pattern of paddy land use in Kerala reveals a nuanced picture of the shift from subsistence paddy cultivation to perennial crops and finally to non-agricultural uses. The paddy cultivation seasonally skewed to single cropping season particularly *Puncha* crops, highlights the decline in cropping intensity in Kerala. *Puncha* crops are mainly concentrated on Kole wetlands area of Thrissur district. Since 2012-13, growth of area and production of paddy in important districts and state average showed positive trend of growth. Moreover, overall growth of productivity showed a positive growth in all break periods. The positive trend in productivity across all districts is due to the small decline in production outweighing the large decline in

paddy area. Although important paddy producing districts shows instability in growth of area, production and productivity of paddy, Thrissur district shows stable share and growth in area, production and productivity in tune with state average. The paddy land use dynamics in Kerala revealed a massive scale of conversion of paddy land towards non-agricultural uses which represents a permanent loss of agricultural potential and ecological services.

3.6 Dynamics of Paddy Land Use in Thrissur

The long-term changes in trend and performance of land use pattern and cropping pattern of Thrissur are analysed under this section. It examines the conversion of paddy area and their trend in production and productivity.

3.6.1 Land Holding Pattern

Land holding pattern refers to how land is owned and operated among individuals, families and institutions within a region. Land holdings are categorized by size, such as marginal, small, semi-medium, medium, and large holdings (DAFW, 2016). The overall number of operational holdings in Kerala rose from 66.57 lakhs in 2000–01 to 69.04 lakhs in 2005–06, then fell to 68.30 lakhs in 2010–11 before rising to 75.83 lakhs in 2015–16, according to the agricultural census. Kerala's average land holding size decreased from 0.24 hectares in 2000–01 to 0.23 hectares in 2005–06, then to 0.22 hectares in 2010–11 and finally to 0.18 hectares in 2015–16. The average size of holding of different size class except large size in Thrissur district is similar to the state average. The average size holding of large size class in Kerala was 51.04 hectares while it was only 26.53 hectare in Thrissur. Out of the total land holdings, 96.7 per cent are marginal holdings in Kerala. But in Thrissur district, 98.14 per cent land holding are marginal (Table 3.11). The number of large sizes of land holding (> 10 hectare) is only negligible in Kerala (0.02 per cent) and Thrissur (0.01per cent).

Table 3.11

Distribution of Land holding Pattern in 2015-16

Sl.	Class and size of holdings	Kerala		Thrissur	
		No. of operational holdings	Average size of holdings (Area in hectares)	No. of operational holdings	Average size of holdings (Area in hectares)
1	Marginal (< 1 ha)	7333248 (96.7)	0.12	706361 (98.14)	0.10
2	Small (1-2 ha)	181372 (2.39)	1.34	10236 (1.42)	1.33
3	Semi Medium (2-4 ha)	55744 (0.74)	2.54	2569 (0.36)	2.57
4	Medium (4-10 ha)	11274 (0.15)	5.32	471 (0.07)	5.22
5	Large (> 10 ha)	1858 (0.02)	51.04	95 (0.01)	26.53
	All	7583496 (100)	0.18	719732 (100)	0.14

Note: Figures in parenthesis are percentage

Source: Agricultural Census, 2015-16, Directorate of Economics and Statistics, GOI

3.6.2 Land Use pattern in Thrissur

Land use pattern stands for the arrangement and organization of different types of land within a given area, which are utilised for various purposes, such as agriculture, forests, pastures, residential housing, commercial activities, and industry. Increasing pressure of population and the rapid urbanisation of Thrissur district in the midst of increasing food demand acquired a special attention to the role of change in land use pattern. With the increase in population, the change in family culture like nuclear family and rapid urbanisation compel the people to utilise the more land for construction of house and building by converting agricultural land. The huge share of agricultural land and fallow land was converted to non-agricultural purposes. Moreover, it is observed that, multiple cropping in paddy area declined drastically along with decline in net sown area, which resulted large decline in total cropped area in Thrissur.

Table 3.12
Land use Pattern in Thrissur

Land Use	1980-81	2007-08	2021-22	Percentage change from 1980-81 to 2007-08	Percentage change from 2007-08 to 2021-22	Percentage change from 1980-81 to 2021-22
Total Geographical area	299390 (100)	299390 (100)	302919 (100)	0	1	1
Forest	103619 (35)	103619 (35)	103619 (34)	0	0	0
Land put to non- agricultural use	21642 (7)	35355 (12)	41359 (14)	63	17	91
Barren & uncultivable land	2192 (1)	424 (0)	57 (0)	-81	-87	-97
Permanent pastures & other grazing land	187 (0)	0 (0)	0 (0)	-100	--	-100
Land under misc. tree crops	1307 (0)	0 (0)	106 (0)	-100	---	-92
Cultivable waste	5452 (2)	6090 (2)	9366 (3)	12	54	72
Fallow other than current fallow	3021 (1)	6050 (2)	4600 (2)	100	-24	52
Current fallow	4860 (2)	14617 (5)	5025 (2)	201	-66	3
Other land use	0 (0)	7014 (2)	5500 (2)	--	-22	--
Net area sown	156810 (52)	129350 (43)	133287 (44)	-18	3	-15
Area sown more than once	74645 (25)	44871 (15)	33848 (11)	-40	-25	-55
Total cropped Area	231455 (77)	174221 (58)	167135 (55)	-25	-4	-28

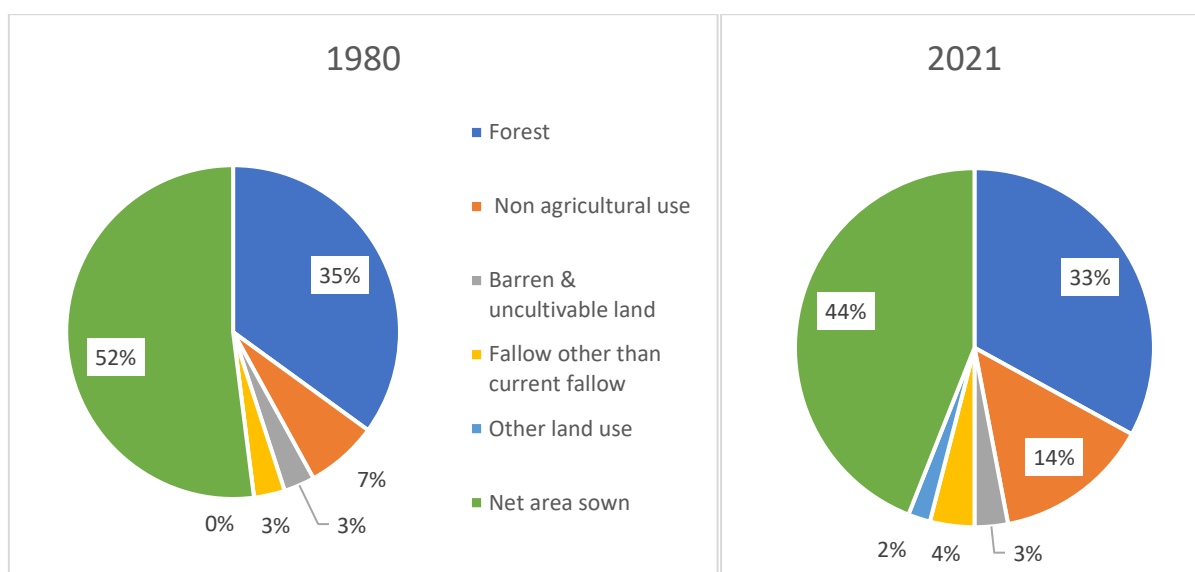
Note: (i) Other land use include still water, water logged and social forestry

(ii) Figures in parenthesis are percentage of TGA

Source: Computed from Department of Economics and Statistics, GoK, (various reports)

Figure 3.7

Percentage changes in Land use pattern of Thrissur in 1980 and 2021



Source: Department of Economics and Statistics, GoK, (various reports)

The land use pattern in Thrissur has been presented in Table 3.12. Three periods of time are taken for the analysis (1980-81, 2007-08 and 2021-22) of share of paddy in different land uses. The year 2007-08 is considered to be a break point because of the implementation of Kerala Wetland Conservation Act, 2008. For accommodating the urbanisation, there has been an increase in land used for non-agriculture purposes. In the year 1980-81, 21642 hectares of land (7 per cent of the total geographical area) were used for non-agriculture purposes. But it increased to 14 per cent (41359 hectares) by 2021-22. The percentage increase of this land use type during the overall period (1980-81 to 2021-22) was 91 per cent. However, during the period of 2007-08 to 2021-22, the per cent increase was only 17 per cent. It is evident from the Table 3.10 that, the share of cultivable waste increased to 3 per cent in 2021-22 from 2 per cent in 1980-81. The cultivable waste land is estimated to increase by 72 per cent over the period. Over the years, there was a 52 per cent increase in fallow other than current fallow. The Net area sown was first declined from 1.57 lakh hectares (52 per cent of TGA) in 1980-81 to 1.29 lakh hectares (43 per cent of TGA) in 2007-08. But later it increased to 1.33 lakh hectares (44 per cent of TGA) in 2021-22 (Figure 3.7). However, over the 42 years, the per cent decline of the Net sown area was by -15 per cent.

3.6.3 Cropping pattern of Important Crops in Thrissur

Cropping pattern stands for the proportional distribution of the cultivated area among the crops. It is identified that there are three principal seasons in Thrissur namely, *Virippu* (Autumn), *Mundakan* (Winter) and *Puncha* (Summer). The total cropped area of Thrissur decreased to 167135 hectares in 2021-22 from 231455 hectares in 1980-81. There has been a 27.79 per cent decline in total cropped area during the period from 1980-81 to 2021-22 which was higher than the state level of 12.54 per cent decline (Table 3.4). During this period, area of paddy, Tapiaco and Arecanut noticed percentage reduction of -78.55, -84.04 and -12.57 respectively. But the area of other important crops showed a significant increase in percentages over this period. Table 3.13 illustrated the share of important crops in Thrissur in relation to Total cropped area and their percentage variations over the break point periods.

Table 3.13

Proportion of area under important crops in relation to Total Cropped Area (In Hectares)

Break Point Period	Total Cropped Area	Paddy	Coconut	Tapioca	Banana & Plantain	Arecanut	Rubber
1980-81	231455	110314 (47.66)	54030 (23.34)	6191 (2.67)	1549 (0.67)	6633 (2.87)	9386 (4.06)
1987-88	215419	84176 (39.08)	69715 (32.36)	4510 (2.09)	1702 (0.79)	6569 (3.05)	8992 (4.17)
1997-98	184674	40977 (22.19)	76656 (41.51)	2113 (1.14)	2561 (1.39)	5377 (2.91)	13105 (7.10)
2007-08	174221	24422 (14.02)	81697 (46.89)	1521 (0.87)	3107 (1.78)	7069 (4.06)	14790 (8.49)
2012-13	177180	23098 (13.04)	86476 (48.89)	1262 (0.71)	2388 (1.35)	6419 (3.62)	15460 (8.73)
2021-22	167135	23659 (14.16)	77020 (46.08)	988 (0.59)	2216 (1.33)	5799 (3.47)	15620 (9.35)
Over all percentage Variation	-27.79	-78.55	42.55	-84.04	43.06	-12.57	66.42

Note: Figures in parenthesis are percentages of TCA

Source: Computed from Department of Economics and Statistics, GOK,

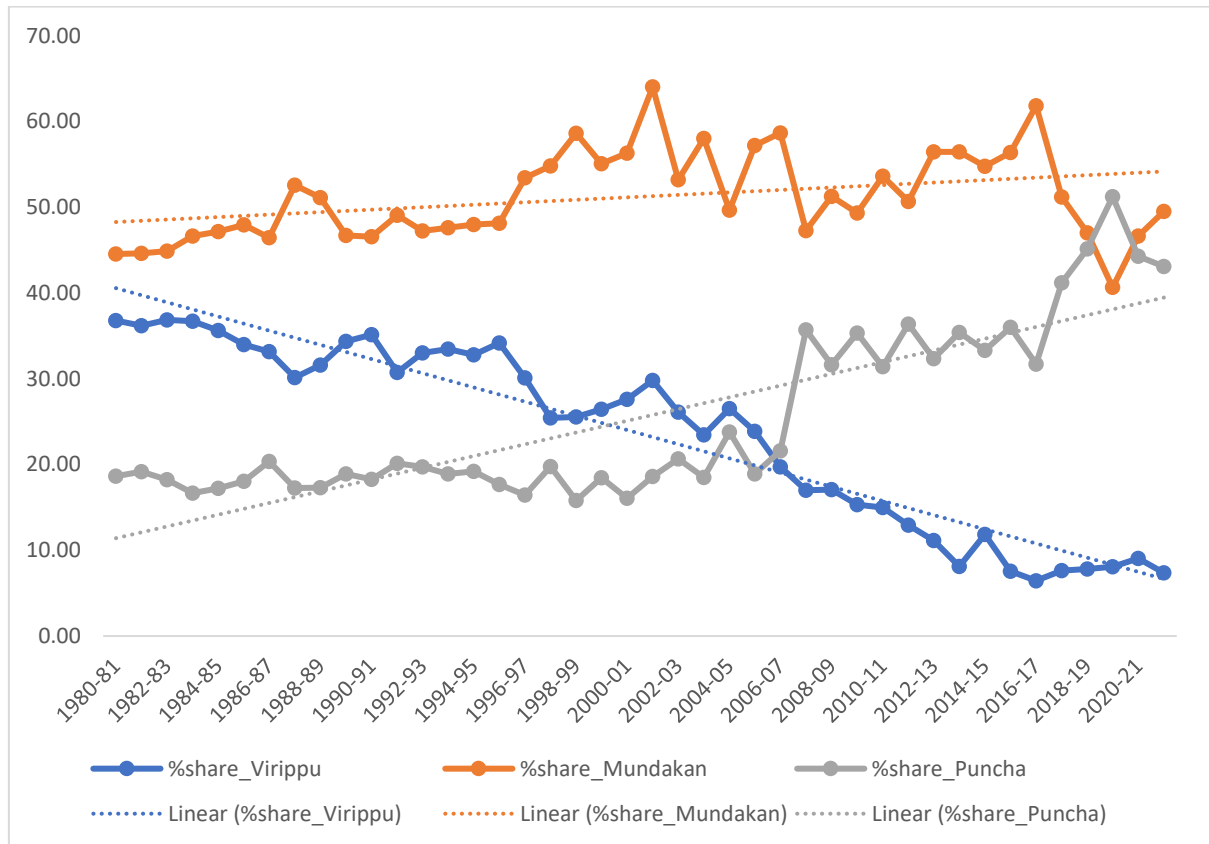
The area of paddy cultivated in Thrissur district was 1.10 lakh hectare in year 1980-81 which was 47.66 per cent of the total cropped area. This was much higher than the Kerala share of 27.79 per cent (Table 3.4). But by 1997-98, it has shrunk more than half and became 40977 hectares. This is about 22.19 per cent of the total cropped area. Subsequently, it was again declined nearly half to 24422 hectares (14.02 per cent of TCA) in 2007-08. Since 2007-08, the area under paddy cultivation in Thrissur district has remained at around 14 per cent of the total cropped area. However, during this period paddy accounted for only 7 to 8 per cent of state's total cropped area. There was significance increase in area of other important crops cultivated except tapioca during this period (Table 3.13). The second important crop in Thrissur, coconut, showed a significant increase over the same period from 54 thousand hectares (23.34 per cent of TCA) to 77 thousand hectares (46.08 per cent of TCA). The proportion of area cultivated for tapioca out of TCA decreased from 2.67 per cent to 0.59 per cent during this period. Unlike Paddy and tapioca, the proportion of area cultivated by Banana and plantain, arecanut and rubber increased from 0.67 per cent, 2.87 per cent and 4.06 per cent to 1.33 per cent, 3.47 per cent and 9.35 per cent respectively in Thrissur district which was similar to overall pattern of Kerala. This shortfall in area under paddy and the corresponding increase in other important crops in Thrissur indicated that paddy area was massively converted into other crops particularly perennial crops like coconut and rubber. The study showed that area under paddy also converted for non-agricultural purposes in Thrissur.

3.6.4 Season wise share of Paddy area in Thrissur

Paddy cultivation in Thrissur occurs in three seasons including *Virippu* (Autumn), *Mundakan* (Winter), and *Puncha* (Summer), similar to all areas of Kerala. It is observed from Figure 3.8 that, *Mundakan* paddy area showed a low growth with instability, while *Puncha* paddy area increases at a stable level with higher growth of share. Conversely, *Virippu* season identified a huge deceleration in share of area growth. During the study period of 1980-81 to 2020-21, the share of *Mundakan* paddy area increases from 44.57 per cent to 49.52 percent, while paddy crops in *Puncha* season increases from 18.64 per cent to 43.12 per cent. *Virippu* season paddy area shares sharply decreases from 36.79 per cent to 7.37 per cent during the same period of study. Thus, it is clear that *Puncha* paddy which is mainly concentrated on Kole wetland area of Thrissur, increased at the place of *Virippu* paddy in tune with state share. The paddy production in Thrissur is completely turned into a single-crop season.

Figure 3.8

Distribution of season wise percentage share of paddy area



Source: Department of Economics and Statistics, GoK, (various reports)

3.6.5 Season wise pattern of Area, Production and Productivity of Paddy crops

Virippu, *Mundakan* and *Puncha* are the major paddy growing seasons in the state of Kerala while *Mundakan* and *Puncha* are the main rice growing seasons in Thrissur district. While *Mundakan* and *Puncha* registered productivity of 3483 kg/ha and 4121 kg/ha respectively, but the productivity of *Virippu* was only 2398 kg/ha in 2020-21. The state average productivity during this period is only 2767 kg/ha, 3165 kg/ha and 3464 kg/ha in *Virippu*, *Mundakan* and *Puncha* seasons respectively (DES, 2022). The *Puncha* paddy production in the district is higher than the state average as it includes the most productive *Puncha* Kole lands in Thrissur district. In 2020-21, the area under paddy in *Virippu* season is only 2160 ha but it is 11,154 ha and 10,588 ha in *Mundakan* and *Puncha* season respectively. The paddy production during *Virippu* season was only 5180 tonnes whereas it was 38846 tonne in *Mundakan* season and 43629 tonnes in *Puncha* season. It is evident from Table 3.14 that the overall percentage change of paddy production declined significantly.

Table 3.14

Season wise percentage variation of paddy area, production and productivity

Break Point Period	Virippu (Autumn)			Mundakan (Winter)			Puncha (Summer)			Total		
	Area	Production	Productivity	Area	Production	Productivity	Area	Production	Productivity	Area	Production	Productivity
1980-81 to 1987-88	-37	-27	17	-10	7	19	-29	-21	12	-24	-11	16
1988-89 to 1997-98	-58	-36	53	-44	-30	25	-41	-34	11	-48	-32	30
1998-99 to 2007-08	-59	-58	1	-50	-39	21	41	85	32	-38	-20	29
2008-09 to 2012-13	-46	-41	10	-9	6	16	-15	-9	8	-17	-6	14
2013-14 to 2021-22	-4	-19	-16	-7	-8	0	29	33	3	6	9	3
Over all (1980-81 to 2021-22)	-96	-93	58	-76	-49	116	-50	4	110	-79	-51	130

Source: Computed from Department of Economics and Statistics, GOK,

The paddy area declined by 96 per cent, 76 per cent and 50 per cent of *Mundakan*, *Virippu* and *Puncha* seasons respectively during the overall period of 1980-81 to 2021-22 (Table 3.14). In *Virippu* and *Mundakan* seasons, the per cent of paddy area declined significantly during all the break periods. However, in *Puncha* season, break period III and IV showed a percentage increase in paddy area cultivated. But there was decline in paddy area in all other break periods. Similar to area of paddy, production of *Virippu* season too showed a significant decline in all break periods. Unlike *Virippu* season, paddy production in *Mundakan* season showed a marginal percentage increase in break period I and IV, while per cent decrease in period II, III and V. However, in *Puncha* season, significant increase in paddy production was experienced during break period III and V and only a slight decline was in period IV. This showed that, since 1997-98, paddy production in *Puncha* season witnessed a better performance than other

seasons. *Puncha* season production went up by a significant amount across all break points. The entire paddy output in the *Puncha* season climbed by 110 per cent, while *Mundakan* increased by 116 per cent. However, the production of *Virippu* increased only by 58 per cent.

3.6.6 Trends in Area, Production and Productivity of Paddy

The Season wise growth rate of Area, production and Productivity of paddy crops in Thrissur based on different break periods is presented in Table 3.15.

Table 3.15

CAGR of Season wise Area, Production and Productivity of Paddy in Thrissur

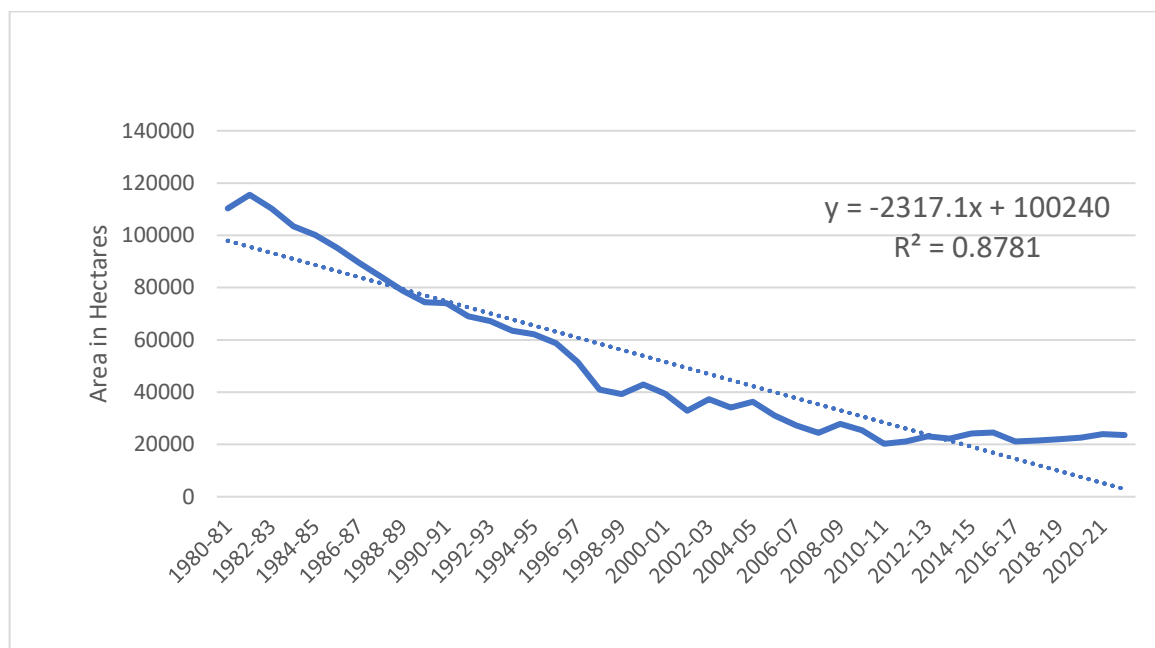
Break Point Period	Area				Production				Productivity			
	Virippu	Mundakan	Puncha	Total	Virippu	Mundakan	Puncha	Total	Virippu	Mundakan	Puncha	Total
1980-81 to 1987-88	-6.6	-2.4	-4.5	-4.2	-3.5	-0.3	-1.5	-1.6	3.30	2.17	3.14	2.79
1988-89 to 1997-98	-7.5	-4.9	-5.9	-5.9	-4.6	-2.6	-3.8	-3.5	3.14	2.40	2.25	2.58
1998-99 to 2007-08	-8.9	-6.2	0.9	-5.0	-8.9	-5.0	5.2	-3.0	-0.01	1.20	4.23	2.07
2008-09 to 2012-13	-14.6	-3.4	-4.8	-5.5	-11.4	1.2	-2.0	-1.5	3.78	4.69	2.95	4.23
2013-14 to 2021-22	-1.3	-3.1	4.7	0.1	-3.8	-2.3	6.0	1.5	-2.55	0.79	1.24	1.38
Over all (1980- 81 to 2021-22)	-8.6	-4.3	-2.1	-4.5	-7.4	-2.4	0.2	-2.3	1.27	1.95	2.33	2.30
CAGR Kerala	-5.07	-4.05	-1.72	-3.99	-3.84	-2.53	0.97	-2.49	1.30	1.58	2.74	1.56

Source: Computed from Department of Economics and Statistics, GOK,

During Period I, area and production of paddy declined annually at a rate of -4.2 per cent and -1.6 per cent respectively across all seasons. Although area under *Virippu* and *Puncha* showed a highest negative growth rate of -6.6 per cent and -4.5 per cent respectively, but the positive growth rate in productivity could have offset the negative growth rate in area particularly in *Puncha* season.

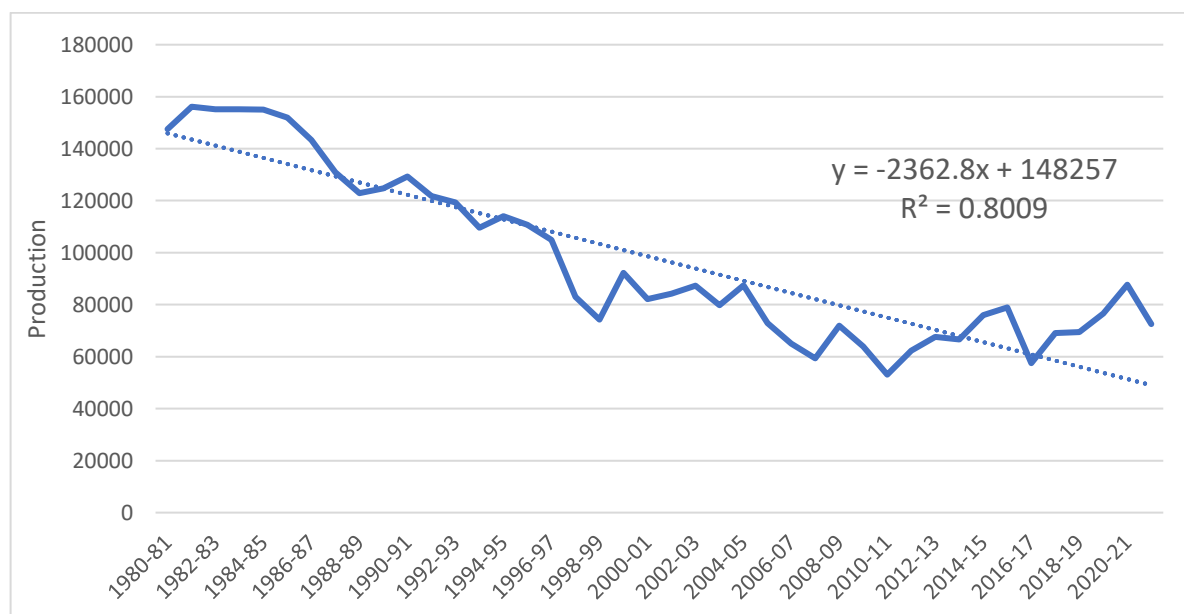
The annual compound growth of productivity of paddy in all seasons recorded a positive trend during the second phase. But the area under paddy as well as production witnessed a decline trend across all seasons (Figure 3.9, 3.10 and 3.11).

Figure 3.9
Trend of Paddy Area in Thrissur



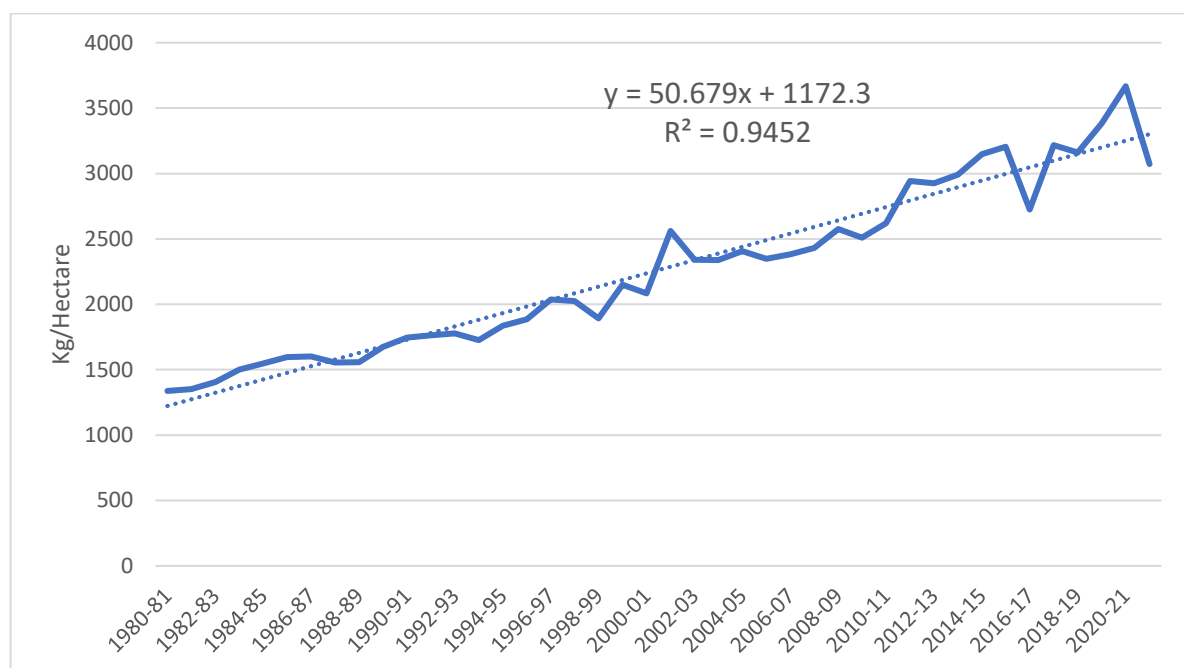
Source: Department of Economics and Statistics, GOK

Figure 3.10
Trend of paddy Production in Thrissur



Source: Department of Economics and Statistics, GOK

Figure 3.11
Trend of Paddy Productivity in Thrissur



Source: Department of Economics and Statistics, GOK

During the third period, *Virippu* and *Mundakan* season marked a highest negative growth rate in area and production (-8.9 per cent and -6.2 per cent respectively in area and -8.5 per cent and -5 per cent in production). But *Puncha* season only recorded annual positive growth rate of 0.9 per cent in area and 5.2 per cent in production. During this period, Kerala's average growth rate was negative for both the area (-6.36 per cent) and production (-6.10 per cent) of its summer crops. During this period, area under *Puncha* paddy cultivation increased to 8721 ha in 2007-08 from 8098 ha in 1997-98 in Thrissur. The production also showed a better growth from 17769 tonnes (1997-98) to 26374 tonnes (2007-08) during this period. Hence, the productivity witnessed a highest ever growth rate of 4.23 per cent compared to all other phases in *Puncha* season. The overall productivity during this phase across seasons was only 2.07 per cent. This highest growth rate in *Puncha* was mainly contributed from Kole wetland paddy production. Kole Paddy cultivation in Thrissur was skewed to *Puncha* farming.

Although, the annual growth rate of area and production in *virippu* season recorded its highest negative growth rate of -14.6 per cent and -11.4 per cent respectively during the fourth phase, the productivity showed a positive growth rate of 3.78 per cent. The productivity in *Mundakan* season exhibited a highest annual growth rate of 4.6 per cent along with positive growth rate of production (1.2 per cent) and a negative growth rate of area (-3.4per cent) under paddy.

Surprisingly, *Puncha* season showed a negative reverse trend in area (-4.8 per cent) and production (-2 per cent) than the previous phase even with the new initiative of Kerala Conservation of Wetland Act 2008. But productivity still showed a positive annual growth.

Conversely, During the fifth phase, *Puncha* season recorded a highest annual positive growth of area by 4 per cent and production by 6 per cent. But interestingly, productivity increased only at a low rate of 1.24 per cent.

Overall paddy area, production and productivity in Thrissur district was significantly declined which was higher than the rate of decline of Kerala state (Table 3.15). However, the *Puncha* paddy production and productivity showed a positive sign of growth comparable to state average.

The area under paddy in Kerala during the overall period significantly declined to 1.95 lakh hectares in 2020-21 from 8 lakhs hectares in 1980-81 (DES, Various years). A reduction of 75 per cent has been recorded in Kerala's paddy area on a long-term basis. It was estimated that, paddy area declined at an annual compound growth rate of 3.99 per cent in Kerala (Table 3.15). However, the productivity of paddy doubled from 1.58 tonne to 3.1 tonne per hectare with a positive growth rate of 1.56 per cent. The significant decline in area was adjusted by lower rate of decline of production. Thrissur district showed a similar trend in area, production and productivity, that is, negative growth rate in area and production but a positive growth in productivity. A 78 per cent decline of paddy area in Thrissur district with a 4.5 per cent negative growth rate per annum during this period. But the decline was moderately higher than the state average. Conversely, summer paddy (*Puncha* season) in Thrissur exhibited a different trend with fall in growth of area, but with a rise in production and productivity. But Summer paddy Kule land area in Thrissur district shows a very dissimilar trend in terms of area, production and productivity is presented in section 3.8.

3.7 Comparative Analysis of Paddy land Use in Thrissur and Kerala

Comparing paddy land use across state average with a district offers a critical insight into how a particular district shapes the paddy land use of a state. This section examines the spatial and temporal variations in area, production and productivity between Kerala and its sub-region Thrissur are presented in Table 3.16 with variability index of both regions. The CAGR value

shows the growth trend, Cuddy-Della Valle Index (CDVI)¹⁰ value indicates the variability or instability of area, production and productivity across break periods. It is evident from Table 3.16 that overall growth rate of paddy area and production showed a decline trend in Thrissur and state average whereas productivity showed a positive trend over the period in state and in Thrissur district.

Table 3.16

Comparative Trends and Instability of area, production and productivity of paddy

Break Period	Attributes	Kerala			Thrissur		
		Area	Production	Productivity	Area	Production	Productivity
Period I	CAGR	-3.95	-3.02	0.96	-4.13	-1.47	2.77
	CV	9.28	7.73	2.74	9.89	5.01	6.88
	CDVI	2.18	3.83	1.82	3.03	4.09	3.16
Period II	CAGR	-4.07	-3.22	0.89	-5.90	-3.45	2.60
	CV	11.94	10.68	3.80	17.03	11.05	7.89
	CDVI	3.42	6.16	3.08	4.78	5.98	2.87
Period III	CAGR	-4.40	-3.21	1.24	-5.16	-2.99	2.28
	CV	12.90	10.98	5.52	15.62	12.68	7.17
	CDVI	2.82	6.39	4.45	6.41	10.30	3.68
Period IV	CAGR	-4.50	-3.43	1.12	-5.48	-1.48	4.24
	CV	6.72	6.47	3.62	11.91	9.85	6.73
	CDVI	2.01	4.87	3.75	9.80	11.07	3.72
Period V	CAGR	0.34	1.27	1.09	0.17	1.51	1.37
	CV	4.70	9.14	5.69	5.09	11.05	7.67
	CDVI	4.93	9.12	5.28	5.42	11.04	7.24
Overall period	CAGR	-3.96	-2.49	1.55	-4.51	-2.29	2.33
	CV	50.28	33.05	19.23	59.15	32.35	28.17
	CDVI	14.48	11.60	4.90	20.65	14.55	6.28

Source: Computed from Department of Economics and Statistics, Various reports, GOK

The comparative analysis of paddy cultivation trends in Kerala and Thrissur from 1980–2021 presented in Table 3.16 reveals that across the periods, Kerala state and Thrissur district level

¹⁰ Cuddy Della Valle Index: The formula to calculate $CDVI = CV \sqrt{1 - R^2}$ where CV is Coefficient of Variation, and R^2 is the Coefficient of determination from time trend regression adjusted to the degrees of freedom. The formula to calculate $CV = (\text{Standard Deviation}/\text{Mean}) \times 100$. Cuddy Della Valle Index formula helps to overcome the problem of overestimation in simple Coefficient of Variation.

CAGR experienced a consistent decline in area under cultivation (-3.96 per cent and -4.51 per cent respectively), but productivity showed a positive long-term growth in Kerala (1.55 per cent) and Thrissur (2.33 per cent). It is evident that the positive trends in productivity offsets the decline in area suggesting improvements in technology and better management practices with intensive farming. Thrissur district generally recorded sharper area declines than state average but achieved higher productivity gains, reflecting more intensive method of farming. The higher variability measures (CV and CDVI) in Thrissur, particularly in area and production, indicate greater instability and vulnerability compared to overall state average. But, during the recent period, (2013 to 2021) turnaround has been marked, with a positive growth in production and productivity both Kerala and Thrissur with persistent fluctuations after decades of decline. During the overall period, both Kerala and Thrissur district displayed relatively stable negative long-term trends in area and production with greater instability, while productivity showed a stronger improvement with lower instability.

In short, the land use change in Thrissur district shows more or less similar trend and pattern of the state. The majority of the land holdings are marginal and the decline in net sown area is three times higher than the state average. Meanwhile, non-agricultural use of land nearly doubled during this period. Moreover, the size of fallow land increased alarmingly and there is a shift from multiple crops to single crop (*puncha* crop) in Thrissur district. The cropping pattern of Thrissur moves from paddy crops to perennial crops such as plantain, coconut and rubber. Similar to the state average, it can be seen that the highest productivity growth in Thrissur district is not due to high production of paddy but rather the negative growth in paddy area is much higher than the decline in production growth.

3.8 Dynamic land use change in Thrissur Kole Wetland Ecosystem

A general picture of land use change in Kole wetland Ecosystem area (Table 3.17) was visible from a study conducted by Centre for Economic and Social Studies, Hyderabad during the period of 1981 to 2007 (Srinivasan, 2010) and Kerala Agricultural University in 2013 (Devi, 2016) by using GIS and remote sensing technologies.

The total Kole ecosystem area is about 54600 ha. Out of this, 71 per cent area classified as Thrissur Kole region and rest as Ponnani Kole. It is shown that 87 per cent of Kole land was used for agricultural production. The most productive agricultural land use is paddy cultivation. House constructions as part of agricultural land use naturally provide ideal conditions for homestead farming. As a result, the area under polyculture from 26,572 hectares in 1981 has

increased to 29,516 hectares by 2013. Mixed crop area recorded an increase of about 9644 hectares during this period (11 per cent increase). This was mainly due to construction activities in Kole lands. Built-up land area in Kole land was only 350 hectares in 1981 but it increased to 2946 hectares in 2013. A substantial hike of 2590 hectare area was witnessed. This was estimated as the 740 per cent hike in area of built land during this period. Most of this hike (91 per cent) was in Thrissur Kole area. Parallel to this, 7145 hectares of paddy land was lost during this period (Table 3.17).

Table 3.17
Land Use Change in Kole Wetland Area

Particulars	Area in Hectares					Area Change in Hectares				
Kole Area	1981	1989	1997	2007	2013	1981 to 1989	1989 to 1997	1997 to 2007	2007 to 2013	1981 to 2013
Built Up area	350	1544	1724	2388	2946	1194	180	664	558	2596
Mixed Crop	26572	27712	29528	30002	29516	1140	1816	474	-486	2944
Paddy	25113	22582	20382	18623	17968	-2531	-2200	-1759	-655	-7145
Waterbody	2558	2755	2751	2743	3616	197	-4	-8	873	1058
Water logged	0	0	109	585	554	0	109	476	-31	554
Waste Land	32	32	131	284	0	0	99	153	-284	-32
Grand Total	54625	54625	54625	54625	54600	0	0	0	-25	-25

Source: Computed from Devi, 2016

In the first three phases of the study period, the area under paddy production decreased at a very high rate. But, in the last phase, the area under production has changed only to a very small extent. In contrast, built area increased at all stages. Along with cultivated land, there has been an increase in the mixed crop area in the other three phases except the last phase. The low profitability in fameless agriculture and the attracted opportunities in gulf countries influenced the youth to shift from less attracted agriculture to non-agricultural activities. In tune with the urbanisation, the paddy area in Thrissur city surroundings was converted for business and

dwelling purposes. However, since 2013, the area of paddy conversion reduced, but the area used for built up land and mixed crop increased significantly.

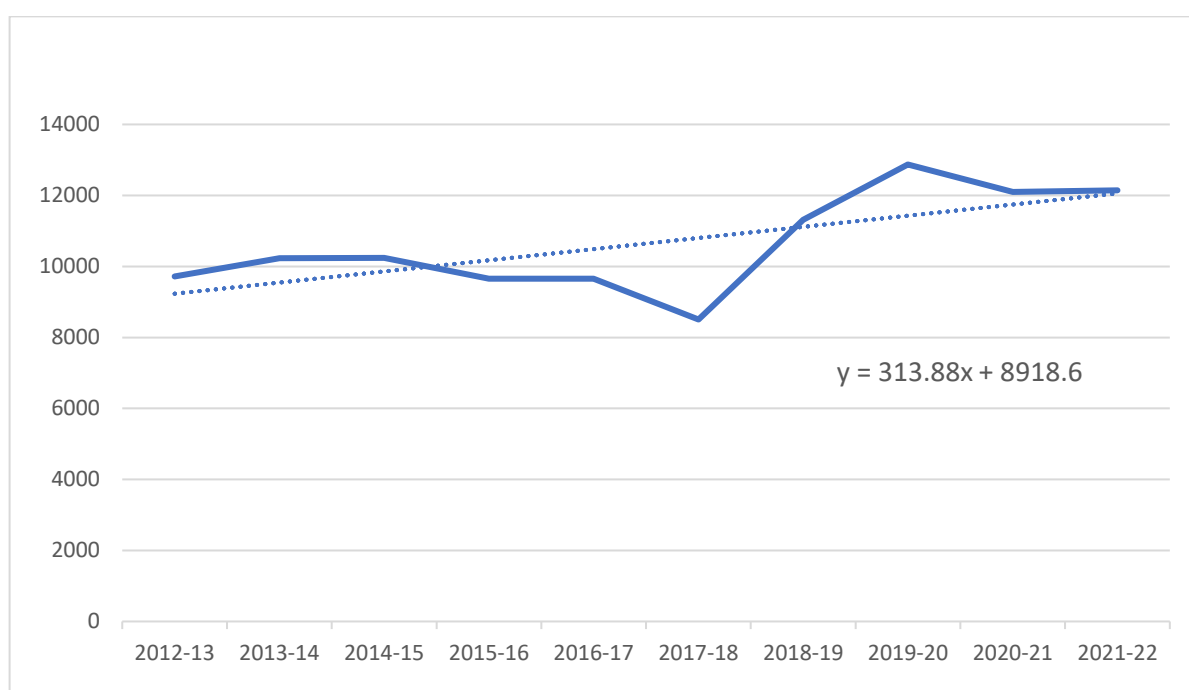
3.8.1 Block wise CAGR of Area, production and Productivity in Kole area in Thrissur

Thrissur district ranks third in the total paddy production of Kerala. More than fifty per cent of the total production in Thrissur was contributed from the Kole lands area of the district. A detailed analysis of Kole lands and their importance as a wetland ecosystem has been given in Chapter IV.

A comparative analysis of area production and productivity of paddy crops in Kerala, Thrissur and Kole area of Thrissur was illustrated in Table 3.18. Kole lands in Thrissur raised only one crop i.e., Puncta crops cultivation (second crop). This was estimated as 95 per cent of the total Kole land cultivation (crop1 and crop 2) in Thrissur.

Figure 3.12

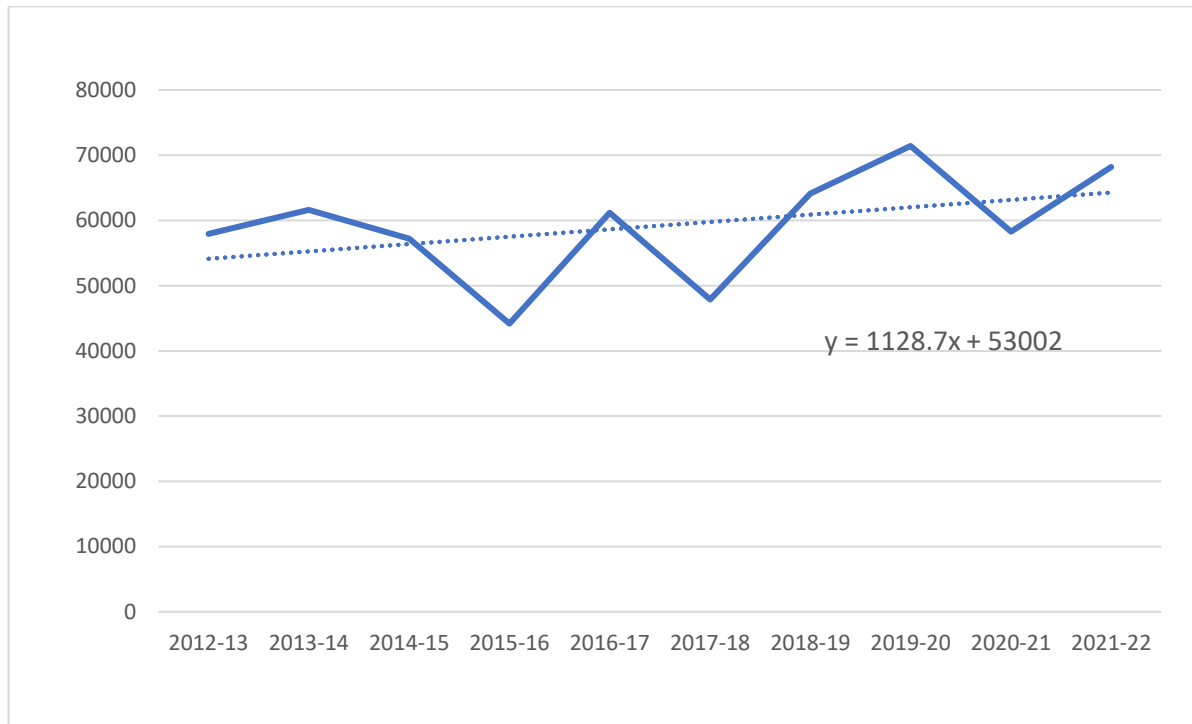
Trend of Area under paddy in Kole lands (in Hectares)



Source: Supplyco Annual Reports

Figure 3.13

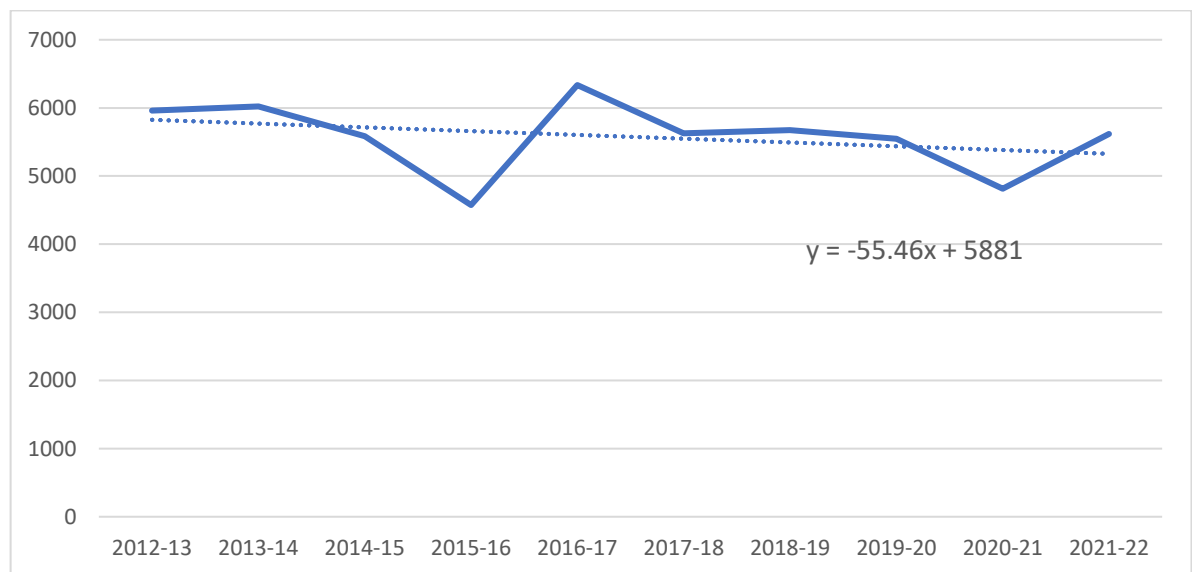
Trend of paddy production in Kole lands (in Tonnes)



Source: Supplyco Annual Reports

Figure 3.14

Trend of productivity of paddy in Kole lands (In Kg/Hectare)



Source: Supplyco Annual Reports

Table 3.18

Compound Annual Growth Rate of Area, Production and Productivity of Paddy in Kole Area during 2013-14 to 2023-24

Kole Area (Blocks)	Area	Production	Productivity
Chavakkad	8.56	7.43	-1.08
Chowannur	1.83	0.77	-1.03
Puzhakkal	0.66	-0.94	-1.59
Mullasserri	0.01	-4.10	-4.11
Anthikkad	1.46	-0.78	-2.21
Cherpu	4.02	2.24	-1.71
Vellangallur	12.96	13.46	0.45
Irinjalakuda	6.81	7.09	0.26
Kole Area Total	2.46	0.56	-1.86
Thrissur District	0.17	1.57	1.37
Kerala	0.34	1.27	1.09

Source: Computed from Supplyco annual statement of various years

During the period of 2013-14 to 2023-24, the area under paddy showed a positive growth rate in all Kole area block panchayaths. The average area growth rate of Kole area together was 2.46 per cent which was much higher than the district (0.17 per cent) and State average (0.34 per cent). However, the paddy production in the block area does not show such a similar trend in all block panchayaths. But the average growth in Kole lands together showed a positive growth rate of 0.56 per cent which was significantly lower than the district average growth of 1.57 per cent and state average growth of 1.27 per cent. A comparison of productivity per hectare of paddy from the Kole land with that of Kerala identified that production per hectare from Kole land is relatively higher than in Kerala. In long tradition, paddy productivity was estimated as 8 tonnes per hectare in Kole lands in Thrissur region. But now, the average yield per hectare of paddy in Kole farms was estimated to be 5162 kgs (Srinivasan, 2012) while it was 2758 kgs/ha in Kerala average.

However, in recent years (2013-14 to 2023-24) the average productivity of paddy in Kole area (Block wise) has decreased from 5.9 tonnes to 5.4 tonnes. Except, two southern blocks of Thrissur Kole, i.e., Vellangallur and Irinjalakuda, all other six blocks witnessed a negative growth rate in productivity. But during the same period, Kerala state average recorded that an

increase in productivity from 1.5 tonnes to 3.1 tonnes per hectare (DES, 2024). It was recorded almost a cent per cent increase in productivity. But, in contrast, the highly productive Kole lands of Thrissur recorded a negative growth rate in productivity (-1.86 per cent) during this period.

Why this paradox occurred in highly productive area has become a recent question among farmers and researchers in Kole wetlands. There are several factors which influence the shrinkage in productivity in Kole area. The Kole lands are the multipurpose wetland agroecosystem; hence the productivity of these lands depends upon the characteristics of the soil, water, and biodiversity. The frequent excessive chemical inputs usage over and above the standard requirements jeopardized the long-term natural fertility of the soil and the deterioration of agroecosystem services. Chapter V of this study has discussed the topic in detail and analysed the chemical input use and their impact on paddy wetland agroecosystem services in Kole land area.

3.8.2 Nature and Causes of Land Use pattern and land degradation in Wetland Ecosystem

There has been a phenomenal change in land use pattern of Kerala during the last 40 years coupled with urbanisation and population growth. Even with several land conservation policies in Kerala, the conversion of agricultural land particularly paddy land to non-agricultural purposes continued unabatedly. In Kerala, 408 hectares of the Net area sown lost every year with an annual compound rate of 0.27 per cent. Conversely, area added to non-agriculture purposes grew at an annual rate of 1.44 per cent and nearly 2 lakh hectares of land was converted to non-agriculture purposes. The cultivable and fallow land also converted for non-agricultural purposes. Along with changes in land use pattern, cropping pattern also showed a shift from food crops to commercial crops particularly from perennial crops like rubber, arecanut, coconut. The pattern of conversion is more visible from paddy crops to coconut, arecanut and rubber through massive land filling. The area of paddy converted during the last forty years was estimated about 6 lakh hectares of land. The Thrissur district showed a similar relative pattern of Kerala state regarding conversion of land area in respect of both land use pattern and cropping pattern. The massive conversion of land for non-agricultural purposes particularly from food crops paddy has become a challenge to the food security of the Kerala state. In order to make up the decrease in regional and individual production loss due to land conversion, farmers have compelled to make use of intensive farming via over use of chemical inputs. In the

year 2022-23. the total amount of chemical pesticides used for agricultural purposes in Kerala was 225.7 MT. Out of this, about 59.7 MT, i.e. 26 per cent of the total, was used for paddy production only. But it was only about 23 per cent in the last year. The highest pesticides consumption in 2021-22 was (59.2 MT) for paddy crop followed by banana (49.2 MT) and coconut (43.6 MT) (KSPB, 2023). Table 3.19 revealed that during the period 2001-02 to 2016-17, Kerala's fertilizer consumption increased by about 91per cent from 139.7 kg/ha to 226.3 kg/ha in the production paddy in irrigated area of Kerala. Meanwhile, the consumption of chemical fertilizers in unirrigated paddy field showed an increase of 207 per cent.

Table: 3.19
Chemical Fertilizer consumption of Paddy crops in Kerala

Year	Source	N (kg/Ha)	P (kg/Ha)	K (kg/Ha)	Total (kg/Ha)
2001-02	Irrigated	61	25.9	52.8	139.7
	Un Irrigated	50	18.4	3.7	72.1
2016-17	Irrigated	140.06	49.93	76.31	266.3
	Un Irrigated	124.68	34.86	61.7	221.24
Percentage change over the period	Irrigated	130	93	45	91
	Un Irrigated	149	89	1568	207

Source: KSPB, Economic Review 2001-02 & 2016-17

The Thrissur Kole wetland paddy region used twice as much chemical fertilizer for paddy cultivation as the average for Kerala (Srinivasan, 2012). Chemical fertilizers are used at an average rate of 123 kg per hectare in Kerala (CACP, 2010) and up to 282 kg per hectare in the Kole fields (Srinivasan, 2012).

Now the farmers are in a dilemma of trade-off between short run profitability and agricultural sustainability. But, the priority of the farmer is not agricultural sustainability but by short run profitability due to financial and livelihood concerns. Hence, the unwise and over use of chemical inputs in paddy cultivation leads to lowering their production and increase the cost of production. The overdosage of chemical inputs in paddy production leads to the degradation of soil and agroecosystem. The major challenge of achieving agriculture sustainability today, is the degradation of the soil by the excessive use of chemical inputs which may affect the ecosystem services.

3.8.3 Importance of Ecosystem Services in Kole Wetlands

The agriculture land particularly paddy land is not merely a food production hub but an agroecosystem service area. These highly productive multifunctional paddy wetland agroecosystems provide market and non-market valued ecosystem services to the society for achieving their wellbeing (Table 3.20).

Table 3.20

Total Economic Value of ESS of Thrissur Kole Land

ESS of Thrissur Kole Land	Value (in Lakhs) 2021
Paddy Production	12678
Fish Production	1196
Lotus Cultivation	14
Duck farming	73
Tourism	949
Flood control	18773
Carbon retention	3644
Ground water recharge	990
Non-Use values	732
Total	39053

Source: Adapted from Tahmankar, N. KAU. 2021

The Kole paddy lands are wetland paddy agroecosystems which provide direct and indirect benefits to the people. These agroecosystem services are classified as provisioning services, regulating services, cultural services and supporting services (MEA,2005). The value of such agroecosystem services in Kole land was calculated by Tahmankar (2021) as Rs. 39053 lakhs (Table 3.20). In fact, the economic and ecological value of ecosystem services is more valuable than this, but, farmers and policy makers does not realise the role and significance of Kole wetland paddy farming as a provider of livelihood and wellbeing of the society. By considering these lands as a capital asset, farmers either convert their land as commercial plot for real estate business or excessively use chemical inputs in farming for earning short term profitability. This kind of anthropogenic activities on land leads to deterioration of Ecosystem services and the related wellbeing of the farmers.

3.9 Conclusion

The study of land use trends and cropping pattern in Kerala in comparisons with Thrissur identified a nuanced picture of agricultural transformation and urban expansion. The lower proportion of Net sown area in Thrissur compared to state average revealed a reduced agricultural intensity. Furthermore, sharper decline in net sown area over the period of time in Thrissur than state average, suggesting a land conversion and agricultural abandonment in the district is severe than state average. Similarly, the more pronounced increase in non-agricultural use of land in Thrissur than Kerala observed the accelerated pace of urbanisation and infrastructural development. In terms of cropping pattern, a severe decline in paddy crops and a sharp increase in the area of other crops including coconut, banana and plantain, and rubber in both regions showed a broader trend of paddy conversion to other perennial crops in both regions simultaneously. The intensity of the conversion is identified as so severe in Thrissur district than over all state average. Additionally, Thrissur showed a sharper contraction in area across all seasons than state average. State average growth of production of paddy in *puncha* season is better whereas reduction in production is highest in Thrissur during *virippu* season. The productivity gain of Thrissur district is comparatively better than Kerala state average. In accordance with Kerala state average and Thrissur district average, Kole land area in Thrissur also showed a similar massive land conversion from paddy land to build land and mixed crops. But recently, contrary to state average, area of paddy production in Kole lands improves while productivity declines substantially. Kole wetland paddy ecosystem provides many ecosystem services which are significant in monetary and non-monetary terms but decline with substantial reduction in paddy area. The over use of chemical inputs is a reality and has been identified as a prime determinant of declining productivity and degradation of ecosystem services. In Kerala, the careless reclamation or conversion of wetlands and paddy fields has become a routine occurrence. Kerala has lawfully lost hectares of wetlands and paddy fields during the past few decades for housing, infrastructural development, and industrial. In the rapidly expanding land market, land has been unlawfully lost to benami (property registered in the name of someone other than the one who financed it) transactions. The state-market nexus is ignoring the ensuing effects on the region's ecological balance, food security, and water security in its pursuit of unchecked economic expansion and development. In order to normalise the conversion and reclamation of wetlands and paddy fields, market pressures frequently exploit and alter the legislative framework that now supports conservation projects. The subsequent chapters in the

present study examine how the intensive paddy farming practices affect the ecosystem services provides by these wetlands and their implications on wellbeing of the farmers.

Chapter IV
Overview of Thrissur Kole Wetland
Agroecosystem

CHAPTER IV

OVERVIEW OF THRISSUR KOLE WETLAND

AGROECOSYSTEM

4.1 Introduction

Paddy wetlands are privately owned agroecosystems and often the only source of livelihood of the farmers. These wetlands provide ecological, hydrological and socio-economic functions which play a pivotal role in shaping agricultural system, biodiversity and livelihood of the people living around the area. Among wetlands, Thrissur Kole wetlands is a unique and productive agroecosystem which provide multiple ecosystem services, that integrate ecological functions with wellbeing of the paddy farmers. Based on the insights on the decline in area, production and productivity of paddy fields discussed in the previous chapter, this chapter attempts to examine the characteristics of the Kole wetland ecosystem and the socio-economic characteristics of farmers in the area. Since the present study pertains to Thrissur Kole land paddy area as an agroecosystem, it is appropriate to analyse the characteristics of these wetlands and their role played in promoting socio economic conditions and livelihood of the farmers. The first part of this chapter examines the features of Wetlands in Kerala, the second part deals with role of wetland as an ecosystem, third part deals with features of Kole wetland ecosystem, fourth part examine the role of Kole wetland ecosystem services and final part examine the socio-economic background of the sample farmers in the Kole paddy wetland as our study area.

4.2 Wetlands

Special habitats, known as "wetlands", are created where land meets water. One of the most prolific ecosystems, wetlands, are crucial to the ecological sustainability of an area. According to Mitsch and Gosselink (1993), wetlands are an integral aspect of human civilization that provide vital necessities for survival, including energy, fodder, biodiversity, drinking water, protein production, water purification, transportation, research and education, and ethical and aesthetic values that sustain numerous communities. Wetlands have overlapping values, but their cultural, economic, and ecological significance cannot be separated.

Wetlands are transitional zones between dry land and open water, dominated by water. They support diverse flora and fauna, providing ecological, climatic, and societal functions. These wetlands are known as the “kidneys” of the earth. India's extensive geography and varied climate support a rich diversity of inland and coastal wetlands.

The Ramsar Convention defines wetlands as: “areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salty including areas of marine water, the depth of which at low tide does not exceed six meters. It may also incorporate riparian and coastal zones adjacent to the wetlands and islands or bodies of marine water deeper than six meters at low tide lying within the wetlands.” (Ramsar, 1971, p.2)

Wetland systems support lakhs of people by providing goods and services, preventing floods, and mitigating natural disasters. They store water, maintain a constant flow regime, and increase biological productivity. Inundated wetlands store rainwater and recharge groundwater aquifers. Wetlands are home to numerous invading birds and waterfowl, with 55 of India's 78 endangered bird species relying on them (Nameer, 2002). They also serve as natural filters, removing pollutants and retaining nutrients by accumulating eutrophic parameters in the sub-soil (Sadokpam, et al, 2023).

The 1971 Iranian Convention on Wetlands highlighted the importance of wetlands and their resources. As of March 2007, 1650 wetland areas totalling 149.6 million hectares had been approved by 154 Contracting Parties to be included to the Ramsar list of Wetlands of International Importance. According to Ministry of Environment and Forests, Government of India, wetlands are broadly divided into Inland wetlands and Coastal wetlands.

Wetlands play a significant role in maintaining ecosystem functions. Wetlands are fragile ecosystems providing diverse services to society. Estimates of their loss are difficult due to the lack of a uniform definition. Approximately 6 per cent of the world's area is covered by wetlands, with Canada containing a quarter of the total. The global wetland area has decreased rapidly, with 87 per cent of area lost attributed to agriculture, 8 per cent to urban, and 5 per cent to other conversions (Barbier et al., 1997).

According to the National Wetlands Conservation Programme, India contains a diverse spectrum of wetland habitats ranging from the Himalayas to the Deccan Plateau. It is expected to have 4.1 million hectares of wetlands, excluding irrigated agriculture fields, rivers, and streams, of which 1.5 million hectares are natural and 2.6 million hectares are constructed. Also, an estimated 6750 square kilometres of coastal wetlands characterised by mangrove vegetation (NWCP, 2009). According to the Directory of Asian Wetlands (1989), India contains a total of 27,403 wetlands, of which 23,444 are inlands and 3,959 are coastal. India has now

around 85 Ramsar wetland sites¹¹ and 113 wetlands protected by the National Wetlands Conservation Programme due to their ecological importance (MoEFC, 2024)

Wetlands cover 18.4 per cent of the total area of the country, out of which 70 per cent is under paddy cultivation. Natural wetlands in India include high-altitude wetlands in the Himalayas, flood plains of major river systems, saline and transient wetlands in arid and semi-arid areas, and coastal wetlands including lagoons, backwaters, estuaries, mangroves, swamps, coral reefs, and so forth. Apart from these natural wetlands, a vast number of artificial wetlands have been created due to the needs of irrigation, electricity, water supply, fisheries, and flood control. These wetlands can be characterised by their origin, flora, nutrient status, and temperature features.

In India, 1.5 million hectares (excluding irrigated agricultural areas, rivers, and streams) of wetlands are natural, whereas 2.6 million hectares are constructed. The coastal wetlands cover an estimate of 6,750 square km and are dominated by mangrove vegetation. According to the Wildlife Institute of India report, wetlands are decreasing at a rate of 2 per cent to 3 per cent every year.

4.2.1 Wetlands of Kerala

The Western Ghats in Kerala, with its western slopes merging with midland plains and the zigzag boundary of the western sea coast, create an ideal topographic feature for wetlands development. Kerala, rich in 43 rivers originating from the Western Ghats, ranks first in India as the state with the largest area of wetlands. MoEF Survey (1990) states that Kerala has 32 natural wetlands which are brackish, and there are a few fresh water lakes. The Vembanad-Kol, Ashtamudi, and Sathankotta wetlands in Kerala were recently added to the Ramsar site. Muriyad is one of eight fresh water wetlands in Kerala, the others being Vellayani, Sasthankiotta, Pookot, Enamackkal, Manakkodi, Eravikulam, Devikulam, and Elephant Lake (Nayar & Nayar, 1997).

Total wetland area of Kerala is estimated to be 160590 acres which is 4.13 per cent of the total geographical area of the state. River/stream (65162 ha), lagoons (38442 ha), reservoirs (26167 ha), and waterlogged (20305 ha) are the most common forms of wetland. Table 4.1 summarises the estimated area of wetlands in Kerala.

¹¹ The first of the contemporary international intergovernmental treaties on conservation and prudent use of nature was the Convention on Wetlands of International Importance, particularly as Waterfowl Habitat, also known as the Ramsar Convention following its approval in Iran in 1971.

Table 4.1
Category wise Wetland Distribution in Kerala

Wetland category	Number of wetlands	Total wetland area	Per centage of wetland area	Open water	
				Post monsoon area	Pre monsoon area
Inland waterways-Natural					
Lakes/ponds	3	2643	1.65	2259	2125
Riverine wetlands	18	410	0.26	410	410
Water logged	922	20305	12.65	11495	7771
River/streams	172	65162	40.58	61853	60338
Inland wetlands- manmade					
Reservoirs/Barrages	39	26167	16.29	24583	23421
Tanks/ponds	439	2435	1.52	1466	530
Total inland	1593	117122	72.93	102066	94595
Coastal wetlands- Natural					
Lagoons	39	38442	23.94	36819	35796
Creeks	19	80	0.05	77	77
Sand/Beach	111	2354	1.47	0	0
Sub total	1762	157998	98.39	138962	130468
Wetland (<2.25ha) mainly tanks	2592	2592	1.61	-	-
Total	4354	160590	100	138962	130468

Source: National Wetland Atlas, 2010. Kerala¹²

¹² The Ministry of Environment and Forests of the Government of India sponsored the National Wetland Atlas Kerala in 2010 as part of the National Wetland Inventory and Assessment (NWIA) project at the Kerala State Remote Sensing & Environment Centre in Thiruvananthapuram and the Space Applications Centre (ISRO) in Ahmedabad.

4.2.2. District wise Distribution of Wetlands in Kerala

District wise distribution of wetlands in Kerala revealed that four districts are wetland rich. Alappuzha has the largest concentration, with 26079 acres of marsh land. This is mostly owing to the proximity of the well-known Vembanad- Kol wetland. Ernakulam (25065 ha), Kollam (13703 ha), and Thrissur (13285 ha) are the other three districts.

Table 4.2

District wise classification of Wetlands in Kerala

District	Geographical area (sq.km.)	Wetland area(ha)	Per centage of total wetland area	Per centage of district geographic area
Kasargode	1961	7561	4.71	3.86
Kannur	2997	10870	6.77	3.63
Wayanad	2132	3866	2.41	1.81
Kozhikode	3345	7690	4.79	3.28
Malappuram	3548	9511	5.92	2.68
Palakkad	4480	11892	7.41	2.65
Thrissur	3032	13285	8.27	4.38
Ernakulam	2408	25065	15.61	10.41
Idukki	4998	10655	6.63	2.13
Kottayam	2204	9523	5.93	4.32
Alappuzha	1256	26079	16.24	20.76
Pathanamthitta	2731	4948	3.08	1.81
Kollam	2579	13703	8.53	5.31
Thiruvananthapuram	2192	5942	3.70	2.71
Total	38863	160590	100	

Source: National Wetland Atlas: Kerala

With a geographically very small area of only 38864 km², Kerala proudly holds an enormous 590 km coastline along which lies the longest series of beaches in the world. The state holds an impressive number of backwaters, lakes, rivers, and canals. The state experiences two rainfall seasons, namely the South West Monsoon, and the North East Monsoon, thereby bringing the whole geographic area of the state to more than a waterlogged state in over 20 percent. Thus,

marshes occupy as much as an eighth of the whole geographic area of the state. Hence, on these grounds, the following principal classification can be proposed to describe the classification of wetlands, as mentioned in the elaborate study on wetlands in Kerala conducted by CED (2003), as mentioned in Table 4.3.

Nair et al. (2001) reported that the total wetland area is 127930.07 ha, comprising 34199.57ha of ‘inland wetlands’ and 93730.5 ha ‘coastal wetlands.’ Geomorphologically the wetlands in Kerala can be classified in to 5 major systems viz, marine, estuarine, riverine, lacustrine and palustrine.

Table 4.3
Wetlands of Kerala: Classification schemes

Wetland classes	Wetland types
Inland Wetland	Fresh water lakes
	Fresh water swamps
	Reservoirs
	Large Ponds
Coastal Wetlands	Estuaries/ Backwaters
	Mangrove Forests
	Kol, Kuttanad and Pokkali wetland Systems
	Coastal Swamps
	Mud flat
	Aquaculture Pond
	Islets/Thuruthu

Source: State Environment Report, 2007

Kerala is well known for its wetlands. Wetlands of Kerala, once vital for agriculture production and livelihood, have been disrupted by development demands such as roads, railways, urbanisation, industrial development, and shrimp farms. These developments have fragmented the wetlands, destroyed coastal vegetation, and disrupted the ecosystem. The high density of population in coastal Kerala makes it difficult to bear these onslaughts, and worldwide, wetlands are in peril due to pollution, dredging, and development.

Kerala wetlands face extreme threats due to high population density, middle-class income, and gulf money boom. The wetland conversion is very common in Kerala due to their preference to

live in an independent homestead rather than in a flat or in a colony. Additionally, Vembanad lake and Kuttanad wetland systems in Kerala have been reclaimed or converted into agricultural and fishery fields. It is estimated that by the end of 1995 about 63-76 per cent of the total area was reclaimed for other purposes (WWF, 1993).

4.2.3 Wetland Ecosystem in Kerala

The specific wetland ecosystems types found in Kerala (Table 4.4) are the Myristica Swamps found in the Western Ghat forests, large polders, and wet areas, which are either associated with backwaters and lakes that are also repositories of flood and storm water, or are marshy and wet (SoER, 2007).

Table 4.4
Wetland Ecosystems of Kerala

Number	Ecosystem	District
1	Kuttanad Paddy fields	Alappuzha
2	Pokkali Lands	Ernakulam
3	Kole Lands	Thrissur
4	Kaippad lands	Kannur
5	Myristica Swamps	Kollam/ Thiruvananthapuram

Source: State Environment Report, KSCSTE, 2007

4.2.3.1 Role of Wetlands as an Ecosystem

Wetlands directly and indirectly provide services to millions of people. Based on the type of wetlands, soil and water characteristics, and associated biotic values, wetland ecosystems are associated with a wide and intricate range of direct and indirect uses. Wetlands are ecosystems which prevent floods by absorbing water in the same way that a sponge does. These ecosystems assist to maintain normal river levels by filtering and purifying surface water. It absorbs water during storms and other situations when water levels are high. Wetlands gently discharge water when water levels are low. Additionally, wetlands release vegetation into rivers, which helps river fish find food. By reviving rivers and the surrounding ecosystems, wetlands help to balance the impact of human activity on rivers. Wetlands are used by many creatures that inhabit different environments for migration or reproduction.

Wetlands as an ecosystem act as natural buffers, absorbing and storing flood water, reducing flood frequency and intensity. They stabilize shorelines and, riverbanks, and act as temporary storage basins, reducing erosion and limiting severe flood destruction. They help to regulate the flow of water and ground water during drought. Wetlands also play an important role in erosion management. Rivers deposit sediment derived from eroded top soil, so counteracting erosive processes in lakes, rivers, and agricultural landscapes. Planting wetlands plants is frequently used in erosion control initiatives. Wetlands filter water, removing nutrients and phosphates from soil, reducing aquatic weeds and algae growth, preventing oxygen depletion and choking waterways for plants and animals. This also enhances the purity of water found in nearby rivers and streams.

Wetlands significantly affect groundwater recharge and discharge. Groundwater recharge involves surface water moving through soil to saturated zones, while discharge involves groundwater moving out. Most of the wetlands are groundwater discharge or through flow areas, known as seepage wetlands. Wetlands improve water quality and air quality by filtering pollutants like sewage, fertilizer runoff, and industrial waste. They trap pollutants and remove excess nutrients, resulting in purer water than entering the wetland. It also serves as natural filters, effectively purifying water by trapping pollutants and removing excess nutrients, resulting in purer water than the water entering the wetland.

Wetlands, rich in water and nutrients, support plant growth and provide food and shelter for various species of plants, animals, and wildlife. They provide temporary or permanent habitats, breeding grounds, and food for a wide range of animals and plants. For both domestic and wild grazers, wetlands—especially those that are periodically and temporarily flooded—may offer extremely important grazing pastures. Wetlands are enjoyable locations for leisure activities. They could provide a location with breathtaking scenery. Boating, fishing, swimming, bird viewing, and hunting are just a few of the leisure activities available in wetlands.

4.2.4 Threats to Wetlands

Wetland formation and disappearance are natural earth geological processes, influenced by factors like land subsidence, sea level rise, drought, flood, and vegetation succession. Many wetlands are temporary, eventually disappearing, while new ones are formed elsewhere (Barbier, et al., 1997). However, human interventions have altered the natural rate of change in the wetlands systems of the world. All physical, chemical, and biological aspects of the fragile ecosystems were impacted by direct and indirect actions of people. One of the primary causes

of wetland loss is ignorance of the policymakers and political leaders. Wetlands are still considered "wastelands" by the majority of people. Wetlands are being converted into residential neighborhoods, industrial complexes, and other mega development projects at an alarming rate. Many of such conversions receive green signals without any ecological appraisals (Goldsmith & Hildyard, 1984). Such changes may have a profound impact on ecological processes.

Wetlands in Kerala are under more threat than those of any other state, owing to high population density. Deforestation, changes in the hydrologic regime in higher water sheds, and conversion of wetlands for business facilities, housing, and apartments have had a significant impact on a huge number of wetlands. The destruction of water bodies diminishes the available water level and boosts the ambient temperature.

Wetlands in Kerala are mostly used for agriculture, aquaculture, reclamation, housing and industrial applications, waste disposal, municipal water and industrial effluent discharge, wood seasoning, duck feeding, and dredging soil dumping. Many wetlands throughout the world are nearing the point where their viability and beneficial uses may be significantly reduced or eliminated. If mismanagement and overuse of wetlands and water sheds continue unabated, corrective action or costly remedies may be required. The inability to appropriately account for their values, particularly non-use and functional values, has been identified as the primary cause of excessive depletion and conversion of wetland resources (Barbier et al., 1997). Since 1980s, Kerala has been rapidly converting wetland paddy fields into residential and commercial plots due to high population density, migrant worker incomes, and the growth of the services sector, leading to increased land prices and speculative assets.

4.3 Kole Wetland Agroecosystem

The Kole land, one of the rice granaries of Kerala, is part of the unique Vembanad-kol wet land ecosystem in Kerala comprising 151250 ha and is a Ramsar¹³ site since 2002. These Kole lands are located in the central Kerala. Some of the key characteristics of the Vembanad- Kol wetland as per the Ramsar Information sheet (Table 4.5).

¹³ Ramsar sites are wetlands of international importance designated under the Ramsar Convention, an intergovernmental environmental treaty signed on 2 February 1971 in Ramsar, Iran. These sites are crucial for conserving biodiversity, ensuring water resources, and managing floods. The Ramsar conventions are also known as 'The conventions of wetlands. There are 2,544 Ramsar sites around the world.

Table 4.5

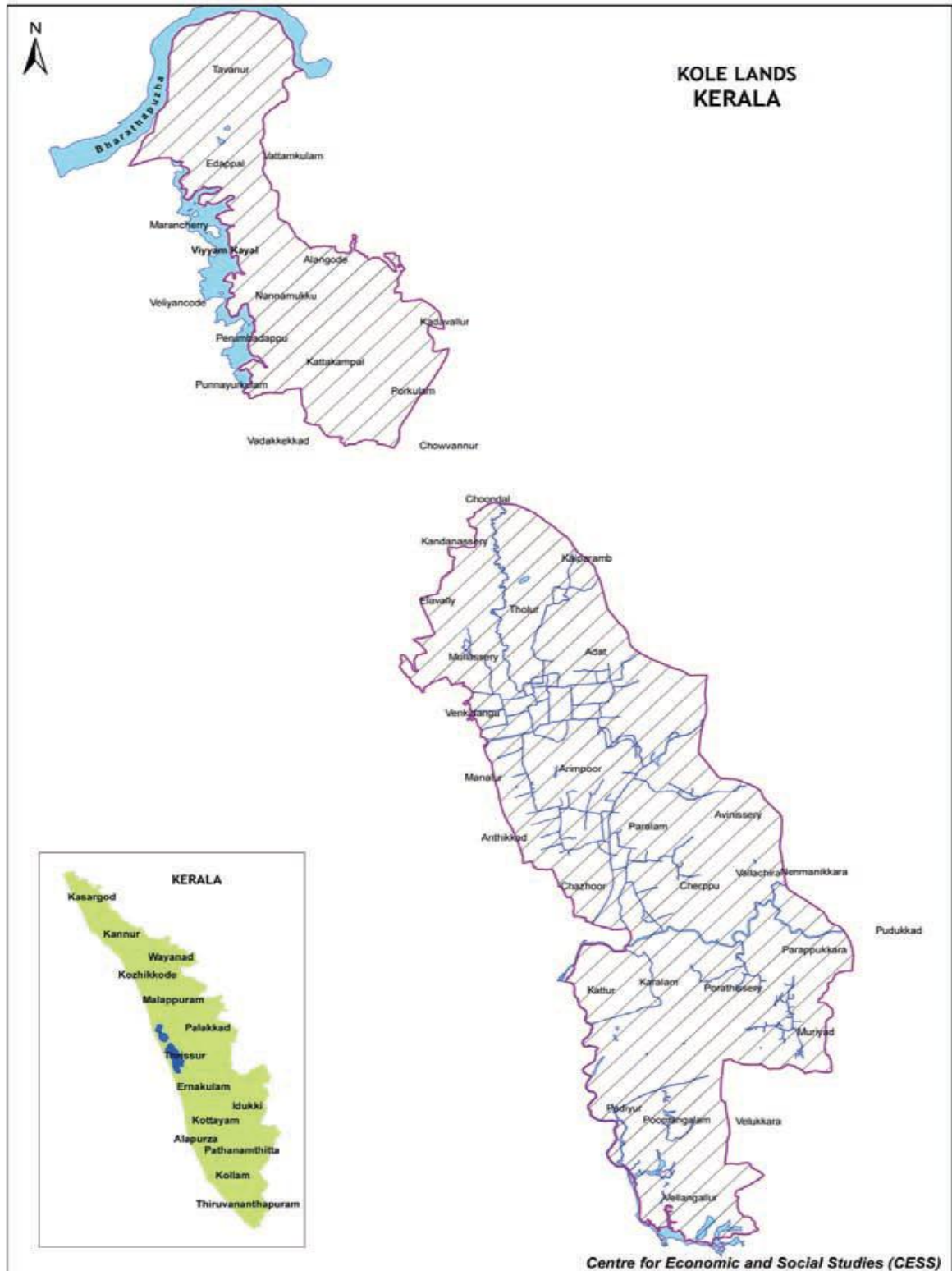
Characteristics of Vembanad-Kole wetland Ecosystem

Item	Details
Geographical coordinates	09 ⁰ 00' – 10 ⁰ 40' N Latitude and 76 ⁰ 00' -77 ⁰ 30' E Longitude coordinates South West Coast of India
Elevation	0.6 – 2.2 m below MSL
Area:(in hectares)	151250 ha
Ramsar Criteria	1,2,4,5 and 8
Criterion 1:	The Vembanad Kol wetland system, which spans 1512 km ² and is supplied by ten rivers, is a typical and one of the biggest estuary systems in the western coastal wetland systems. It is well known for its sub-fossil deposits and live clam resources.
Criterion 2:	The wetland supports vulnerable species Spot-billed pelican (<i>Pelicanus philippensis</i>)
Criterion 4:	During the winter, the Vembanad sustains India's third-largest number of ducks. The Kol region is home to 50 kinds of migratory birds and 91 species of resident/locally migratory birds. It is a breeding and feeding place for them.
Criterion 5:	Over 20,000 ducks make up India's third-largest population, which is supported by the Vembanad. Vembanad Lake was home to 27 species of waterbirds totaling 29,991 in 1994, 33 species totaling 21,416 in 1995, and 35 species totaling 21,724 in 1996, according to the Asian Waterfowl Census 1994–96.
Criterion 8:	Vembanad is a transitional ecotone between the sea and the land, a nursery for many aquatic species, and a home for a variety of finfish and shellfish.
General Location	Alappuzha, Kochi and Thrissur towns in Kerala State
Physical Features	The catchment areas could be classified physiographically based on their elevation: Highland with areas above 75 m above mean sea level. Wetland system receives water from 10 rivers, which have their origins in the Western Ghats, draining towards the west through the wetland system to Lakshadweep / Arabian Sea. The wetlands have freshwater in the Southern region and salty water in the Northern part.
Hydrological Values	The locals have a wealth of navigating options because to these waterways. In addition to the river's constant flow, the region is subject to daily tidal cycles. About 3500 square kilometers of densely populated coastal areas in three districts of Kerala are protected from flood damage by this body of water, which retains floodwaters.
Ecological features	The ecosystem acts as an ecotone between the sea and the land, a nursery for several aquatic species, and a home for a variety of fin fish, shellfish and prawn. It serves as a sink and transformer for the municipal and agricultural garbage that is dumped into it. In the wetland, fishing and agriculture are seen as opposing ideals.

Source: Ramsar Information Secretariate (2002)

Figure 4.1

Location map of Kole Wetlands in Thrissur, Kerala



Source: Centre for Economic and Social Studies (CESS), 2010. Hyderabad

Thrissur Kole land is a low-lying region with rich alluvium deposits carried by the Kechery and Karuvannur rivers within the Vembanad Kole habitat. It is a saucer-shaped basin surrounded by laterite hills on the western and eastern borders. A region of the Kole area has a lacustrine climate with black carbonaceous soil, luxuriant plant growth, and withered tree trunks (Johnkutty & Venugopal, 1993). According to earlier official estimates, the Kole paddy fields are low lying tracts located at 0.5 to 1 m below mean sea level that cover an area of 13632 acres in Kerala's Thrissur and Malappuram districts. The Chalakudy river forms the southern boundary, while the Bharathapuzha river forms the northern boundary. The region is found between latitudes 10°20' and 10°40'N and longitudes 75° 58' and 76° 11'E. The Kole land in Thrissur district is found in Mukundapuram, Thrissur, and Chavakkad taluks, while Ponnani Kole is located in Chavakkad and Thalapilly taluks in Thrissur district, and Ponnani taluk in Malappuram district.

Historically, Kole lands were recovered from the kayal region by erecting temporary earthen bunds and cultivating paddy (Johnkutty & Venugopal, 1993). The practise of paddy farming on the Kole land has developed over time in response to various climatic, ecological, institutional, socioeconomic, and technical circumstances.

The Kole wetland agroecosystem is the most productive paddy agroecosystem in Kerala. In Malayalam, "kole" refers to a certain kind of paddy farming that is done from December to May. If crops are not damaged by floods, this word denotes a bumper harvest with great returns. (Johnkutty & Venugopal, 1993). Kole farming accounts for 40 per cent of the rice output of the state. Paddy farming in Kole land began in the 18th century.

4.3.1 Climate

Moderate climatic conditions are experienced in the Kole land area with an average temperature between 21- 40°C. Similar to other areas of Kerala, Kole lands also have two well-defined rainy seasons, the southwest and north-west monsoons. However, due to climate change, the summer temperature has been rising to 38-40°C for the past 4-5 years. Meanwhile, the water temperature in this area has been rising to 40-42°C, which is having a positive impact on paddy cultivation. The region experiences a bimodal rainfall distribution, with the southwest and northeast monsoon as the main rainy seasons. The area receives a mean annual rainfall of 2757 mm, with 67.3 per cent during the southwest monsoon and 18 per cent during the northeast monsoon. Relative humidity ranges from 85 to 95 per cent between June and September, dropping to 70 per cent in January (Atlas of Kole lands, 2024). Wind is a common phenomenon in the Kole

areas. Wind speeds peak at 20 km/h during the southwest monsoon and decreases starting from November. The average pan evaporation rate¹⁴ in the Kole lands is 5.8 mm/day. This seems to be very favourable to paddy production.

4.3.2 Soil and Fertility Status

The soil in the Kole lands is composed of clay and sand with some clay content. The fertility varies slightly depending on the flow of the clay and the proximity of the sea. In general, the surface of the deep Kole fields is silty clay. The subsoil is clay with decomposed organic matter, which causes high acidity. The organic residues deposited over time in the Kole wetlands enrich the Kole soils. In addition, approximately 11 to 15 tons of soil are deposited per hectare annually (KAU, 2016). The organic matter content at the surface ranges from 2.07 per cent to 4.16 per cent, but in the subsoil, it varies from 1.37 per cent to 9.7 per cent (Hameed, 1975). Based on the characteristics of the soil particles, the soils of the Kole lands are classified as clay, sandy loam, and sandy clay (Johnkutty & Venugopal, 1993). The area also contains deposits of fine particles derived from the surrounding cut stone hills, and carbonaceous clay from large decomposed tree trunks. The normal colour of the soil ranges from light grey to dark brown.

Soil acidity is higher in the Kole areas compared to the agricultural lands of Kerala. It is observed that acidity increases with increasing depth as organic matter increases. Because the soil is waterlogged for most of the year, the soil is highly acidic. Therefore, a method of retaining and draining water is followed in paddy cultivation. The level of salinity in the soil of these areas is found to be 0.16 to 6 decimetres/meter. The level of salinity is higher in the Kole lands close to the sea due to the possibility of salt water intrusion when the water table is high.

Kole crops have been found to contain up to 7 per cent organic matter, and also have a high content of primary and secondary micronutrients required for plant growth. The total nutrient content was fairly high in Kole soils. Nitrogen content ranges from 0.14 to 0.57 per cent, phosphorus from 0.02 to 0.24 per cent, and potassium from 0.19 to 0.6 per cent. Among the secondary elements, calcium and magnesium are found in high amounts, while sulphur is found in low amounts. Among the microelements, copper, zinc, and boron are found in low amounts in many areas. However, iron and manganese levels are very high. This causes increased acidity

¹⁴ Pan evaporation rate is the amount of water that evaporates from a standard-sized pan, measured in millimetres per day

Anusree, 2022). The soils of the Kole area in general are acidic with PH ranging from 2.6 to 6.3. The total nutrient content was fairly high in Kole soils.

4.3.3 Irrigation

The sources of irrigation in the Kole area are the Peechi Irrigation Project, Vazhani Irrigation Project, Chalakudy Project and Chimoni Project. The Peechi Dam is a straight embankment constructed across the Manali River at Peechi. The Chalakudy Irrigation Project is a diversion project from the Chalakudy river. The river water is sometimes diverted through circuit routes and used for Kole fields, but it does not serve the purpose effectively.

The Chimoni Project was started with the aim of converting the entire Kole area into a double cropping system, one from September to December and the other from January to May (puncha). During the months of September-December, due to the rains and the river flow, there will be sufficient water for irrigation. From January to May, there will be water scarcity for summer crops. With the construction of the dam across the Chimani River, the required water storage was made possible. Another source of water for irrigation in the Kole areas is water stored in the canal system within the Kole areas. The canals are very narrow and cannot store water in a timely manner (Johnkutty & Venugopal, 1993).

4.3.4 River and canal system in Kole Land area

The Kecheri and Karuvannur rivers have a combined drainage area of 1685 km² with a monsoon flow of 2265 Mm³ and a total flow of 2388 Mm³ in the Kole region (Anonymous, 1997). The Kole land act as a natural reservoir of water flowing from these two rivers during monsoon. Manali and Kurumali are tributaries of the Karuvannur river. The Peechi River and its tributaries supply water to the Manali River. The Kurumali River is formed by the confluence of the Chimoni and Muppley Puzhas. All of these rivers originate in the Western Ghats. The Karuvannur River divides as it runs west, with one branch entering straight into the Chettuva estuary and the other flowing south and joining the Manakodi estuary (Johnkutty & Venugopal, 1993). The Kecheri River, which flows from the Machad highlands, drains the north Kole and empties into the Enamackal estuary. The 'North Kole' is a river that runs from the Kecheri River in the north to the Karuvannur River in the south. 'South Kole' refers to the territory spanning from the south bank of the Karuvannur River to the Vellangalur region in the south. Historically, the Kole land area experienced heavy flooding during the monsoon season (Johnkutty & Venugopal, 1993). However, it is stated that with the construction of the Chimoni

and Muppy irrigation projects, more efficient floodwater control became feasible, and continuous flow is typically maintained during the summer.

The main outlet channel for the flood water in the northern Kole region is Enamakkal and Idiyanchira regulators. These two are salt barriers. The main advantage of these salt barriers is to deflect a part of the flood waters of northern Kole towards the back waters, namely, Kanoli canal, and eventually into the sea at Chettuva Azhi. The region of north Kole is further divided into two basins. The first includes the northern Kole and its divisions, namely: Kechery, Naduthodu, Chiyaram, and Kokkala. The other basin includes the southern Kole, which further consists of Puthenthodu, Herbert Canal, and Chirakkal Thodu. 'Thodu' means Channel (Atlas of Kole Lands, 2024). The main outlet channel for the flood water entry into the South Kole region is 'Thuppanthodu'. It brings flood water entry into the Kole region from 'Villichira'. The secondary entry flood water into the region is from 'Nedumthodu' carrying 'Thommana' and discharging into the eastern and northern eastern regions of 'Irinjalakuda' town. It passes through 'Muriyadu Kayal' and further joins 'Thuppanthodu' near 'Anandapuram bund'. The 'Kanoli canal' passes through the northern and north-west regions of 'Irinjalakuda' in the 'Chemmanda' region and eventually joins 'Chemmanda Kayal'. The drained water from Karalam region is discharged into Karuvannur River via a canal known as Nandi sluice and into Kanoli canal via and Muriyad-Moorkanad canal (Muraleedharan, 1984).

4.3.5 Season Wise Paddy Cropping Pattern

The principal crop raised in Kole lands is paddy. The major crop period is Punja. Other crop periods are Virippu and Mundakan. In certain regions of Kole land, paddy and fish are grown alternatively. Flooding of fields after paddy crop yields fish. Virippu grows in higher paddy fields surrounding the Kole land. Here, floods are for a short period of few days. Sowing takes place along with the onset of monsoons. The crop at that time will be 30-40 days old upon the arrival of flood water. Crops that withstand floods for a short period are raised in Virippu regions. Mundakan grows in average elevation fields surrounding Kole land. Here, flood water drains away in August. It requires water through its entire period. Kadumkrishi in Kole land shares the period of Mundakan in normal lands. Normally, its period starts in September. Here, bunds are constructed to protect the individual Padasekaram from flooding. As soon as the floodwaters in the Kole area start receding by the end of the south west monsoons, the pumping operation to drain out the water takes 10 to 15 days. In Kadumkrishi, water management is a crucial process that requires continuous draining out of the water, and by the end of the growing

period, irrigation supply for agriculture becomes a requirement. Punja is a cultivated crop throughout the entire Kole area. In areas where bund elevation for Kadumkrishi has not been implemented, temporary earthen bunds are established around clusters of paddy fields or Padasekharams in the months of December-January (Atlas of Kole lands, 2024). For Punja, water need for the initial phase of growing crops can be obtained either by the supply due to the summer flow in rivers and storage canals, or by the use of dam water for irrigation in the latter phase.

Table: 4.6

General seasons of Paddy cropping in Kole lands

Item	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Virippu (in higher elevated fields)												
Single crop Kadum- krishi/ Mudakan												
Single crop <i>Puncha</i>												
Double crop Additional crop <i>Puncha</i>												

Source: Atlas of Kole Lands of Kerala: Volume 1. Kerala Agricultural University, Thrissur

4.3.6 Kole Farming Societies

In the early stages of Kole cultivation various land development activities and other agricultural operations were performed by the farmers individually. Since the area was small the individual farmers had to bear more cost which reduced their profit and also caused more risks in farming. Later the works connected with preparation of bunds, irrigation and drainage etc. were carried out collectively for contiguous paddy fields. This collection of contiguous paddy fields is called the '*Padasekharam*' or '*Padavu*'. The land owners formed themselves into groups to form a *Padasekharam committee* which was formulated in a democratic way under section 7A of the

Kerala Land Development Act, 1964 (17 of 1964) and registered under the Societies Act. These *padasekharams* follow the Co-operative method of farming to reduce the cost of cultivation.

Dewatering of fields, an energy intensive activity, is carried out with the help of free electricity supplied by the State to *padasekharams*. The labour and other expenses of bunding and dewatering are borne by the *Padasekharams*, and are shared by each farmer according to the size of his land. Zonal agriculture is practiced to solve water management problems. Kole farms in the north of Karuvannur River are divided into 3 zones and that of south into two zones for water management. Under this system, dewatering is carried out zone wise. Water pumped from one zone is collected in other zones and used as irrigation water when required. The district administration pre-determines the start and end dates of dewatering in each zone in consultation with the *Padasekhara committees*, which carries out the 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 Padasekhara committees decide when to begin dewatering and agricultural operations after consulting with individual farmers and, in certain cases, with representatives of cooperative banks that provide loans for common agricultural operations like bunding, canal cleaning, and dewatering (Srinivasan, 2011). The District Administration, after consultations with the Padasekhara samithies, prepares guidelines for executing various agricultural operations keeping special emphasis on water management.

4.4 Kole Wetland Ecosystem Services

The Millennium Ecosystem Assessment (MEA, 2005) introduced a new classification of the services provided by ecosystems such as: provisioning services, regulating services, cultural services and supporting services (Hassan, et al., 2005). Understanding these services is useful for identifying the linkages and interactions between various ecosystem services and determining those whose services are mutually supportive or incompatible. The Thrissur Kole paddy fields provide these multiple ecosystem services.

4.4.1 Provisioning services

Kole Wetlands provide multiple of physically identified goods and services. These products are provisioning services which are produced directly by exploiting the terrestrial related properties of these wetlands. These services directly and indirectly support the wellbeing of the local population and related farmers. The major provisioning services in Kole wetlands are paddy production, fish and fish farming, lotus cultivation, duck rearing etc.

4.4.1.1 Paddy cultivation

Thrissur-Ponnani Kole paddy lands contributed one fifth of the total paddy production of Kerala. Paddy cultivation in Kole lands is more lucrative than regular paddy cultivation. However, considering the importance of Kole lands in Kerala, generous financial assistance is being provided to the farmers. The overall reported area is 13632 hectares, albeit this has been decreased in many areas owing to infilling and conversion for industrial uses, but it is notable that 10,000 ha remains as agricultural land, while around 800 ha of farm land has been substantially converted.

The first step in paddy cultivation is the dewatering of fields at the end of the South West monsoon season; the water will be pumped away in 10 to 15 days. The process of dewatering is energy intensive and costly. Therefore, the government provides Padasekharams with free power for dewatering. Each farmer is responsible for paying their own portion of the additional costs associated with dewatering, including labour. Following dewatering, farmers work individually to build bunds and till and level the ground, primarily using power tillers. To till a hectare of paddy field, power tillers need around 15 hours. Kole lands are often acidic. In order to adjust the acidity content and related toxicants at this point, lime is added to the soil as needed after allowing water to enter and then draining the water. In addition to lime, some farmers also apply organic manures to the field during the time of preparation of land. The direct sowing or transplanting methods is usually followed in Kole cultivation. The average seed required for direct sowing was estimated around 100 to 110 kg per hectare. But only 60 to 80 kg seed required for transplanting method. However, around 20 to 30 per cent more seeds used by the farmers due to the fear of low germination rate by the more acidic nature of soil. A high seed rate in the study area has been observed in most of the studies (Johnkutty & Venugopal, 1993; Srinivasan, 2012). The high yielding variety seeds like Uma, Jyothi and Manuratna are commonly used in Kole lands. Seeds made available at free of costs by Kerala State Seeds Authority. The summer flow in the rivers and storage canals provides the water needed for the early stages of the crop, while water from the Peechi and Chimony dams is used for irrigation later on (Muraleedharan, 1984).

Use of chemical fertilisers in Kole land for paddy cultivation is more than double of state average. A study made by Jeena T. Srinivasan, in 2012, reported that use of chemical fertilisers is as high as 282 kgs per hectare in Kole lands while it was only 123 kgs per hectare in Kerala (CACP, 2010). There is an overuse of pesticides and herbicides too reported in Kole land farms. The application of high dose of weedicides and manual weed removal too are used in the Kole land farms. It is estimated that an amount of rupees 4500 to 5000 is required for plant protection measures. Generally, more labour hours are required for Kole land paddy cultivation than state level farming. Approximately 176 labour days per hectare are required for paddy cultivation. Due to the non-availability of domestic labours, migrant labours are employed in the paddy cultivation.

Harvesting in Kole lands is completely mechanised. In order to harvest one hectare of paddy land requires about 5 hours. Along with harvest, straw is also available in bundles for marketing. The productivity and cost of cultivation of paddy in Kole land are different in each Padasekharams. The state average productivity of paddy was only 2875 kgs while productivity in Kole lands was 5450 kgs per hectare. Majority of the farmers sell their paddy to Supplyco at a procurement rate of Rs.28.20 per kg.

4.4.1.2 Fish and Fish Farming

Rice and fish are cultivated alternately in the Kole lands. Rice is cultivated in the summer and fish is cultivated after paddy harvest when these lands are flooded. The services provided by the Kole lands and its fish to the local population are numerous. In addition to providing a livelihood to many people through fishing and their marketing, it provides nutritious food regularly. The miniature fishes in the Kole lands prevents many infectious diseases by eating the eggs and larvae of many disease-carrying organisms. Many of the fish in the river basins have medicinal properties, and each small fish is as nutritious as or even more than the larger fish. In addition to serving as vital links in the food chain, they also increase the productivity of the wetland as tenfold. Since most of the fish in this wetland are ornamental, their capture and marketing are a source of livelihood for a few people. In earlier times, only natural fishing was practiced but recently, commercial basis fish farming is usually carried out during March to September. 66 species of indigenous fishes have been found in the Kole lands. Some of the local fish species found in Kole lands are: *Padanna*, *Bral*, *Karimeen*, *Mundathi*, *Kolaan*, *Mushi*, *Koori*, *Aral*, *Kadu*, *Vala*, *Pallathy*, *Paral*, *Potta*, *Chekkori*, *Kalluthy*, *Kadu*, *Malinjeen*, and

chelli. Instead of natural fishing, recently, farms are leased out for about 3 years and fishes like Rohu, Katla, Prawn etc are cultivated on commercial basis.

4.4.1.3 Other Provisioning Services

Apart from paddy and fish, Kole wetland ecosystem makes suitable for other uses like lotus cultivation, duck rearing, vegetable farming, livestock grazing, agrobiodiversity, collection of medicinal plants and other herbs. Along with duck farming, the relationship between ducks and paddy farming is the most visible example of mutualism in nature. Not only does the duck feed on fallen paddy in the fields, but it also creates a situation that helps in weed and pest control by consuming harmful insects and weed seeds.

However, Mining, a major non-agricultural activity, adversely affects the Kole land ecosystem. The severe clay mining not only obstructs waterflow but also causes erosion in Kole land and nearby areas.

4.4.2 Regulating Services

Kole wetlands provide a natural barrier between the Western Ghats and the Arabian Sea. The primary use of the Kole wetlands region is flood storage. The Kole land offers valuable hydrological functions. According to reports, the Kole land has around 233.74 mm³ of water, which is more than what is kept in the Chimmomy and Peechi dams for irrigation of the summer crop. It also contributes significantly to the recharging and outflow of the water table. The water levels in the neighbouring wells are heavily reliant on the Kole land. Additionally, it functions as a water filter. The Kole area plays a significant role in making Thrissur city and its suburbs habitable. As a natural watershed, the Kole fields serve as a water reservoir for about six months and as a groundwater recharge area throughout the year. Kole wetlands aid to maintain a ground water table and helps to provide ground water recharge and discharge among other waterbodies. Soil, vegetation, site, perimeter to volume ratio and water table determined the ground water recharge of a Kole wetland area.

Carbon sequestration is another critical function of Kole wetlands. It is the long-term removal, capture, or storage of carbon dioxide from the atmosphere in order to prevent or reverse the CO₂ pollution and climate change. These areas are the important source and sink for greenhouse gases, influence local and regional temperature, precipitation and other climatic processes and act as a climate regulator. Additionally, soil erosion prevention, flood control etc are some other regulatory services of Kole wetland ecosystem.

4.4.3 Cultural Services

The reservoir and network of canals in Kole area are important for water transportation and tourism activities. The Kole Wetlands is a major heaven for migratory birds. Apart from being a productive system, the Kole Wetland act as a source of rich biodiversity and culture. In fact, it supports a large number of endangered birds. It provides opportunities for research and educational activities. It is also said that the main cultural activities in Thrissur are related to paddy cultivation in the Kole farms. Other services offered by this area include bird watching, swimming, kite flying, fishing, photography, wedding photo shoot, and provide a good chance for enjoying the greenish natural beauty.

4.4.4 Supporting

Supporting services are the key processes or components that are necessary to maintain the ecosystem services provided by wetlands. They include key ecological cycles related to hydrology, nutrient flows, and soil formation (FAO, 2008).

Kole Wetlands are biodiversity hotspot with rare flora and fauna. From unicellular algae, i.e., single-celled plants and animals that cook their own food, to flowering plants, it is found here. Kole wetlands are home to 114 plant species, 20 animal species, 14 reptile species, 243 bird species, 6 amphibian species, and 43 fish varieties (Nameer, 2002). The wetland is part of the 'Central Asian Indian Flyway' (Sivaperuman et al., 2000) and acts as a stepping stone for trans-continental migratory species'. Migratory birds constantly follow certain flying paths. The pathways used by various animals vary significantly. The Kole Wetlands sustain twelve threatened bird species, three of which are fragile and nine are threatened with extinction (Nameer, 2002). The main mammals associated with the wetlands are the otter, wolf, wildcat, fox, and amphibians and crocodiles that live in both water and land.

4.5 Study area-Thrissur Kole

The Thrissur Kole land is divided into North Kole and South Kole. The 'North Kole' stretches from Kechery river in the north to Karuvannur river in the south. The area extending from south bank of Karuvannur river to Velukkara region in the south is called 'South Kole'. The Karuvannur divides Thrissur Kole into North and South Kole. Thrissur North Kole lies in Thrissur taluk and part of Chavakkad taluk. South Kole lies in Mukundapuram taluk. Thrissur Kole lands are found in the Anthikkad, Cherpu, Irinjalakkuda, Mullassery, Puzhakkal, and Vellangallur block panchayaths (Atlas of Kole Lands, 2024).

Table: 4.7

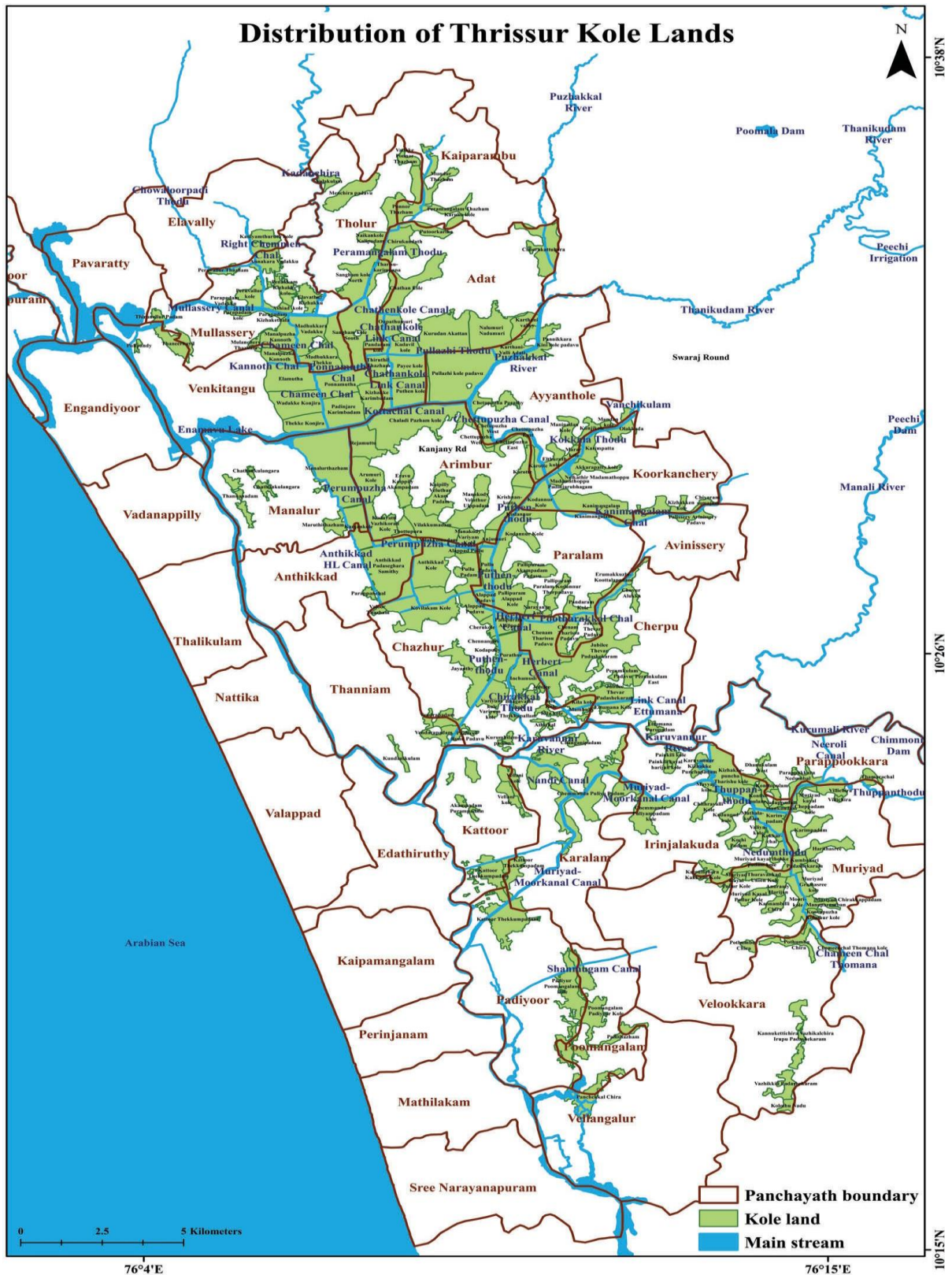
Block Wise Distribution of Thrissur Kole

District	Block	Panchayaths/Krishibhavans	Area Cultivated (ha)
Thrissur	Anthikkad	Anthikkad, Arimbur, Chazhur, Manalur, Thanniam	2861
	Cherpu	Avinissery, Cherpu, Koorkkanchery, Paralam	1473
	Irinjalakkuda	Irinjalakuda Municipality, Karalam, Kattoor, Muriyad, Parappookkara, Porathissery	1693
	Mullassery	Elavally, Mullassery, Venkitangu	1255
	Puzhakkal	Adat, Ayyanthole, Kaiparambu, Tholur	2343
	Vellangallur	Padiyoor, Poomangalam, Velookkara, Vellangallur	527

Source: Atlas of Kole Lands of Kerala: Volume 1. Kerala Agricultural University, Thrissur

There are 272 *padasekharams* in Thrissur-Ponnani Kole. Out of which 72 per cent (196) of them are in Thrissur Kole and the remaining 28 per cent in Ponnani Kole (Table 4.8). Although *padasekharams* are cooperative forms but their size of land holdings is small. 83 percent of the paddy fields in Thrissur Kole and 85 percent of the paddy fields in Ponnani Kole have only less than 100 hectares of paddy land. Meanwhile, only 5 percent of the paddy fields have 200 to 500 hectares of paddy land. Of these, only a few (less than three) paddy fields have about 500 hectares of paddy land.

Figure 4.2
Map of Thrissur Kole lands



Source: Atlas of Kule lands, 2024

Table 4.8
Size wise distribution of Kole *Padasekharams*

Size of Padasekharams (In Hectares)	No. of Padasekharams in Thrissur Kole	No. of Padasekharams in Ponnani Kole	Total No. of Padasekharams
0 to 10	18	11	29
11 to 50	99	37	136
51 to 100	44	17	61
101 to 200	25	9	34
201 to 500	10	2	12
Total	196	76	272

Source: Atlas of Kole lands, 2024

4.5.1 Socio-Economic Background of the sample respondents

The general socio-economic background of the sample households is described in this section. The sample households are selected from paddy farmers of Kole lands in Thrissur Kole, which are extended over an area of six block panchayats. The samples have been selected at proportionately random on the basis of total number of farmers in respective blocks. The samples are selected from North and South Kole separately. 393 sample households are selected from 18 *padasekharams* spread in six blocks (Table 1.1). The understanding of socio-economic background of these sample households is essential to determine the beings and doings that a person can achieve (Sen's capability). In this section, Table 4.9 describes the socio-economic background variables of farmer such as age, family size, years of schooling, ownership of land holdings, generation of the farmer, source of income, and occupation, across different block panchayats (Section 4.5.1.1). The socio-economic background of farmers is also analysed based on the source of income (Section 4.5.1.2) as well as annual income of the farmer (Section 4.5.1.3).

4.5.1.1 Socioeconomic economic conditions among Block Panchayats

The age wise distribution of the respondents presented in Table 4.9 illustrated that among the total 393 respondents, 49.36 per cent (194 farmers) of the farmer respondents are in the age group of above 60, and 43.77 per cent are in the age group of 45 to 60. It is identified that the

mean age of all the sample respondents is 60 years. Among the age group of 60 and above, 32.99 per cent are in Anthikad block followed by Puzhakkal blocks with 24.23 per cent. The middle-aged farmers (45-60 age) are distributed more or less evenly across all blocks except Vellangallur. Only a small number (27) of farmer respondents are in the age group of below 45. Out of which, major share of young farmers is in Anthikad, Irinjalakuda and Mullassery blocks.

The educational status of the respondent farmer is an indicator of their ability or access of ecosystem services and farming resources which are assessed in terms of the years of schooling. The years of schooling are classified into Primary, having 1 to 7 years; High School with 8 to 10 years; Higher Secondary with 11 to 12; and Graduation and Above with more than 15 years of schooling. Among the total respondents, 39.44 per cent of farmer respondents have education level of graduation and above, 18.07 per cent have higher secondary education, and 36.64 per cent have secondary education as presented in Table 4.9, indicating a relatively high level of educational attainment in these regions among paddy farmers. The proportion of the respondents having secondary education is higher in Anthikad followed by Puzhakal and Cherpu. Among farmers with graduation or above, 29.68 per cent are distributed in Anthikad and 19.3 per cent in Puzhakkal Block. The higher secondary education is well distributed across majority of the sample blocks even with lower overall share compared with Graduation and secondary level.

The size of the family is an important determinant of the wellbeing of the farmers at microlevel is presented in Table 4.9. The family size composition reveals that 62 per cent of the sample households have a family size of 3 to 6 members (241 out of 393). On the other hand, small families with less than 3 members are fairly common in Anthikad and Puzhakkal blocks, with 28.63 and 23.65 per cent, respectively, which extends to nuclear families or even single families. Meanwhile, large families with more than 6 members are prevalent in the Cherpu block, with 32.26 per cent of households. It is observed that medium sized families are more prevalent across all blocks whereas large families are less common.

The highest per cent of third and fourth generation farmers with a more or less stable share of all blocks seen in the overall block-wise distribution of farming families presented in Table 4.9 reflects the deeply rooted agricultural continuity between generations in all regions. A significant proportion of fourth generation farmers (35.11 per cent), skewed in Anthikad (31.16 per cent) and Puzhakkal (24.64 per cent) blocks, highlighting the stable involvement of

households in paddy cultivation over decades. On the contrary, the less involvement of first and second generations highlights that young generations are not interested in agriculture, particularly paddy farming. However, the relatively higher proportion (45.71 per cent) involvement of first-generation farmers in Anthikad block highlights the new influx of youth in this area. Furthermore, 60 per cent of the fifth-generation farmers are in Anthikad, reflects the sustainable farming lineage in this block.

In terms of the size of land, ownership holdings of Kole lands are divided into five classes, such as no land owned (Nil), less than 0.25, between 0.25 and 0.49, between 0.5 and 1, and above 1 hectare. According to Table 4.1, the majority of the households (73 per cent) owned only less than half a hectare of Kole lands, while just 9.16 per cent of the households owned more than one hectare. Moreover, 3.31 per cent of the respondents surveyed do not own any paddy Kole land. It is also observed that 135 respondents have less than 0.25 hectare of land, 40 of whom (29.63 per cent) are in the Anthikad block. The area of ownership holding 0.25 to 0.49 is common across all blocks, while large-size holdings (> 1 hectare) are rare across blocks but relatively higher in the Anthikad block (41.67 per cent).

Even though sample households are paddy farmers, 48 per cent of them do not consider paddy farming as a source of income to maintain their livelihood, especially because of the uncertainty and risk of loss due to climate change and low return from farming (Table 4.9). It is observed that a quarter of the total respondents consider paddy cultivation as only a subsidiary source of income. However, it is observed that 72 per cent of the farmers consider paddy is either not a source of income or only a subsidiary source of income, which is showing the diversification of income source towards non-farm or other agricultural activities in all areas. Although there are a few farmers still favour paddy cultivation as their sole source of income, a significant portion of them (45.76 per cent) are from the Anthikad block.

Table 4.9
Distribution of socio-economic variables across different Block Panchayath (In Percentage)

Variables	Attributes	Name of the Block						Total
		Anthikad	Cherpu	Irinjalakuda	Mullassery	Puzhakkal	Vellangallur	
Age	Below 45	29.63	11.11	25.93	22.22	7.41	3.70	100
	45-60	22.09	18.02	19.19	15.70	24.42	0.58	100
	Above 60	32.99	20.10	10.82	9.28	24.23	2.58	100
Years of Schooling	Primary	39.13	4.35	8.70	8.70	34.78	4.35	100
	Secondary	29.86	20.14	11.11	8.33	28.47	2.08	100
	Higher Secondary	16.90	21.13	23.94	21.13	16.90	0.00	100
	Graduation and above	29.68	18.06	16.77	14.19	19.35	1.94	100
Size of the Family	<3	26.45	22.31	13.22	11.57	25.62	0.83	100
	3-6	28.63	14.94	17.01	13.69	23.65	2.07	100
	>6	29.03	32.26	12.90	12.90	9.68	3.23	100
Generation of the Farmer	First	45.71	8.57	22.86	8.57	11.43	2.86	100
	Second	17.11	17.11	19.74	11.84	32.89	1.32	100
	Third	19.33	24.37	17.65	17.65	21.01	0.00	100
	Fourth	31.16	18.12	11.59	11.59	24.64	2.90	100
	Fifth	60.00	12.00	4.00	8.00	12.00	4.00	100
Area of Ownership of Land (In Hectares)	Nil	23.08	46.15	0.00	15.38	15.38	0.00	100
	< 0.25	29.63	17.78	17.04	9.63	23.70	2.22	100
	0.25-0.49	25.66	18.42	15.79	17.76	22.37	0.00	100
	0.50-1.00	22.81	19.30	14.04	12.28	26.32	5.26	100
	> 1	41.67	11.11	16.67	5.56	22.22	2.78	100
Paddy Cultivation as Source of Income	Only source	45.76	15.25	10.17	3.39	23.73	1.69	100
	Main source	28.00	26.00	10.00	6.00	26.00	4.00	100
	Subsidiary Source	16.84	9.47	29.47	17.89	24.21	2.11	100
	Not as a source	28.04	22.22	11.64	15.34	21.69	1.06	100

Source: Primary Survey

4.5.1.2 Source of Income and Socioeconomic conditions

The distribution of background variables of the sample farmers on the basis of their source of income reveals that 48.1 per cent of the households, i.e. 189 out of 393 respondents, do not consider paddy as a reliable source of income (Table 4.10). It is observed from the table that young and middle-aged people do not prefer paddy as a reliable source of income, while the elderly people still consider paddy cultivation as a primary source of income. It is evident from the table that 21.1 per cent of the elderly (above 60 years of age) consider paddy cultivation as their sole source of income and 16.5 per cent as their main source of income, while young farmers predominantly (55.6 per cent) rely on non-paddy sources and middle-aged people skewed towards non paddy sources by 55.2 per cent. It is interesting to note that diversified income sources other than paddy is predominant across blocks, but paddy dependence increases with age of the farmer.

It is obvious from the analysis that, as years of schooling increases, from primary to graduation and above, dependency on paddy as a source of income decreases. Table 4.10 revealed that 43.48 per cent of the farmers with primary education depends solely on paddy while only 5.16 per cent of the farmers with graduation and above depends on paddy as single source. It is also noted that, among respondents having graduation and above, 60.65 per cent are nondependent of paddy, indicating that attaining higher education shifts the people away from it. While 38.19 per cent of farmers with secondary education consider paddy farming as a primary source of income and, the same percentage of people with secondary education do not rely on paddy farming.

Small households with less than 3 members depend more on non-paddy source of income (46.28 per cent), but 53.72 per cent of them depend relatively higher on paddy as their single source of income. On the other hand, more than 50 per cent of the middle-sized families (3-6 members), rely on diversified source of income. It is observed that, out of the total large families, 16.13, 19.35, and 29.03 per cent, depend on paddy as their sole, main, or subsidiary source of income respectively.

Most families across all categories have a farming family background rooted in generations. Out of the total respondents, 30.28 per cent of households are third generation farmers and 35.11 per cent of them are fourth generation farmers. Though these generations dominate in paddy, majority do not depend paddy as a source of income. As per Table 4.10, 37.14 per cent of the first-generation farmers, that is new entrant into paddy farming, only depends on paddy

as a subsidiary source. The study highlights that, second to fifth generation, especially third and fourth generation, paddy farming dependency steadily declines or otherwise, non-paddy dependency increases significantly.

Table 4.10

Distribution of the Socio-economic variables across different Source of Income Groups (In Percentages)

Variables	Attributes	Source of Income				
		Only Paddy	Main Paddy	Subsidiary Paddy	Not Paddy	Total
Age	Below 45	11.11	3.70	29.63	55.56	6.87
	45-60	8.72	9.88	26.16	55.23	43.77
	Above 60	21.13	16.49	21.65	40.72	49.36
Years of Schooling	Primary	43.48	8.70	34.78	13.04	5.85
	Secondary	22.22	15.97	23.61	38.19	36.64
	Higher Secondary	12.68	11.27	23.94	52.11	18.07
	Graduate and above	5.16	10.97	23.23	60.65	39.44
Size of the Family	<3	23.97	9.92	19.83	46.28	30.79
	3-6	10.37	13.28	25.73	50.62	61.32
	>6	16.13	19.35	29.03	35.48	7.89
Generation of the Farmer	First	17.14	5.71	37.14	40.00	8.91
	Second	9.21	11.84	30.26	48.68	19.34
	Third	13.45	10.92	21.85	53.78	30.28
	Fourth	18.84	15.94	19.57	45.65	35.11
	Fifth	16.00	16.00	24.00	44.00	6.36
Area of Ownership of Land (In Hectares)	Nil	0.00	0.00	46.15	53.85	3.31
	< 0.25	17.04	9.63	18.52	54.81	34.35
	0.25-0.49	12.50	13.82	26.32	47.37	38.68
	0.50-1.00	22.81	8.77	28.07	40.35	14.50
	> 1	11.11	30.56	22.22	36.11	9.16
Annual Income of the Family	<50000	67.74	3.23	12.90	16.13	7.89
	50000-300000	17.96	17.48	28.16	36.41	52.42
	300000-500000	1.32	15.79	21.05	61.84	19.34
	>500000	0.00	1.25	21.25	77.50	20.36
Total		15.00	12.70	24.2	48.10	100

Source: Primary Survey

Table 4.10 reveals that majority of farmer's (73 per cent) area of ownership of land is below 0.5 hectare, specifically 34 per cent have only less than 0.25 hectare of land. 22.81 per cent of the medium sized farmers (0.5 to 1 hectare) solely depend on paddy farming as source of income

while, 30.56 per cent of the large size farmers (> 1 hectare) depends paddy as main source of income. But, marginal size farmers (< 0.25 hectare) depend on mixed sources of income and dominating in non-paddy (54.81 per cent) source. The study highlights that as farmer's size of ownership of land increases, their dependence on paddy farming as a source of income increases, while those who do not own land or have only marginal land rely on a variety of income sources rather than paddy.

The majority of farmers across all categories (52.42 per cent) fall into the 50,000-300,000 annual income brackets. Among these income brackets, a significant majority depend on paddy as a sole, main or subsidiary income (collectively 63.59 per cent). Likewise, lower income farmers (< 50000 group) overwhelmingly depend on paddy as a sole source of income (67.74 per cent). On the other hand, farmers with an annual income of over 3 lakhs have non-paddy income as their main source of income. The study highlights that high-income farmers are more likely to be associated with diversified income sources other than paddy, while low-income farmers are more likely to be solely or mainly dependent on paddy, leading to greater economic inequality and vulnerability among landholders.

4.5.1.3 Annual Income and Socio-economic conditions

The study has taken into account the annual income of all the earning members of the family together. This section tries to examine the distribution of socio-economic background variables across different income groups which are presented in Table 4.11. In terms of age distribution of the respondents, only 3.70 per cent of young farmers (below 45 years of age) have an annual income of less than Rs. 50,000, while 11.34 per cent of the elderly (above 60 years of age) fall into this income bracket, as shown in Table 4.3. Conversely, 25 per cent of the young farmers earn income above 5 lakhs whereas only 15.46 per cent of the elderly farmers earn this income level. Among 45 to 60 ages, 53.49 per cent of the farmers have middle income (50000-300000) and 25 per cent have more than 5 lakhs income. It is observed that, middle and lower-income groups are economically better off while elder farmers are likely to be in lower income level.

Majority of the primary educated farmer (65.22 per cent) households earn income between 50000 to 300000, while, only few (3.41 per cent) earn higher income of above 5 lakhs. The 9.72 per cent of the farmers with secondary education, 21.13 per cent with higher education, and 32.26 per cent of the graduation and above earn more than 5 lakhs per annum. This shows that higher education and income are highly correlated. While 14.05 per cent of small households fall into the lowest and highest income brackets, 23.24 per cent of middle-income households

fall into the income range of Rs 3 to 5 lakhs and 23.65 per cent have incomes above Rs 5 lakhs. But, in large families (> 6 members), though mostly fall in middle income, 12.90 per cent fall in lower income of less than 50000.

Table 4.11

Percentage Distribution of background variables across different Income Groups

Variables	Attributes	Annual Income of the Family				Total
		Below 50000	50000-300000	300001-500000	Above 500000	
Age	Below 45	3.70	48.15	22.22	25.93	100
	45-60	4.65	53.49	16.86	25.00	100
	Above 60	11.34	52.06	21.13	15.46	100
Years of Schooling	Primary	13.04	65.22	17.39	4.35	100
	Secondary	13.89	59.03	17.36	9.72	100
	Higher Secondary	7.04	52.11	19.72	21.13	100
	Graduate and above	1.94	44.52	21.29	32.26	100
Size of the Family	< 3	14.05	58.68	13.22	14.05	100
	3 - 6	4.15	48.96	23.24	23.65	100
	> 6	12.90	54.84	12.90	19.35	100
Generation	First	2.86	62.86	14.29	20.00	100
	Second	10.53	42.11	22.37	25.00	100
	Third	10.92	47.90	22.69	18.49	100
	Fourth	5.80	56.52	16.67	21.01	100
	Fifth	4.00	68.00	16.00	12.00	100
Occupation	Paddy Cultivation	20.18	66.97	11.93	0.92	100
	Government Service	7.41	14.81	14.81	62.96	100
	Private Job	1.17	46.78	27.49	24.56	100
	Business	0.00	50.00	15.22	34.78	100
	Agriculture & Livestock	12.50	65.00	12.50	10.00	100
Ownership of Land (In Hectares)	Nil	7.69	38.46	23.08	30.77	100
	< 0.25	8.89	59.26	15.56	16.30	100
	0.25-0.49	6.58	48.68	21.71	23.03	100
	0.50-1.00	12.28	54.39	21.05	12.28	100
	> 1	2.78	44.44	19.44	33.33	100
Total		31	206	76	80	393

Source: Primary Survey

The generation wise distribution of annual income of the farmer reveals that 62.86 per cent of the first-generation farmers have high dependency on middle income group of 50000-300000, while 20 per cent fall in highest income of above 5 lakhs (Table 4.11). But only 2.86 per cent have lower income of less than 50000. Among second generations, 25 per cent have more than 5 lakhs and 23 per cent have 1 to 3 lakh income. The fourth generations also have better balanced distribution with relatively higher income brackets. 21 per cent of the fourth generations earn above 5 lakhs income indicating the diversification of income sources among these generations.

Among 393 sample households, 171 farmer respondents i.e., 43.51 per cent of the farmers engaged in a private job along with paddy farming. Likewise, 109 household's (27.73 per cent) main occupation is paddy farming. Only one farmer whose main occupation is paddy has an income of more than 5 lakhs. Of the rest, 66.97 per cent of the families are in the middle-income bracket of 50000-300000, and 20.18 per cent are in the income of less than 50,000. There is moderate distribution of private job respondents with 27.49 per cent representation in 3 to 5 lakhs income class and 24.56 per cent representation in above 5 lakhs class. The respondents with government job and business people have highest representation (62.96 and 34.78 per cent respectively) in higher income bracket of above 5 lakhs.

The income distribution by ownership shows that 30.77 per cent of landless farmers earn more than Rs 5 lakh by engaging in non-farm activities. Meanwhile, 33.33 per cent of farmers with land holdings of more than one hectare earn more than Rs 5 lakh. The 0.5 to 1 hectare land ownership category has a moderate percentage across all income groups, with the highest proportion in the 3 to 5 lakh income group.

The annual income distribution of the sample farmers across different blocks is presented in Table 4.12. The study revealed that half of the farmers families (52.42 per cent) fall in the middle-income category indicating the typical case of semi urban or rural Indian economy case. In Anthikad Block, majority of the families (60 per cent) fall in the middle-income category of 50000 to 300000 while 30 per cent fall into the income category of above 3 lakhs. However, 42.47 per cent of the families in Cherpu block earn more than 3 lakhs per annum. Mullassery (27.45 per cent), Irinjalakuda (22.95 per cent) and Cherpu (21.92 per cent) block panchayaths showed a high-income presence (Above 5 lakhs annually) among farmers indicating the better economic status of farmers.

Table 4.12

Distribution of Income Status across blocks (In Percentages)

Block Panchayath	Annual Income of the Family				Total
	Below 50000	50000- 300000	300001- 500000	Above 500000	
Anthikad	10.00	60.00	12.73	17.27	100
Cherpu	9.59	47.95	20.55	21.92	100
Irinjalakuda	4.92	54.10	18.03	22.95	100
Mullassery	3.92	41.18	27.45	27.45	100
Puzhakkal	8.79	52.75	20.88	17.58	100
Vellangallur	0.00	42.86	42.86	14.29	100
All Farms	7.89	52.42	19.34	20.36	100

Source: Primary Survey

4.5.1.4 Background variables across Ownership of land holdings

Land ownership is the asset capital of the agrarian economy. It is the foundation indicator of all socio-economic conditions as well as their capability source of wellbeing of the farmers. Understanding the distribution of background variables across landholding is crucial for studying the socio-economic status of farmers (Table 4.13).

The age wise distribution of land holding presented in Table 4.13 showed that middle and young farmers have higher proportion of ownership (48.15 and 44.77 per cent respectively) of 0.25 - 0.49-hectare range of land, while old aged farmers (38.14 percent) are less likely own small holding of less than 0.25 hectare. Moreover, large holdings are evenly distributed among different age group of farmers though slightly lower in middle aged farmers.

Education and ownership holding are showing positively correlated (Table 4.13). It is shown that farmers with higher secondary and above education have more land holdings while majority (56.52 per cent) of the primary educated farmers have only small holding of less than 0.25 hectare.

In large families (> 6 members), a joint family set up is existing with multiple generations living together with collective ownership of land. Hence, they maintained larger average holding size with higher share (19.35 per cent) in land category of 0.50-1.00 hectare. Conversely, small families (< 3 members) have highest proportion of small holdings (> 0.25 Ha). However, study

identified that middle sized families are highly balanced across all land size with highest share (11.62 per cent) of large holding (> 1 hectare).

Table 4.13

Percentage distribution of background variable across Land ownership holding

Variables	Attributes	Size of Kule Land Ownership Holding (in Percentages)					
		Nil	< 0.25	0.25-0.49	0.50-1.00	> 1	
Age	Below 45	3.70	22.22	48.15	14.81	11.11	100
	45-60	3.49	31.98	44.77	12.21	7.56	100
	Above 60	3.09	38.14	31.96	16.49	10.31	100
Years of Schooling	Primary	0.00	56.52	30.43	13.04	0.00	100
	Secondary	2.78	37.50	36.81	14.58	8.33	100
	Higher Secondary	5.63	29.58	36.62	16.90	11.27	100
	Graduate and above	3.23	30.32	42.58	13.55	10.32	100
Size of the Family	<3	2.48	40.50	36.36	15.70	4.96	100
	3-6	3.32	32.37	39.42	13.28	11.62	100
	>6	6.45	25.81	41.94	19.35	6.45	100
Generation of the Farmer	First	22.86	25.71	37.14	5.71	8.57	100
	Second	6.60	40.80	36.80	9.20	6.60	100
	Third	0.0	28.60	45.40	16.80	9.20	100
	Fourth	0.0	36.20	38.40	14.50	10.90	100
	Fifth	0.0	44.00	16.0	32.00	8.0	100
Annual Income of the Family	< 50000	3.23	38.71	32.26	22.58	3.23	100
	50000-300000	2.43	38.83	35.92	15.05	7.77	100
	300000-500000	3.95	27.63	43.42	15.79	9.21	100
	> 500000	5.00	27.50	43.75	8.75	15.00	100
Total		13	135	152	57	36	393

Source: Primary survey

The highest percentage (22.86 per cent) of landless first-generation farmers enter in to paddy farming is a significant change in agriculture particularly paddy farming. However, most of the first-generation farmers are clustered around the land holding size less than 0.50 hectare. The second-generation farmers are highly concentrated between the land holding size of less than 0.25 and 0.25 – 0.49 range. It is also shown that largest share (40.80 per cent) of second generations have an inherited and accumulated small holding property (< 0.25 hectare). Among third generations, 45.40 per cent of the farmers have ownership of 0.25 – 0.49-hectare land holding and 16.80 per cent have land holding of 0.50 – 1.00 hectare indicating the improved land security and distribution. It is also noted that third generation onwards land security is enjoyed though land fragmentation begins. Among fourth and fifth generations, 14.50 and 32.00 per cent respectively have a land holding between half and one hectare.

The land holding distribution among different income class showed that low-income families have higher concentration in small holdings while high-income families on large size of holding. Among low-income group (less than 3 lakhs), more than 40 per cent have land holding of less than 0.25 hectare, whereas nearly 70 percent of the high-income group farmers (above 3 lakhs) have more than 0.25-hectare land holding.

4.5.1.5 Land Use Pattern across *Padasekharams* and Ownership holding

The average size of individual homestead property, ownership holding, leased land holding and operational holding across all *padasekharams* are illustrated in this section. In the sample selection, *padasekharams* are divided arbitrarily into large (above 1000 hectares), medium (between 500 and 1000 hectares) and small size (below 500 hectares). The distribution of land holding and land use pattern among farmers are presented in Table 4.14 across all *Padasekharams* and ownership holding. The distribution of operational holding of Kole land among farmers is significant to understand the socio-economic conditions and their capability to achieve wellbeing of the farmers.

The average individual homestead property¹⁵ of the Kole land farmers is estimated to be 0.16 hectare (0.40 acres) which is higher than the state average area (0.067 ha) per household (DES, 2013). The average homestead property is evenly distributed (around 0.16 ha) among the farmers irrespective of size of *Padasekharams* or the ownership of Kole land holding. However,

¹⁵ According to Hanman (1986), a homestead is a household's home and the land that surrounds it, including the immediate area around the dwelling unit, as well as the area utilized for vegetable and tree production.

the average size of ownership holding of Kole lands across all *Padasekharams* are 0.55 ha while in Large and small *Padasekharams* it is 0.58 ha and 0.57 ha respectively.

Table 4.14

Average Size of Land Use by Size of *Padasekharams* and Size of Land Holding (Per Hectare)

Size Farms	Size Class	Homestead Property (1)	Area of Ownership Holding (2)	Area of Land Leased (3)	Area of Operational Holding (2+3)
Size of Kole Padasekharam	Large	0.18	0.58	0.48	1.05
	Medium	0.16	0.52	0.27	0.79
	Small	0.16	0.57	0.40	0.98
Size of Land Holding	Nil	0.21	0.00	1.36	1.36
	< 0.25	0.13	0.24	0.27	0.51
	0.25-0.49	0.16	0.50	0.24	0.74
	0.50-1.00	0.21	0.91	0.45	1.36
	> 1	0.22	1.56	0.73	2.29
All Farms		0.16	0.55	0.37	0.92

Source: Primary Survey

Meanwhile, the average operational holding was 0.92 ha (2.27 acres) which is four times higher than rural Kerala average (0.21ha) in 2013. The average operational holding in medium size *Padasekharams* (0.79 ha) is much lower than the all-farms average. But surprisingly, leasing of Kole paddy land is comparatively higher in small *Padasekharams* and achieved a better operational holding of 0.98 ha. The underlying increase of leased land leads to a higher proportionate increase in operational holding with increased ownership of holding. The operational holding of the landless farmer and medium size land holder have same operational holding (1.36 ha) indicating the significance of leased land in Kole land paddy farming. The study reveals that most of the land kept previously as fallow is being effectively cultivated on lease by landless and large sized farmers.

4.6 Conclusion

The study area is the Thrissur Kole Wetlands, which provide productive multipurpose agroecosystem services, including provisioning, regulation, and cultural services to farmers. These services or benefits from Kole lands support the farmers to earn their livelihood and wellbeing. The socio-economic background of the farmer households selected from these Kole lands are analysed on the basis of the different variables such as age, gender, year of schooling, annual income, source of occupation, generation, source of income ownership holding and operational holding. The analysis revealed that the mean age of sample paddy farmers is sixty. Majority of these aged farmers have paddy cultivation as their sole source or an important source of income. The increase in educational attainment of farmers reduces the dependency of paddy. It is evident that farmers solely depend on paddy tend to be less educated and have likely to be small size families reflecting limited opportunities in land and perhaps the generational contraction. In contrast, among better educated farmers, paddy is not a sole source and have better family composition indicating greater economic and social development of farmers. The heavy dependence on paddy cultivation correlates with lower education, smaller land holding and lower income perpetuating economic vulnerability. Though, traditional farmers continue paddy farming in Kole lands and passes through generations but today for their better living families tend to diversify their source of income. Dependency of paddy as a primary occupation and a main source of income relates to the size ownership of land holding. Large size owners depend heavily on paddy farming for their livelihood, while others rely on diversified source of income. Leasing of land for cultivation is very common in Kole lands. The distribution of socio-economic variables and operational farm holdings of farmers assessed in this chapter is a measure of their ability to access farm inputs and ecosystem services efficiently to produce paddy. This ability or opportunity to access ecosystem services is considered as one of the indicator variables of wellbeing, which is discussed in detail in the Chapter VI of the study on how farmers basic capabilities are translated into wellbeing.

Chapter V
Paddy Farming Practice and Ecosystem Services

CHAPTER V

PADDY FARMING PRACTICE AND ECOSYSTEM SERVICES

Paddy farming, which is deeply rooted in traditional agricultural systems, sustains the livelihoods of millions of rural people. Beyond its role in food production and livelihoods, it plays a crucial role in shaping landscapes and cultural identities. It also provides important ecosystem services, including water regulation, biodiversity conservation, and climate resilience. But the intensive nature of farming practices directly influences the productivity and quality of ecosystem services. Farming practice means the various inputs used and the method of farming adopted in paddy cultivation. Since the green revolution, the adoption of intensive farming through high-yielding varieties of seeds and mechanisation is very common in every farm field. The freedom to adopt and engage in these farming practices depends on the basic capabilities of the farmers to access their farm resources. The socio-economic and demographic conditions of the farmer respondents were discussed in the previous chapter, which highlighting the basic capabilities of the farmers to access their farm resources. In Kole paddy wetlands, the method and quantity of inputs used are more or less same in all paddy fields irrespective of size, and location. The paddy farming in Kole lands is under the control and management of *padasekhram* committees in respective locations, leads to uniformity in farm practice in all locations. The earlier agricultural economics literatures used only traditional farm inputs as independent variable to estimate yield of paddy by using Cobb Douglas Production Function. The present chapter estimates the yield of paddy by using farm inputs and ecosystem inputs (commonly used in environmental economics) as explanatory variable by using Ecological Production Function (EPF). This part of the study also examines whether the profitability of paddy farming varies with different size of Kole *padavu*, the size of the operational land holding, and the location of the Kole lands by using net returns approach or benefit-cost analysis. The intensive farming practices followed in Kole wetland paddy fields have wide range of impacts on ecosystem services provided by wetlands such as provisioning services, regulating services, cultural services and supporting services (MEA, 2005). In particular, paddy wetland agroecosystem provides services including food production, water retention, carbon sequestration, nutrient cycling, soil erosion control, recreation, aesthetic and information. The wellbeing of the farmer community depends on extent of these services provided by the paddy wetland agroecosystem. The farming practices, specifically the intensified nature of modern farming system through application of chemical inputs, lead to the degradation of the soil and

in turn affects the ecosystem services particularly regulating services. The changes in regulating services either positively (synergy) or negatively (trade off) impact the other two services such as provisioning and cultural services. Understanding the impact of intensive farming practices adopted in Kole wetland paddy fields on ecosystem services and their interrelationship is significant to assess the wellbeing of the farmers. This chapter examines the viability of Kole wetland paddy farming through input-output mix (better farming practice) and their impact on ecosystem services provided by the Kole lands in Thrissur. The first part of this chapter analyses the economics of paddy cultivation in Kole lands with the adoption of intensive farming practices with the help of cost benefit analysis. The second part of the chapter assesses the role of Ecosystem Services of Kole Paddy Wetlands and their interrelationship with the help of ecological production function and ecosystem services association index.

5.1 Economics of Paddy Cultivation in Kole lands

To understand the economic viability of paddy cultivation in Kole land, it is important to study the different farming practices used by the farmers and their cost return analysis. This section initially tries to work out the various inputs usage or farming practices applied in paddy cultivation with their respective cost. After that, the present study examines the revenue from paddy to assess the economic viability of paddy production. The economic viability and their profitability are important drivers to achieve wellbeing among farmers.

5.1.1 Farming Practices in Kole Paddy Cultivation

5.1.1.1 Land Preparation

First step in paddy cultivation in Kole wetlands is land preparation. It includes the process of dewatering, tilling and bunding. The dewatering process in low lying Kole wetlands is directly made by the *Padasekharam* committees¹⁶. As the wetlands submerge during south west monsoon, water from paddy fields is drained and is stored in canals by using traditional pump sets (*petty and para* in Malayalam language) or modern pump sets like Vertical Submersible Pumps or Vertical Propeller Pumps. The whole process of dewatering is energy intensive. The cost of dewatering is met by the *Padasekharam* committees by the subsidy of government. Farmers split labor and other expenses related to watering and dewatering based on the size of their land holdings.

¹⁶ Institutional arrangement for paddy farming is known as *Padasekhraams*. Each padasekhrams have unique size of holding ranging from 20 cents to 5 acres.

Following dewatering, the farmers individually till the field using tractors and power trillers and build bunds. A hectare of paddy ground is tilled by power tillers for over twelve hours. The time duration of power tillers differs in different locations, which depends on the type of soil structure. Sometimes, farmers use tilling 2 to 3 times for preparing their fields in various *Padasekharams* (Srinivasan, 2011).

5.1.1.2 Lime Application

Lime is usually applied during the final tillage to neutralise the acidity of the soil. The pH value (measuring unit of acidity of the soil) of Kole lands lies between 3.5 to 4 (This value varies in different *Padasekharams*) and the required pH value for better growth of the plant is 6 to 7. Since the soil in the Kole land is acidic, lime should be applied and watered as needed. The water should then be drained to eliminate the acidity and associated toxins. Some farmers reported that ‘Dolomite’ also applied to reduce the acidity of the soil. While the average lime application rate for all farms is 200 kg per hectare, the average lime application rate for large and small paddy fields is 225.68 kg and 243.93 kg per hectare respectively (Table 5.1). The table also shows that the average lime application rate for medium-sized paddy fields is lower than the average for all farms. However, the average lime application rate does not vary with the size of the farm. The quantity of lime application varies in different locations according the pH level of the soil. Although, the requirement of lime application is fully aware by the farmers, but in all locations, the lime dosage is much lower than the prescribed quantity in Kole lands. Mostly farmers use only the quantity of lime obtained from authority at subsidised area. This is generally due to the non-availability of lime at the required time, which is a serious challenge faced by the farmers in all *Padasekharams*.

5.1.1.3 Seedling and Transplanting

‘Jyothi’, ‘Uma’, and ‘Manurathna’ are the major high yielding varieties cultivated in Kole lands. Most farmers in the study area used seeds provided free of charge by the State Seed Development Authority. In cases of emergency, they procure them from private individuals. Some farms in the study area, used broadcasting of seed, while in other farms, transplanting of seeds was used. The average seed quantity applied in sample Kole farms has been estimated to be around 83 kg/ha. But large *Padasekharams* and Medium and marginal size holdings used nearly 89 kg seeds per hectare (Table 5.1). Medium and marginal farmers used more seeds due to the fear of seed germination. It is generally a scientifically prescribed standard rate that one hectare of land requires 100 kgs seeds for sowing and 62-75 kgs for transplanting. But a high

seed rate is observed in all size holdings than prescribed rate of transplanting and sowing in the study area. All the sample farmers in the study area at present use HYV seeds in their fields. Majority of the farmers used the most popular variety of seed ‘Uma’.

5.1.1.4 Labour Use

Human labour is an integral part of agricultural operations. But, the introduction of machine in most of the operations, particularly harvesting and land preparation results the decline of labour force in Kole paddy farming. The labours are mainly involved now only in few operations in paddy farming like bund preparation, seedling or transplanting, spraying fertiliser and insecticides. Previous studies about Kole land paddy farming showed that rice cultivation on Kole land required 176 man-days per hectare; however, this has been now reduced by about four times to just 40 man-days (Table 5.1).

Table 5.1
Average Quantity of working inputs used per hectare

Size Class		Seed (Kgs)	Tilling (Hr)	Harvesting_ Machine (Hr)	Labour (Days)
Kole <i>Padasekharams</i>	Large	88.70	11.23	2.42	44.27
	Medium	81.82	11.55	2.56	39.73
	Small	82.52	11.96	2.73	38.43
Operational Holding	Marginal	85.47	11.72	2.55	41.68
	Small	79.19	11.86	2.77	40.07
	Semi-medium	81.72	11.87	2.93	40.18
	Medium	87.22	11.31	2.30	35.10
All Farms		83.24	11.71	2.63	39.76

Source: Primary survey

Highest amount of labour days (44 days) reported in Large *Padasekharams* and lowest labour days reported in medium holdings (35 days). In terms of farming activity, almost 65 per cent of the labour force is used for seed transplanting and broad casting, 12 per cent is used for land

preparation and bundling, 10 per cent for fertilisation, 8 per cent for plant protection operations like spraying of insecticides and weedicides and 5 per cent for remaining operations. Manual harvesting is completely ended in Kole lands. Harvesting machines are used by all *Padasekharams*. The substantial reduction in labour days reduces the cost of paddy farming in Kole lands. The number family labour and domestic labour reduced at maximum. Migrant workers from Jharkhand, Bengal and Tamil Nadu states are the main labour force in Kole lands. They undertook major farming operations like transplanting, bundling, fertiliser application, spraying chemical inputs, etc.

5.1.1.5 Fertilisation

In Kole fields, biomass naturally occurs as sediment accumulates through rainwater. Generally, the soil contains the necessary amounts of micronutrients and secondary elements required for the growth of the rice plant. But, recently the scarcity of these elements is identified by the Agricultural Research Station, Mannuthy. The efficient and appropriate dosage of fertiliser application is very much needed for the better growth of the plant to attain optimum yield. Both chemical fertilisers and bio fertilisers were applied on the basis of soil fertility structure. Commonly applied chemical fertilisers are Urea, Muriate of Potash, and Factomfose. Though there are prescribed standard rate of fertiliser usage advocated by the Agricultural University on the basis of soil quality of the different *Padasekharams*, the use of chemical fertilisers per hectare in Kole lands is found to be six times more than that of all Kerala average. According to CACP (2010) study, the quantity of chemical fertiliser used in Kerala was 123 kg/ha, whereas the present study estimated it is as high as 654 kg/ha (Table 5.2).

Across different size classes of *Padasekharams*, relatively higher amount of fertiliser use has been observed (746 kg/ha) in medium size *Padasekharams*. Meanwhile, bio fertiliser usage is also much higher in medium size *Padasekharams* (268 kg/ha) than all farms average of 111 kg/ha. It is observed from the study that a mean difference 195 kg/ha is estimated between marginal and medium cultivators in Kole lands is statistically significant at 1 per cent level in One Way ANOVA. Among size of holding, a scale advantage is observed in the usage of chemical fertilisers. That is, as size of holding increases, the usage of chemical fertilisers decreases. Conversely, in the case of bio fertilisers, as size of holding decreases, the usage decreases. It is evident that, small and marginal farmers tried to balance the usage of fertilisers to optimise their production. But the over use and inappropriate mix of fertilisers lead to lower production and productivity of paddy in Kole lands. It is also observed that the use of bio

fertilisers decreases at an alarming level. This is because of the non-availability and higher price of bio fertiliser.

Table 5.2

Average Quantity of Nutrients and Plant Protection inputs used per Hectare in Kgs

Size Class		Chemical Fertiliser	Bio Fertiliser	Lime/ Dolomite	Chemical Insecticides	Weedicides	Bio Weedicides
Kole Padasekharam	Large	624.34	134.90	225.68	2.39	2.60	0.00
	Medium	746.26	268.56	169.70	4.17	2.49	0.07
	Small	648.46	221.05	243.92	3.56	2.16	0.00
Operational Holding	Marginal	706.18	96.01	205.34	4.07	2.42	0.00
	Small	694.45	82.88	194.11	3.74	2.40	0.00
	Semi-medium	611.27	156.49	209.80	2.41	2.89	0.15
	Medium	511.79	154.744	193.12	3.25	1.60	0.00
All Farms		654.10	111.27	200.19	3.57	2.33	0.02

Source: Primary survey

5.1.1.6 Plant Protection

Weeds and insects are very common in Kole wetlands. Therefore, the use of weedicides and pesticides is also very high in these farms. Most common weeds present in Kole lands are *Echinochloa* sp. ('Kavada'), *Fimbristylis* sp. ('mangu'), *Cyperus* sp. ('Muthanga varieties'), *Leptochloa* sp. (Kuthiravali'), Weedi rice ('Vari nelli'), *Monochoria* sp. ('Neelolpalam'), *Ludwigia* sp. ('Neergrampu'), *Salvinia* ('African Payal'), and *Eichhornia* sp. ('Kula Vazha') (Latha, 2016). To avoid crop loss due to weeds, remove all types of weeds within 45 days after planting the seeds. Hence, each farmer individually makes use of different chemical weedicides at a higher dose. Traditional methods like water regulation, duck rearing and manual weed removal are not common today. On an average, farmers reported that, more than 2 litres of weedicides were used per hectare of land (Table 5.2). The study noted that in large size

Padasekharams and semi-medium farmers used higher dose of weedicides than all farms average. But medium sized farmers reported lower use of weedicides (1.6 litres/ha).

The important insects attack by paddy crops are '*Thanduthurappan*', '*Olachuruttipuzhu*', '*Kuzhalpuzhu*', '*Munja*', and '*Chazhi*'. To prevent these insects and bacterial diseases, high dose of chemical insecticides is applied. The average use of chemical insecticides per hectare is found to be 3.5 litres/ha in all farms. Usually, in Kole lands, a farmer irrespective of size of holding or size of *Padasekharams*, applied insecticides 3 to 4 times to prevent the attack of insects. The study noted that in small *Padasekharams* or in small and marginal operational holdings, farmers use more than 4 litres of insecticides. Farmers in the *Padasekharams* reported that, due to the non-availability of labours for spraying the insecticides in time, spraying extend from early morning to noon on the same day. This is not effective to control the insects properly which compel the farmers to apply more quantity and times leads to the over use of insecticides and weedicides. Additionally, farmers reported in the survey that unskilled workers improperly mix pesticides with water, resulting in pesticide waste. All these inefficient methods of application results over use of insecticides and weedicides in Kole lands. The excessive and unwise use of these chemical inputs affects the ecological environment of the Kole wetlands.

5.1.2 Cost of Farming Practices in Kole Lands

In the theory of production, the cost of production of commodities is of great importance to assess the profitability of agricultural operations. The cost of cultivation of crops measures efficiency in production or cultivation of crops. Cost of cultivation per hectare, both operation-wise and input-wise, was worked out for both size of *Padasekharams* and size of operational holding.

In production analysis, the major items included in cost of production of paddy are costs on land preparation, seed and seedling cost, human labour, chemical fertilizers, bio fertilisers, chemical insecticides, weedicides, harvesting, transportation, and interest on working capital. The average quantity of major inputs, used per hectare by the sample farms is given in Table 5.1 and 5.2. The cost per hectare, both input wise and operation wise is given in Table 5.3 and 5.4.

Table 5.3

Cost of Nutrients and Plant Protection inputs used per hectare (in Rs)

Size Class		Chemical Fertiliser	Bio Fertiliser	Lime	Chemical Insecticides	Weedicides	Total Cost of Nutrients and Plant Protection
Kole Padasekharams	Large	15634 (22.64)	781 (1.13)	2117 (3.06)	3315 (4.80)	4470 (6.47)	26317 (38.11)
	Medium	16702 (21.49)	1436 (1.84)	1839 (2.36)	4169 (5.36)	5080 (6.53)	29226 (37.60)
	Small	17119 (21.39)	1258 (1.57)	2033 (2.54)	5077 (6.34)	4326 (5.40)	29813 (37.25)
Operational Holding	Marginal	16734 (21.23)	1216 (1.54)	1961 (2.48)	4638 (5.88)	4852 (6.15)	29401 (37.32)
	Small	17702 (23.29)	1019 (1.34)	2033 (2.67)	4150 (5.46)	4426 (5.82)	29330 (38.60)
	Semi-medium	15948 (21.22)	2242 (2.98)	1789 (2.38)	4146 (5.51)	3990 (5.31)	28115 (37.41)
	Medium	12572 (18.57)	2063 (3.05)	2213 (3.27)	4194 (6.19)	2135 (3.15)	23177 (34.25)
All Farms		16761 (21.59)	1261 (1.62)	1972 (2.54)	4495 (5.79)	4631 (5.96)	29120 (37.51)

Note: Values in the parenthesis are the percentage to total cost within size class

Source: Primary survey

The expense on nutrients and plant protection is estimated to be 37.51 per cent (Rs 29120 per ha) of the total cost of production across all farms. No significant difference in expense is identified among all types of *Padasekharams* and size farmers. The single largest item of cost in paddy cultivation was found to be the expenses of chemical fertiliser. It is seen that irrespective of *Padasekharams* and size of holding, cost per hectare for chemical fertilisers is estimated to be Rs 16761 and it comes about to 21.59 percent of the total cost of production. However, it is observed that small and marginal farmers spend more on fertilisers while medium farmers spend comparatively less for chemical fertilisers in quantity (Rs.12572 per ha) and in

per centage (18.57). The mean difference of Rs 5130 per ha between small and medium is found statistically significant at 1 per cent level. This could be possible by the scale advantages of medium farmers than small and marginal farmers. Some farmers in the study area reported that medium-sized farmers are using high amounts of fertilizers to increase and balance productivity, leading to overuse of fertilizers. However, small and medium cultivators cannot take advantage of economies of scale. Also, the use of bio fertiliser is not common in paddy fields today. Hence the cost incurred for bio fertiliser was only negligible.

Expense of plant protection is another important component of total material cost. The frequent attack of pest and the growth of weeds increase the use of pesticides and weedicides in paddy farming. Cost of chemical insecticides/pesticides used in large *Padasekharams* was estimated to be Rs.3315 per ha (4.8 percent of the total cost) which is increased to Rs 5077 (6.34 per cent of the total cost) as the size of *Padasekharams* decreased to small size. Based on size of holding, the cost incurred for insecticides was found out to be mostly same in quantity and percentage. However, average cost of weedicides per hectare incurred by marginal farmers works out to Rs.4852 (6.15 per cent of TC), and it is only Rs.2135 (3.15 per cent of TC) for medium cultivators. The mean difference of Rs 2717 (3 per cent of TC) across marginal and medium farmers is found statistically significant at 5 per cent level of significance.

Another important input used for land preparation, lime, is made available by Krishi Bhavan to all farmers at subsidised rate. Irrespective of size of *Padasekharams* and the size of holding, around Rs. 2000 is spent on lime or dolomite with subsidy. Though, soils in the Kole lands are more acidic, the use of lime is comparatively very low. The use of lime is mainly depended up on the availability from Krishi Bhavan.

Seed is the main ingredient of Paddy farming. The quality of the seed is the determinant of germination of seedling. It is rare in Kole lands to procure seeds from their farms and use for their own needs. Instead, most farmers use seeds that are available from time to time from the National Seed Authority. Some of the *Padasekharams* make available the seed to farmers at free of cost. Though, Government has a subsidised scheme to make available it at free of cost, farmers depend on other sources to get it at right time with high price. The seedlings prepared by the other medium farmers are used by most of the marginal and small size farmers.

In fact, the transplanting cost is the cost for labourers engaged in transplanting. But it is not included in labour cost components, instead kept as separate components in the calculation of cost of working inputs (Table 5.4). Since the transplanting is done entirely by migrant workers

on a contract basis, this study estimates the two costs separately to get clear picture about the labour cost. Among the components of cost considered, labour cost of all farms forms the second-largest variable, accounting for 16.91 per cent (Rs. 13,131 per ha), followed by transplanting cost at 14.08 per cent (Rs.10931 per ha (Table 5.4). Both items together come about 31 per cent of the total cost of production. Among all size of farms, medium farmers incur relatively higher amount (35 percent) of total cost for transplanting and labour cost together.

Table 5.4
Cost of Working inputs and Seed per Hectare

Size Class		Seed	Tilling	Pumping	Harvesting	Transportation	Transplanting	Labour	Total Cost of Working Input
<i>Kole Padasekharams</i>	Large	2449 (3.54)	7392 (10.70)	1191 (1.72)	5301 (7.67)	3736 (5.41)	9182 (13.29)	13472 (19.51)	42723 (61.88)
	Medium	2957 (3.80)	8642 (11.12)	3632 (4.67)	5702 (7.33)	3401 (4.37)	11799 (15.18)	12358 (15.90)	48491 (62.39)
	Small	2480 (3.09)	10400 (12.99)	2964 (3.70)	5936 (7.41)	4020 (5.02)	10770 (13.45)	13635 (17.03)	50205 (62.74)
Operational Holding	Marginal	2664 (3.38)	9873 (12.53)	3101 (3.93)	5824 (7.39)	3635 (4.61)	11481 (14.57)	12808 (16.25)	49386 (62.68)
	Small	2493 (3.28)	8273 (10.88)	2675 (3.52)	5666 (7.45)	3821 (5.02)	9792 (12.88)	13936 (18.34)	46656 (61.40)
	Semi-medium	3430 (4.56)	7629 (10.15)	3034 (4.03)	5669 (7.54)	4797 (6.38)	8732 (11.61)	13744 (18.28)	47035 (62.58)
	Medium	2698 (3.98)	7116 (10.51)	1064 (1.57)	5143 (7.59)	3866 (5.71)	10559 (15.60)	14049 (20.76)	44495 (65.75)
All Farms		2672 (3.44)	9327 (12.01)	2941 (3.78)	5762 (7.42)	3749 (4.82)	10931 (14.08)	13131 (16.91)	48513 (62.49)

Note: Values in the parenthesis are the percentage to total cost within size class

Source: Primary survey

In terms of cost, next largest components are tilling cost which comes about 12.01 per cent of total cost across all farms. Small size padasekhams and marginal farmers incur relatively higher expenses for tilling, while large *Padasekhams* and medium farmers incur relatively lesser expense.

Harvesting is the significant part of paddy cultivation. The study identified that among size holding and size of padasekhams, 100 per cent of the farmers make use of harvesting machine. It is cost effective and time saving. Duration of harvesting per hectare constitutes 3 to 4 hours and cost comes about Rs.5762 per hectare. No significant variation is identified across *Padasekhams* and size of holdings in cost of harvesting.

Transportation cost, which incurred manly to carry paddy output from distant Kole farms to road side. In addition, packing and loading charge of paddy output were included in transportation cost. Also, some farmers incur a reasonable amount on transportation of inputs, while others do not.

Since working capital interest makes up a very small portion of the cost of paddy cultivation in the research region, it is not included in the cost estimate. Because Kole wetlands have an advantageous canal system, irrigation is thought to be a non-binding element. The cost of energy for pumping is met by the government and a small amount of cost for labour and other cost for pumping in only incurred by the farmers individually.

To sum up, item wise average cost of nutrients and plant protection is Rs.29120, and seed and working inputs is Rs.48513 per hectare for all farmers. The cost of seed and working inputs in percentage out of total cost of production among medium farmers estimated to be 65.75 per cent, which are higher than all other farmers and size of *Padasekhams*. But in monetary terms, expenses incurred by medium farmers are relatively lower than all other farmers. It is observed from Table 5.3 and 5.4 respectively that, as size of *Padasekhams* or size of holding of farmers increases, the cost incurred for total cost of production decreases. Among the cost of all inputs, cost of chemical fertiliser constitutes the largest one.

5.1.3 Cost - Benefit Analysis of Paddy Cultivation in Kole Lands

In Kole lands, only one crop season called *Puncha* (summer crop) is cultivated in the entire area. To assess the economics of paddy cultivation, it is important to look into the costs and return for farmers. Both gross return and net return are estimated to assess the profitability of farmers. The gross return is defined as the value of both paddy output and straw. The net return

is the gross return minus cost of cultivation. Table 5.5 gives the details of average area of operational holding, Yield per hectare and gross value of paddy and straw. The operational holding in Kole *Padasekharams* includes both ownership holding and leased land used for paddy cultivation. Lease in and out are very common in Kole lands.

The estimated average size of land holding across all *Padasekharams* in Kole land is 0.92 ha. Marginal farmers hold an average area of 0.46 ha while medium farmers hold 5 ha. The mean difference between marginal and medium farmers is statistically significant at 1 per cent level of significance. The average individual operational holding is high in large *Padasekharams* (1.05 ha) and lowest in medium size *Padasekharams* (0.79 ha).

The average yield of paddy per hectare estimated from sample Kole farms is 5379 kg/ha as against 2790 kg per hectare for Kerala state average estimated during 2022-23 (Section 3.5.2) in chapter III. The study found that there was a significant average difference in yield per hectare between small and large paddy fields. The yield per hectare of large paddy fields was only 4431 kg/ha, which was 20 percent less than that of small paddy fields. It was also observed that there was no significant difference in yield per hectare of paddy based on the size of operational holding held by farmers. Although the yield per hectare and size holding difference are not statistically significant, small size operational holding have relatively higher productivity than other size of holding and all farms average. When comparing the average yield of paddy from Kole fields with the state and all-India average yield, it is generally found that the yield in Kole fields is very high, but the study highlights that although the yield per hectare is high in Kole fields, the growth rate is low (Table 3.14 in chapter III).

Gross value of paddy output presented in Table 5.5 is obtained by multiplying the yield from Kole paddy to procurement price given by “Supplyco” (Kerala State Civil Supplies Corporation) at farm level. Generally, all farmers sell their paddy output to “Supplyco”. The procurement price fixed by the Supplyco during the study period is Rs.28.20 per kilogram. Since this price is uniform to all farms, the Gross value of paddy output is varied only in proportion to yield per hectare.

Gross value of income from paddy production is the sum of gross income from paddy and gross income from straw which is presented in Table 5.6. The average income from straw per hectare obtained by farmers is relatively very low than the actual value of straw. Since there is little demand for straw in the market, farmers are leaving it on the farm or burning it. Only a few farmers in Kole lands are getting adequate price and others get only small return. The average

return from straw per hectare is Rs.9340. The average revenue obtained to small and marginal farmer is much lower than all farm average.

Table 5.5
Average Yield Per Hectare and Gross value of Output by size Class

Size Class		Area of Operational Holding (In Hectare)	Yield Per Hectare (Kgs)	Procurement Price (Rs)	Gross value of paddy output (Rs)	Gross value of Straw (Rs)
Kole Padasekharam	Large	1.05	4431.96	28.20	124984	9744
	Medium	0.79	5562.95	28.20	156875	10135
	Small	0.98	5459.89	28.20	154028	8718
Operational Holding	Marginal	0.46	5364.52	28.20	150732	7637
	Small	1.42	5522.09	28.20	153915	9514
	Semi-medium	2.26	5200.26	28.20	149137	11024
	Medium	5.00	5301.89	28.20	147328	11011
All Farms		0.92	5379.52	28.20	151190	9340

Source: Primary survey

The economic viability of Paddy production in Kole lands is measured in terms of the profitability or net return from paddy. Net return from paddy is obtained by deducting cost of production from Gross value of output from paddy production. The average gross value of paddy production from Kole farms obtained is estimated to be Rs. 1,60,530 per hectare. Based on the size of the paddy fields, the study observed that the gross value of paddy production in large paddy fields is 17 percent lower than that in small paddy fields. The study highlighted that the average net income from paddy is Rs. 82897 per hectare. In comparison to size of Kole *Padasekharams* and size of farmers, study estimated that while the average net income from large paddy fields is Rs. 65688, medium-sized paddy fields earn up to Rs. 89293 per hectare. Similarly, while medium-sized farmers earn a high income of Rs. 90667 from paddy cultivation, marginal farmers earn only lower average income of Rs. 79582 per hectare. It is evident that yield per hectare is lower in medium land holdings than even marginal and small holdings

whereas net income from paddy is higher in medium size holdings than other size of holdings. This is due to the higher income from straw to medium size holding than other size of holdings.

Table 5.6
Comparison of Cost and Returns of Paddy Production Per Hectare

Size Class		Gross Value from Paddy Production (In RS)	Cost of Production (In Rs)	Net Returns from Paddy (In Rs)	Ratio of gross value of output to cost
Kole <i>Padasekharams</i>	Large	134728	69040	65688	1.95
	Medium	167010	77717	89293	2.15
	Small	162746	80018	82728	2.03
Operational Holding	Marginal	158369	78787	79582	2.01
	Small	163429	75986	87443	2.15
	Semi- medium	160161	75150	85011	2.13
	Medium	158339	67672	90667	2.34
All Farms		160530	77633	82897	2.07

Source: Primary survey

In order to pursue the margin of profit from paddy cultivation, we have worked out benefit cost ratio (ratio of gross value from paddy production to cost of production). The ratio presented in Table 5.6 shows that the gross value of output exceeds the costs across different size class *Padasekharams* as well as size of operational land holding classes. While the ratio is found to be 2.07 for all types of farms, it ranges from 1.95 for large *Padasekharams* to 2.34 for medium cultivators. In fact, although the high average value indicates profitability among farmers, in reality 46 percent of the sample farmers (171 farmers) have a ratio between gross income and production costs is less than two (their average value is only 1.49). Among these, 8 per cent of farmers have a ratio of gross value to cost of production that is less than one with average of 0.81. This pointed out that even a slight increase in the cost of production for these farmers or an occasional decrease in the gross value of paddy could make paddy cultivation economically

not viable and the possibility of gradual abandonment of paddy cultivation cannot be ruled out. It is seen from the analysis that profit margin improves with the size of the holding (Table 5.6).

5.1.4 Spatial comparison of cost and return of paddy production

Spatial analysis compares the cost and returns from paddy cultivation across different geographical locations. Geographically, Kole lands in Thrissur are divided into North Kole and South Kole. The economic viability of paddy cultivation among these two geographical locations is presented in Table 5.7. The spatial comparison of north and south Kole reveals the differences in gross value from paddy production are primarily influenced by the ecological characteristics and farming practices. The ecological profile of the soil is an important driver of yield of paddy in Kole lands. Marked differences exist between blocks in relation to ecological features. Though farm practices are similar in Kole *Padasekharams* across blocks, ecological services provided by these locations are different.

Among Kole fields, South Kole farms (5540 kg/ha) were found to show much higher yield per hectare than those in North Kole farms (5261 kg/ha). The highest yield was recorded at Irinjalakuda block (6074 kg/ha) in South Kole and the lowest in Anthikad block in North Kole (4866 kg/ha). The mean difference among South and North Kole was found to be statistically significant at 1 per cent level.

The gross value of output from paddy cultivation in North Kole was Rs.155228, highest was in Mullassery and lowest was in Anthikad. For South Kole, the total value of output was Rs.165879, among which highest income was obtained from Irinjalakuda and the lowest from Cherpu block. Among all farms, it was estimated that Irinjalakuda block obtained the highest value of Rs.180751. Gross income from South Kole is 6 per cent higher than North Kole. In terms of cost of cultivation of paddy crops, cost per hectare is lowest in Anthikad and highest was in Puzhakkal block (Rs. 78454). In terms of net return from paddy, margin of profit is enjoyed by South Kole over North Kole. It accounts to Rs.88369 in South Kole which is moderately higher than the North Kole area (Rs.80548).

In order to compare the economic viability across Kole farms in different regions, the ratio of gross value of output from paddy to cost of cultivation is assessed. The ratio for North Kole and South Kole is higher than 2, indicating the profitability from paddy in all farms among all regions.

Table 5.7

Block wise comparison of Cost and return of paddy cultivation

Block	Yield per Hectare	Gross Value from Paddy Production (In RS)	Cost of Production (In Rs)	Net Returns from Paddy (In Rs)	Ratio of gross value of output to cost
Mullassery	5610	163789	76069	87721	2.21
Puzhakkal	5543	162370	78454	83917	2.17
Anthikad	4866	145350	70915	74435	2.06
North Kole	5261	155228	74680	80548	2.15
Cherpu	5124	153962	77368	76594	2.01
Irinjalakuda	6074	180751	77890	102861	2.61
Vellangallur	5226	160565	75697	84868	2.15
South Kole	5540	165879	77511	88369	2.33
All Farms	5379	160530	77633	82897	2.07

Source: Primary survey

In nutshell, the study on the economics of paddy cultivation observed a marked differences in yield and profitability across different size of operational holdings and different size of *padasekharams*. There is significant gap in average yield per hectare between small and large paddy fields, with smaller operational holdings performing comparatively better. Higher gross value is observed in small holdings, but medium sized holdings achieved better net returns from paddy due to higher revenue from straw, low input cost and more efficient use of high valued chemical inputs. Overall, profitability improves with increasing farm size. As a spatial variation, the south Kole shows statistically significantly higher yields and net profits compared to the north Kole, a trend that may be influenced by more favourable ecological conditions. These findings highlight the importance of specific strategies that consider farm size and regional characteristics to enhance the economic sustainability of paddy farming.

5.2 Ecosystem Services in Kole Paddy Wetlands

Paddy cultivation produces more than just a food crop. It produces many services to human being other than food provisioning. Farm practices in paddy cultivation have environmental impacts that affect the ecosystem services of paddy wetlands. Ecosystem services are the direct and indirect benefit derived from the natural wetlands to human being. These benefits are classified by Millenium Ecosystem Assessment (MEA, 2005) into provisioning, regulating, cultural and supporting services. Among these services, supporting services such as soil formation, nutrient cycling and net primary production are indirect contributor to wellbeing and often forming ecological basis for other ecosystem services. Hence, the study excludes supporting services from ecosystem service analysis and their interrelationship assessment to avoid multiple counting (DeGroot et al., 2012; MEA, 2005). This part of the chapter examines how the paddy farming practices and ecological services affect the yield of paddy and also how farm inputs affect the ecological services provided by the Kole wetland paddy farming. Ecological Production Function (EPF) introduced by Nelson et al, (2009), which is an extension of Cobb Douglas Production function is used in this chapter to assess the impact of farm inputs and ecological services. Section 5.2.1 examines the different ecosystem services provided by the Kole wetland paddy farming agroecosystem and the input efficiency of both conventional inputs involved in an agricultural production function and ecological inputs in ecosystem services, while section 5.2.3 assesses the interrelationship of different ecosystem services resulting from paddy farming.

5.2.1 Ecosystem Services Flows and their Interrelationships in Kole Wetland Paddy Agroecosystem

Kole Wetland Paddy Agroecosystem provides bundles of ecosystem services which are directly and indirectly contribute the wellbeing of the people. The bundles of ecosystem service flows from paddy wetlands by the result of anthropogenic management of paddy farming on natural ecosystem. The anthropogenic contributions, like, land preparation (tilling & bundling), seedling, fertilisation (chemical & bio fertilisers), plant protection (insecticides & weedicides), to natural ecosystem services make direct and indirect impact on wellbeing of the farmers via interrelationship between different ecosystem services such as provisioning, regulating and cultural services. The section 5.1.1 of this chapter examines those anthropogenic activities on natural wetland ecosystem, while Section 5.2.1 examines the contributions of different ecosystem services and their interrelationships.

5.2.1.1 Provisioning Services

Provisioning services obtained from Kole wetland agroecosystems are food production, livestock and forage supply that are presented in Table 5.8. Kole wetlands are paddy farming agroecosystems where food products including paddy, fish, duck, vegetables and miscellaneous crops are produced with the proper farm practices by the farmers. As a byproduct of paddy, straw or forage and living space for livestock are other important provisioning services provided by the paddy fields. In addition, as a wetland, sufficient quantity of water is available in the Kole paddy fields.

Table 5.8

Distribution of Provisioning services across regions (In Rupees/ha)

Block	Paddy (1)	Fish (2)	Duck (3)	Vegeta bles and Others (4)	Food production (5=1+2+3+4)	Livestoc k (6)	Forage supply (7)	Provisio ning Services (8=5+6+7)
Mullassery	158210	675	0	969	159853	1292	5580	166726
Puzhakkal	156309	1091	210	550	158160	175	6061	164397
Anthikad	137233	1197	0	1616	140046	2052	8117	150214
North Kole	148367	1053	76	1100	150596	1220	6861	158677
Cherpu	144520	558	484	1241	146803	2918	9442	159162
Irinjalakuda	171276	986	290	1831	174384	196	9475	184055
Vellangallur	147371	1941	0	2435	151747	2542	13195	167483
South Kole	156237	812	376	1556	158980	1722	9643	170345
All Farms	151190	966	184	1264	153604	1400	7859	162863

Source: Primary survey

Paddy, an important crop grown in Kole wetlands, is a major source of revenue to the farmers for their livelihood and wellbeing. Total provisioning services supplied by the Kole farms in money terms has been estimated to be Rs.162863 per hectare. As an important provisioning services, paddy produces Rs.151190 per hectare which comes about 92 per cent of the provisioning services. Average revenue from provisioning services on South Kole farms is

about 5 per cent higher compared to all farms, and 7.5 per cent higher than North Kole. The return from provisioning services was highest in Irinjalakuda block of South Kole and lowest was in Anthikad block of North Kole.

Usually, in Kole lands, rice and fish are cultivated alternately. Fish are raised after the paddy harvest when the fields are flooded. The detailed explanation of the fish farming system in Kole lands is presented in the section 4.2.1.2 of Chapter IV. It is evident from our study that the revenue from fishing decreased significantly in all blocks. Farmers surveyed reported that fish farming delays the draining of water for paddy cultivation, which leads to delayed harvest and crop losses due to early rainfall and other related problems. As a result, most paddy fields have abandoned commercial fish farming. Natural fish stocks are also low as the government's "rice and fish" programme which has mostly ended after flooding. Only a few *Padasekharams* are now investing in fish farming. The average area used now for fish farming by the farmers are only 187 hectares in entire Kole fields. The average revenue received from farmers per hectare from fishing was only Rs.966. Among blocks, farmers of Vellangallur blocks in South Kole received relatively high amount of Rs 1941, followed by Anthikad block in North Kole with Rs.1197.

Now a days, duck rearing is very rare in Kole *padavu padasekharams*. This is due to heavy dosage of chemical input application in Kole fields. Only few Kole fields are suited for duck rearing. The duck farmers pay on an average Rs.184 per hectare to paddy farmers. In South Kole, it was Rs.376 where as in North Kole it was only Rs.76. Table 5.8 showed that in several blocks, no duck rearing revenue received to farmers.

Another important revenue component of provisioning services is vegetable, and floriculture cultivation in Kole lands. Farmers cultivate vegetables and fruits including watermelon (*Thannermathan*) during the dry season. Average income of the farmer in all farms is estimated to be about Rs.1264 per hectare. All blocks in South Kole have received highest revenue with an average of Rs.1556 per hectare.

Livestock farming is decreasing considerably in Kole land areas. Cherpu block in South Kole received highest revenue from livestock, followed by Vellangallur in South Kole and Anthikad block in North Kole.

Straw is a good source of income for paddy farmers. Only few farmers have their own cattle. Majority of the farmers sell their straw privately. But due to irregular rainfall at the time of harvest or just after harvest damages the straw and compel the farmers to sell it at lowest price.

The average revenue from straw output from paddy is estimated to be Rs.7859. Large farmers in different blocks receive higher revenue than marginal and small farmers. Most of the marginal and small farmers either keep the straw in the farm level to decay or burn after harvest. To sum up, the study noted that, from all components of provisioning services, South Kole farmers receive higher revenue than farmers from North Kole.

5.2.1.2 Regulating Services

Regulating services are described as the ways through which living things can regulate or interact with the environment, and its equivalents that are non-living (Haines-Young & Potschin, 2018). The soil system is the most important part when it comes to the regulation of ecosystem processes such as the management of air quality, climate, water, erosion, water purification and management of waste, promotion of plant growth, and control of diseases (Brevik, 2018). The soil organic matter affects many properties of soil, which have importance in relation to the regulation of ecosystem services and crop production (Powlson et al., 2010). Soil is an exhaustible resource, which serves as a substrate for plant growth. It serves as a habitat to various microbes, supports plant growth, and hence can be regarded as an ecosystem service provider on the planet (Safnathmol, 2022). The soil quality indicators have a strong positive relation to ecosystem services, which is very susceptible to changes in soil management and climatic factors (Andrews et al., 2004). Based on the above literature, present study considered soil quality as a good proxy for the measurement of regulating services of Kole wetlands.

Soil quality cannot be measured directly, but it can be assessed through measurements of the physical, chemical, and biological properties of the soil. It encompasses the ability of a particular soil type to function effectively by supporting the survival of plants and animals without compromising environmental quality (NRCS, 2012). Soil quality is a combination of inherent and dynamic soil quality. According to Carter (2002), dynamic soil quality is strongly affected by agronomic practices and can change over comparatively short periods. Hence, most studies have focused on dynamic soil quality. Soil organic carbon, Soil Organic Matters fractions, soil structural components, and microporosity are indicators of soil quality. Dynamic soil quality reflects changes in past or current land use and anthropogenic management activities (Karlen et al., 2001).

In agriculture, particularly in paddy farming, the intensive farming practices have affected the dynamic soil quality and leads to soil degradation. Soil degradation implies a change or disturbance in soil quality and a decline in the capacity of soil to fulfil various functions through

natural or anthropogenic activities (Lal, 2009). To analyse the ecosystem services particularly regulating ecosystem services of Kole paddy farms, it is essential to monitor chemical and physical quality of the soil.

This study calculated the regulating services index through soil quality assessment. This was done by selecting a set of soil properties that are considered soil quality indicators. With the help of the Soil Survey and Soil Conservation Department of Kerala, the private Soil Testing Agency, and Kerala Agricultural University, soil data of the Kole fields in selected *padasekhrams* were collected. The soil testing results were cross-checked with the help of scientists of the Agricultural University and experts in this field. To avoid the collinearity that occurs when constructing the Regulatory Services Index using large soil data properties (24 soil properties are available from the soil test), a minimum data set was selected using Principal Component Analysis (PCA). The variables included in the study are bulk density, particle density, porosity, maximum water holding capacity, soil moisture, aggregate stability, pH, electrical conductivity (EC), organic carbon, effective cation exchange capacity (ECEC), exchangeable acidity, available N, P, K, Ca, Mg, S, B, Fe, Mn, Zn, Cu, dehydrogenase activity and microbial biomass carbon (MBC).

For the dataset, the principal components can be described as linear combinations of the variables, defining the vectors that form the best fit to the n data points in p -dimensional space, which are orthogonal to each other and explain the largest amount of variance in the set (Greenacre et al., 2022). All the physical, chemical, and biological data collected were analysed using principal component analysis (PCA), which can reduce the dimension of massive data and make indicator selection easier since the soil properties can be grouped into principal components in a categorical manner (Safnathmol, 2022). The system attributes were best represented by principal components with high values. Therefore, principal components with eigenvalues greater than one were selected. To maximize the correlation, the variables were subjected to varimax rotation between the principal components and measured attributes. While considering a particular principal component, a weight or factor loading was assigned to each variable that represents its contribution to the principal components. Only the highly weighted variables were retained from each principal component for the minimum data set. Highly weighted variables are defined as those whose factor loading lies within 10 per cent of the absolute values of the highest factor loading. In case more than one variable was highly weighted in a single principal component, a determination of the linear correlation of the two variables could have ensured that they are not redundant or dispensable in the minimum data

set. Among the strongly correlated variables within a principal component, the variable with the highest loading factor (> 0.6) was selected for the minimum data set are presented in (Annexure 5.1). Based on the results of principal component analysis, the transformed indicator data were weighted. A certain amount of variation was explained by each principal components in the total dataset. The value of weightage factor was calculated by dividing the total percentage of variance by the percentage of cumulative variance of each of the principal components. The derived weightage factor for each principal components was multiplied by the selected indicator from the respective principal components. Summation of weighted variables resulted in the value of index for all sites. Assessment of soil quality was performed by using a technique devised by Andrews et al. (2002). A minimum dataset (MDS) was selected by principal component analysis of soil quality indicators.

Based on the Principal Component Analysis, seven components are included in the minimum data set. The seven components are categorised as different independent indices of regulating services depending upon the factor loading in the respective components. For the purpose of analysis of the indices, compound index of all independent index and over all regulating index are calculated with using respective weights. The respective weights of each principal component are presented in the (Annexure 5.2). In the minimum data set, principal components 4 and 6 are reflecting the provisioning services. All other five principal components are categorised as a proxy of different regulating services as: Soil Compaction Index (PC-I), Soil Carbon Sequestration and Fertility Index (PC-II), Nutrient Retention Index (PC-III), Soil Salinity and Acidity Index (PC-V), and Water Retention Index (PC-VII). The block wise distribution of these indices is presented in Table 5.9. The major components of each regulating services index and their respective supporting literature are presented in Annexure 5.3.

Table 5.9.

Block Wise distribution of Regulating services

Blocks	Soil Compaction Index (PC-I)	Soil Carbon Sequestration and Fertility Index (PC-II)	Nutrient Retention Index (PC-III)	Soil Salinity and Acidity Index (PC-V)	Water Retention Index (PC-VII)	Regulating Services Index (RES)
Puzhakkal	0.36	0.44	0.63	0.51	0.52	0.51 (Fair)
Mullassery	0.26	0.56	0.69	0.89	0.34	0.43 (Fair)
Anthikad	0.33	0.20	0.70	0.44	0.57	0.23 (Bad)
Cherpu	0.65	0.51	0.52	0.41	0.10	0.55 (Fair)
Irinjalakuda	0.38	0.58	0.30	0.30	0.70	0.49 (Fair)
Vellangallur	0.60	0.66	0.26	0.36	0.35	0.45 (Fair)
All Farms	0.40	0.43	0.56	0.46	0.63	0.46 (Fair)

Note: Text given in the parenthesis represent the rating class of soil quality

Source: Primary survey

The compound index of regulating services which comes about 0.46 is reflected as almost fair indicating that, Kole lands supply regulating services relatively fair level. The study identified that regulating services are fairly distributed across all blocks. The soil quality was categorised in to five class or ranges by Partoyo (2005) based on the score and weight of each factor of soil properties. The classification of regulating index or soil quality is presented in (Annexure 5.4). The PC-I with high positive and negative loading factors together forms a Soil Compaction Index, as an indirect proxy for soil erosion. Soil erosion as a regulatory ecosystem services is closely linked to soil compaction with risk of soil erosion. Low Porosity of soil leads to high runoff and low infiltration. But high bulk density results low root penetration and plant cover. The low soil structure reflects the high surface sealing and high susceptibility to erosion. Therefore, high soil compaction Index is a clear indication of degraded soil with lower regulating services. The compaction index of Cherpu (0.65) and Vellangallur (0.60) blocks are high, indicating that the soil erosion risk is very high in those blocks than other blocks.

The factor loading variables in the second principal component represent the key elements of regulating ecological functions played by the Kole land soil. The factor loading of Available N measures the nutrient cycling and plant growth. Similarly, soil moisture factor support water regulation, affecting microbial and root process. The strong positive loading of Soil Organic Carbon and Microbial Biomass Carbon together partially reflects the Carbon sequestration

potential of the soil. Hence this component is meaningfully represented as “Soil Carbon Sequestration and Fertility Index”. In Anthikad Block, the index is very low (0.20) reflecting the lower fertility status and low carbon sequestration potential of the area. All other blocks, particularly, Vellangallur, Irinjalakuda, Mullassery and Cherpu are having a good rating of fertility index.

As a regulating ecosystem service, the principal component III indicates the soil chemical fertility status or “Soil Acidity and Nutrient Retention” factor of Kole lands. The nutrient retention capacity of the soil indicates how well the soil keeps the nutrient within itself rather losing them to waterways. The high ECEC (Effective Cation Exchange Capacity) relates to high nutrient-holding capacity, while high EA (Exchangeable Acidity) reflects acidic stress on plants. The negatively loaded particle density reflects the high organic content of the soil. The study noted that nutrient leaching is very high in Irinjalakuda and Vellangallur blocks. But all other blocks have a good nutrient retention status and high organic content in the soil (more than 0.5).

The PC-IV represents the strong association of micronutrients and secondary macronutrients in soil which reflects the Micronutrient Availability Index or factor. It supports the provisioning services of ecosystem services. The PC-VI also reflects the micronutrient imbalance or toxicity regulation.

High positive loading of Electrical Conductivity (EC) and a strong negative loading of pH in PC - V captures the gradient of soil salinity and acidity. This component indicates the regulating services of ecosystem services as salt buffering pH regulation and soil toxicity control. In the study area, the values of factor loading of this component indicates the reducing plant productivity, nutrient leaching and limiting microbial function. The low pH value and high EC value indicates a high soil salinity and acidity. The average pH value in Kole farms is 5.42 which indicates a high acidity in soils (Anusree et al., 2023). The high soil salinity and acidity in Mullassery blocks are due to salt water intrusion in those areas. The average pH value in Mullassery (pH 4.4) was far below the average of all Kole farms.

The PC - VII reflects the high positive loading of maximum water holding capacity as a soil property, which primarily reflects the soil’s capacity to retain water. According to Millennium Ecosystem Assessment Report (2005), Soil water retention is the core part of regulating services. This function supports the soil moisture condition, microbial habitat support and sustained productivity. The water retention is fairly good in all blocks except Cherpu block.

5.2.1.3 Cultural Services

Cultural ecosystem services are intangible in nature, for example, landscapes are aesthetic, recreational, spiritual, and educational. Natural and managed landscapes can be used for enjoyment and relaxation. Cultivated landscapes establish a strong connection between the farmer and their environment. Recently, the microclimate within the Kole Wetlands makes the farmlands suitable for ecotourism. Several paddy fields are being developed to open up opportunities for tourism promotion. Many farm households and outside families nearby Kole lands visit the Kole land for mental relaxation and a space for regular exercise. Wedding photography, content creation, short film production, etc. are very common in the Kole Wetlands during growing season. The Kole Wetlands are a paradise for birds and birdwatchers during just after harvest. The Kole wetlands are among the top ten wetlands in India with the highest bird population. However, changes in farming practices and climate change are reducing the total number of birds in the Kole lands. Swimming and fishing are other important cultural activities in the Kole lands. However, present study showed that the canal width and canal water in Kole lands are being depleted due to excessive use of chemicals for paddy cultivation and the spread of weeds in Canals. As a result, swimming and fishing have decreased. There are several traditional and cultural festivals celebrated by the farmers of the Kole lands and their families. In addition, by associating the paddy farming, irrespective of age, farmers acquire knowledge and information about farming with the help of *Padasekharams* and other officials. All these cultural ecosystem services enhance the social relations of farmers in Kole land area.

Cultural ecosystem services index of the study area is constructed by using Principal component analysis method explained in section 5.2.1.2. The data related to cultural services are collected from interviews, discussions and questionnaire survey with farmers living around the Kole lands by using 10-point Likert scale data. By the method of principal component analysis, two components are identified based on factor loading. The per cent variation explained by the principal component is 56.498. It's KMO is 0.820 and Bartlett's sphericity test is statistically significant. These two components are classified as Aesthetic/recreational and social relation in terms of the factors loading of variables. The factors loaded in the first principal components are questions related to enjoyment of aesthetic beauty and recreational activities. The second component factors relate to educational information and social relations among farmers. The normalised value (between 0 to 1) of the weighted index of two components and over all compound index of cultural ecosystem services are presented in Table 5.10.

Table 5.10.

Block wise Distribution of Cultural Ecosystem Services

Blocks	Aesthetic & Recreational Services (PC1)	Social Relation Services (PC2)	Cultural Service Index
Puzhakkal	0.28	0.69	0.39
Mullassery	0.28	0.60	0.36
Anthikad	0.31	0.62	0.40
North Kole	0.29	0.64	0.39
Cherpu	0.28	0.63	0.37
Irinjalakuda	0.32	0.69	0.44
Vellangallur	0.35	0.63	0.45
South Kole	0.30	0.65	0.40
All Farms	0.30	0.64	0.39

Source: Primary Survey

Aesthetic and recreational services (PC1) assessed the visual appreciation like photography, film making, marriage album, and opportunities for recreation like bird watching, fishing and swimming. The normalised mean value of the PC1 in overall farms presented in Table 5.10 indicated a clear positive relation between a higher social relation values and aesthetic & recreation value to overall Cultural services index. Irinjalakuda and Vellangalur are the two model blocks for cultural ecosystem services with highest factor loading of social relation services where as in Mullassery and Cherpu blocks have a lowest aesthetic value and moderate social relations. The cultural service index in the north and south Kole lands is balanced by good social relations. However, it does not show good aesthetic service for Kole farmers. The results showed that farmers have a good social relation in terms of educative information about paddy farming and a high degree of close relation among farmers and their families. However, aesthetic beauty and recreational opportunities given by Kole farms are not fully exploited by the farmer households.

To sum up, Kole wetland agroecosystem and paddy farming provide provisioning, regulating and cultural services to farmers for their wellbeing. But intensive farming practices in Kole lands affects the ecosystem services. The study identified that provisioning services are relatively good with better net return from paddy, regulating services are fair but not good and

cultural services are comparatively performed only at an average level. These three ecosystem services are mutually interrelated particularly provisioning and regulating ecosystem services. The understanding of their relationship is useful to assess the wellbeing of the farmers. In general, ecosystem services are not independent of one another and the relationships between them are likely to be highly nonlinear. That is, ecosystem services are interconnected. For example, provisioning services like paddy farming are likely affect the aesthetic and social relations as a component of cultural services but may also impact the regulating services positively or negatively due to intensive farming.

The study of Ecological production function explains in the section 5.3 links the agricultural output and ecosystem services. The study of the association between ecosystem services is important to understand the trade-off between these services and their causal relationship to human wellbeing.

5.3 Resource Use Efficiency in Kole lands and Ecosystem Services Association

Resource use efficiency in Kole land paddy farming was examined by using the Ecological Production Function (EPF). The EPF is mainly used in environmental economics studies to estimate the integration of biophysical inputs and ecosystem service indices. This is a modified version of the Cobb-Douglas production function (Nelson et al. (2009). The EPF examines how farm inputs like seed, ploughing hours, chemical fertilisers, chemical insecticides, weedicides, lime and labour hours affect the paddy yield per hectare. Similarly, how ecosystem services particularly regulating services like soil compaction, carbon sequestration, nutrient retention, soil acidity and salinity, and water retention capacity of the soil influence the yield of paddy crops.

Ho: The yield of paddy does not significantly relate to traditional farm inputs and ecosystem services inputs.

H1: Farm inputs and ecosystem services inputs together significantly influence the yield of paddy in Kole fields.

The following Cobb-Douglas production function type model has been fitted to examine the relationship between yield output as a dependent variable and farm inputs and ecosystem services are independent variable.

Cobb-Douglas ecological production function form:

$$Y = A X_1^{\beta_1} X_2^{\beta_2} \dots X_n^{\beta_n}$$

Taking mixed form: $\ln Y = \beta_0 + \beta_1 \ln X_1 + \dots + \beta_n \ln X_n + \gamma_1 Y_1 + \dots + \gamma_n Y_n + \epsilon$

Estimated model specification form:

$$\begin{aligned} \ln(\text{YIELD}) = & \alpha + \beta_1 \ln(\text{SEED}) + \beta_2 \ln(\text{PLOUGH}) + \beta_3 \ln(\text{CHEM.FERT}) + \beta_4 \ln(\text{BIO.FER}) \\ & + \beta_5 \ln(\text{WEED}) + \beta_6 \ln(\text{INSECT}) + \beta_7 \ln(\text{LABOUR}) + \beta_8 \ln(\text{LIME}) + \gamma_1 (\text{SCI}) + \gamma_2 (\text{CSI}) + \\ & \gamma_3 (\text{NRI}) + \gamma_4 (\text{SASI}) + \gamma_5 (\text{WRI}) + \epsilon \end{aligned}$$

where: β is elasticities of yield with respect to farm inputs

γ is marginal effect of ecosystem services score on yield

X_i is traditional farm inputs

Y_i is ecosystem services indices

ϵ is random error

SCI is Soil compaction Index

CSI is Carbon Sequestration Index

NRI is Nutrient Retention Index

SASI is Soil Acidity and Salinity Index

WRI is Water Retention Index

The estimated ecological production function regression results presented in Table 5.11 revealed that both farming inputs and ecosystem inputs are significantly influence the paddy production in the study area. The model exhibited a higher explanatory power with R square value of 0.556 and an F-statistic of 2.990 ($p = 0.000$), confirming the overall significance of the regression with 1 per cent level of significance. The sum of the estimated elasticities ($\sum \beta_i = 0.308 < 1$) suggest decreasing returns to scale, implying that proportional increases in all inputs together result less than proportional increases in output.

Table 5.11

Ecological Production Function (Regression Results)

Variables (in Logs)	Coefficients	Std. Error	t value	p value
Constant	7.782	0.633	12.290***	0.000
Quantity of Seed per ha in Kgs	-0.127	0.058	-2.190**	0.029
Use of (Ploughing) Tillers in hrs per ha	-0.273	0.109	-2.505**	0.013
Quantity of Chemical Fertilisers used per ha (in Kgs)	-0.135	0.052	-2.596**	0.010
Quantity of Bio-Fertilisers used per ha (in Kgs)	0.022	0.019	1.157 ^{ns}	0.248
Quantity of Chemical Insecticides used per ha (in Kgs)	-0.034	0.019	-1.789 ^{ns}	0.074
Quantity of Chemical Weedicides used per ha (in Kgs)	0.218	0.099	2.190**	0.030
Quantity of Lime used per ha (in Kgs)	0.105	0.038	2.760***	0.006
Labour used per ha (in Labour days)	0.432	0.120	3.518***	0.005
Soil Compaction Index	-0.113	0.043	-2.630**	0.009
Carbon Sequestration Index	0.035	0.063	0.561 ^{ns}	0.576
Nutrient Retention Index	0.226	0.058	3.901***	0.000
Soil Acidity and Salinity Index	-0.132	0.063	-2.110**	0.036
Water Retention Index	0.203	0.080	2.540**	0.012
Dependent Variable = Yield per hectare (In Kgs) Number of Observations = 393 R squared =0.556 Sig = 0.000 F = 2.990 Adjusted R squared=0.487				Returns to Scale = 0.308 < 1

***, ** and “ns” are 1, 5 per cent level of significance and non-significant respectively

Source: primary survey

Among the farm inputs, seed ($\beta = -0.127$), tilling ($\beta = -0.273$), chemical fertilisers ($\beta = -0.135$), chemical weedicides ($\beta = 0.218$), lime ($\beta = 0.105$) and labour ($\beta = 0.432$) employed are all significant with p value less than 0.05, while bio fertilisers ($\beta = 0.022$) and chemical insecticides ($\beta = -0.034$) are not significant with p value greater than 0.05 in paddy production. Similarly, ecological services inputs such as soil compaction ($\beta = -0.113$, $p < 0.01$), nutrient retention (β

= 0.226, $p < 0.01$), Soil acidity and salinity ($\beta = -0.132$, $p < 0.05$) and water retention capacity ($\beta = 0.203$, $p < 0.05$) are also significantly influencing paddy production whereas carbon sequestration capacity of soil ($\beta = 0.035$, $p > 0.05$) is not significant in paddy production. The negative sign of seed, tilling and chemical fertilisers suggest that over use of these inputs into paddy cultivation leads to decrease in yield per hectare. The negative sign of soil compaction means the increase in density of the soil leading to degradation of the soil which decrease the yield. The acidity and salinity in Kole land soils are already high. The negative sign of regression coefficient value indicates the negative relation of soil acidity and yield of paddy crop. Therefore, it is clear from Table 5.11 that the overall model is significant at 1 per cent level ($p < 0.01$), thus the null hypothesis is rejected and confirms that farm inputs and ecosystem services inputs together impacted the yield of paddy. It also indicates that regulating services like soil compaction, acidity and salinity have a significant “trade off” with provisioning services. Additionally, Nutrient retention and water retention reveals a significant “synergy” with provisioning services. Though, carbon sequestration and provisioning services have synergy but not significant. These negative signs and the lower value of some variables are the clear indication of over use and unwise use of inputs in intensive farming and their impact on ecosystem services. The significance level of both biophysical and ecological inputs underscores the integrated role of farm inputs and ecosystem services inputs in paddy production. These findings also suggest the efficient use of all inputs rather the increased quantity of inputs in production. The study suggests the need for the proper planning of ecological services in achieving better output of paddy along with optimum use of farm inputs.

5.3.1 Relation between Regulating services and Chemical inputs

Understanding the increased pressures on ecosystem services resulting from intensive farming practices by the paddy farmers on their Kole lands is useful for the assessment of wellbeing of the farmers. Intensive farming on Kole lands like tillage, use of chemical inputs for better provisioning services of ecosystem services generally affects regulating services. Tables 5.1 and 5.2 in Section 5.1 of this chapter show that 654 kg of chemical fertilizers were used per hectare, which is 3 times more than the state average consumption in paddy fields. In addition, it is estimated that 3.57 litres of chemical pesticides and 2.3 litres of herbicides per hectare are used in paddy cultivation, which is much higher than the state average. It was also found that tilling/ploughing is done more than 2 to 3 times in paddy fields. The excessive use of such inputs seriously affects the regulating services such as soil compaction, water retention, carbon sequestration, fertility, salinity, acidity status, nutrient index which are closely related to the

soil quality of the land. The study finds that although the Kole lands are the most fertile lands, the repeated excessive use of chemical inputs significantly reduces the inherent soil quality. These results of the study are tested with multiple regression analysis and assess the hypothesis.

Ho: There is no significant relation between farm input use and regulating ecosystem services

H1: Farm inputs used in paddy cultivation significantly affects the regulating ecosystem services

Multiple regression model is:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \epsilon$$

Where;

Y = Regulating services index

X_i = farm inputs

B = regression coefficients

ε = random error

The multiple regression analysis results presented in Table 5.12 shows that the overall model was significant (F = 3.055, p = 0.001, R² = 0.306). The R square value explains the overall goodness of fit and explains that 30.60 per cent variations in regulating services are due to the effect of chemical inputs and other farm inputs used in paddy production. Among the inputs, chemical insecticides (β = -0.111, p = 0.023), chemical fertilisers (β = -0.201, p = 0.000) and tillage (β = -0.024, p = 0.014) had significant negative effects on regulating services, while weedicides (β = 0.018, p = 0.000) had a significant positive influence. The moderate R square 0.306 (Adjusted R square = 0.294) indicate the role of other factors outside the model determining regulating services. Surprisingly, the negative coefficient value of seed (β = -0.001), though not significant (p > 0.05) indicates the over use of seed in paddy farming due to fear of low sprouting rate. These results suggest that higher chemical inputs generally reduce soil-based regulating functions, whereas lime application (β = 0.001, p = 0.521ns) may mitigate such effects by improving soil health and, chemical weedicides application may target the weed management which supports the regulating services.

Table:5.12

Regression Results of Regulating services and Farm inputs

Model	β	Std. Error	t	Sig.
(Constant)	0.916	0.213	4.303***	0.000
Seed	-0.001	0.001	-0.776 ns	0.438
Ploughing	-0.024	0.010	-2.476**	0.014
Chemical Weedcides	0.018	0.005	3.767***	0.000
Chemical Insecticides	-0.111	0.054	-2.069**	0.023
Lime	0.001	0.167	0.007 ns	0.521
Labour	0.015	0.003	4.395***	0.000
Chemical Fertiliser	-0.201	0.396	-9.821***	0.000
a. Dependent Variable: Regulating Service Index				
R square = 0.306 Adjusted R square = 0.294 F value = 3.055 sig. 0.001				

***, ** and “ns” are 1, 5 per cent level of significance and non-significant respectively
Source: Primary survey

It is clear from Table 5.12 that the overall significant F statistic of the model, along with the negative and positive individual coefficient values and their respective significant p-value (at 1 per cent and 5 per cent level of significance), thus failed to accept the null hypothesis. Therefore, it is confirmed that there is significant impact of farm inputs on regulating services.

The study suggests that paddy production and its yield depend not only on the agricultural inputs used, but also on ecosystem services in the Kole lands, especially regulatory services. At the same time, these regulatory services depend mainly on the chemical inputs used in paddy production in these areas.

5.4 Ecosystem Services Associations

The interrelationship of ecosystem services has either negative associations (Trade off) or positive associations (synergy) or no effect. Generally, previous literatures identified a trade-off between regulating and provisioning services whereas synergies are common among

regulating and cultural services. These relationships open up the ecological and socio-economic factors driving ecosystem services. To assess the ecosystem associations quantitatively, three possible combinations of associations have been used in the present study. Rodriquez et al., (2006) identified the supply side trade off classification based on MEA assessment while TEEB (2010) identified demand side trade off based on stakeholders' perceptions about socio economic benefits of ecosystem services. A unified typology of supply demand trade-off is classified by Mouchet et al., (2014). The literally word “trade-off” encapsulates both trade-off and synergy. Based on these classifications presented in previous literatures, the present study examines the ecosystem services associations at the farm level across space. Based on the theoretical literature reviewed, the study assumes the trade off or synergy among different ecosystem services provided by the wetlands through Kole paddy farming. These assumptions are studied and tested at supply – demand perspective and spatial level based on following hypothesis.

Ho: There is no significant association (trade off or synergy) between different Kole wetland ecosystem services.

H1: Between any two of the Kole wetland ecosystem services are either negatively (trade off) or positively (synergetic) related.

5.4.1 Ecosystem Services Trade off or Synergy

Pair wise correlations are estimated to assess the associations between different ecosystem services provisions (Lee and Lautenbach, 2016). The normalised value of various metrics of ecosystem services is estimated to find the correlation between provisioning, regulating and cultural ecosystem services and t test is used to find its significance, depending on the normality of the distribution (Table 5.13).

The provisioning and regulating services are showing weak negative correlation ($r = -0.32$), but are statistically not significant ($p > 0.05$). This implies that even though it is statistically insignificant, the negative correlation value indicates that when the provisioning of paddy increases, the regulating services might reduce marginally. Thus, study does not provide strong evidence of trade-off. Between provisioning and cultural services, there are moderate negative correlation with statistically significant relationship indicating a clear trade off ($r = -0.49$, $p = 0.001$). This could be due to land degradation resulting by paddy production which might adversely affect the aesthetic and recreation value of the Kole lands. There is a strong positive correlation between regulating and cultural services indicating a highly significant synergetic

relationship ($r = 0.64$, $p = 0.000$). Therefore, it is clear from Table 5.13 that correlation between regulating and cultural services and also between provisioning and cultural services are significantly correlated with 1 per cent level of significance.

Table 5.13
Pair wise correlation of Supply of Ecosystems Services

Relationship	Correlation	Sig. value	Association
Provisioning Services V/S Regulating Services	-0.32	0.710 ^{ns}	No Strong Trade off
Provisioning services V/S Cultural Services	-0.49	0.001**	Trade off
Regulating services V/S Cultural Services	0.64	0.000**	Synergy

‘**’represents the 1 per cent level of significance and ‘ns’ represents the non-significance
Source: Primary survey

Thus, the study confirms that provisioning services have trade off with regulating services and cultural services, while regulating services have synergy with cultural services. This trade off highlights the land degradation through chemical inputs usage in paddy production and their negative effects on the regulating services like soil erosion, water retention which might influence the cultural services adversely.

5.5 Spatial Ecosystem Services Trade off

The ecosystem services associations are different in spatial or regional in terms of their supply and demand of ecosystem services. The supply trade off related to ecology and demand trade off related to socio economic aspect. The combination of this is given by Mouchat et al, (2014) as a unified typology of supply trade off, demand trade off, and supply-demand trade off.

5.5.1 Spatial Distribution of Ecosystem Services Supply Trade off

To assess the ecosystem services supply association or trade off spatially, mean log ratio of Ecosystem Services Trade off Index (ESTOI) was calculated (Zou et al., 2020).

Ecosystem Trade off Index is calculated as follows,

$$ETOI_{12} = \ln (\text{Relative ESSI}_1 / \text{Relative ESSI}_2)$$

$$ETOI_{23} = \ln (\text{Relative ESSI}_2 / \text{Relative ESSI}_3)$$

$$ETOI_{13} = \ln (\text{Relative ESSI}_1 / \text{Relative ESSI}_3)$$

$$\text{Relative ESS} = (\text{ESSI}_i - \text{ESSI}_i \text{ Min.}) / (\text{ESSI}_i \text{ Max.} - \text{ESSI}_i \text{ Min.})$$

Decision Rule: Positive mean log ratio of ETOI₁₂ means, ESS 1 dominates than ESS 2; if it is negative, ESS 2 dominates than ESS1; and it is zero means balanced or synergy between ESS1 and ESS2.

Where ESS1 is Ecosystem Provisioning Services, ESS2 is Ecosystem Regulating Services and ESS3 is Ecosystem Cultural Services. ESSI for 1,2 and 3 represents Ecosystem Services Indices of provisioning, regulating and cultural services respectively. Index is weighted compound index which is calculated by using Principal component Analysis. The normalised value each ESSI (between 0 to 1) measure the Relative ESSI of each service.

The spatial trade off index across blocks in North Kole and South Kole are presented in Table 5.14 shows that mean log ratio of relative Ecosystem Service Trade off Supply Index (ETOSI₁₂) between provisioning and regulating across all blocks are less than zero (all values are negative) indicating that regulating services in all blocks dominate compared to provisioning services (trade off) in Kole lands. In fact, provisioning and regulating services are negatively correlated, but regulating services still play a major role in providing provisioning services in Kole lands. It means that supply of regulating services is higher than provisioning services in paddy Kole wetland agroecosystem. The lowest negative value (-0.79) in the Irinjalakuda block indicates synergistic or mild trade off. The highest yield per hectare (6074 kg/ha) in Irinjalakuda block (Table 5.7) confirms the clear dominance of provisioning services than regulating services. It highlights that only Irinjalakuda block utilised the power of soil regulating services. The negative value indicates that natural productivity of the soil (regulating services) in other Kole land blocks cannot be optimised by the farmers and hence the paddy productivity of the Kole lands per hectare declined or was low (Table 5.7).

Table 5.14

Spatial distribution of Ecosystem Service Supply Trade off

Block Wise	ETOSI_12		ETOSI_13		ETOSI_23	
	Mean	SD	Mean	SD	Mean	SD
Anthikad	-1.15	1.56267	-2.08	1.29198	-0.94	1.10495
Mullassery	-1.74	0.98913	-1.52	0.87337	0.22	0.56402
Puzhakkal	-2.30	0.91214	-1.72	0.94056	0.63	0.73382
North Kole	-1.73	1.23546	-1.77	0.97457	-0.03	0.98623
Cherpu	-2.15	0.98016	-1.59	1.16540	0.56	0.79379
Irinjalakuda	-0.79	1.46253	-1.82	0.99876	-1.03	1.31058
Vellangallur	-1.59	1.54156	-1.43	2.00651	0.16	0.73900
South Kole	-1.51	1.35487	-1.61	1.99778	-0.31	0.89764
All Farms	-1.58	1.37917	-1.78	1.12719	-0.19	1.20698

Source: Primary Survey

Similarly, mean log ratio of ETOSI between provisioning and cultural services is also showing a negative value (trade off) indicating that cultural ecosystem services are significantly higher than provisioning services. It reflects that Kole lands are high valued aesthetically and culturally with good social relation than decline in yield per hectare. It highlights the significance of ecotourism opportunities in Kole wetlands. In contrast, the low negative value of ETOSI_23 (-0.19) indicates a synergistic or mild trade-off between regulating and cultural services. However, the positive value of ETOSI in Puzhakkal, Mullassery, Cherpu and Vellangallur blocks reflects the clear dominancy of regulating services over cultural services. The synergetic relationship between regulating and cultural services shows that both services are always going hand in hand. When, particularly regulating services decline, the aesthetic and cultural beauty of the land declines. This relationship indicates the need for protecting regulating services to maintain a good cultural ecosystem services. To sum up, the supply of ecosystem services trade off indicates that regulating services are in the top of the order of supply and followed by cultural and provisioning services (Regulating services > Cultural Services > provisioning

services). This pattern reflects the significance of natural quality of soil (regulating services) in Kole Wet lands. However, the study shows that this regulating ecosystem service has not been optimised by maximizing the provisioning services to farmers.

5.5.2 Spatial Distribution of Ecosystem Services Demand Trade off

The spatial ecosystem services demand trade-off is assessed based on farmers' perceptions of changes in the quantity and quality of ecosystem services received from paddy farming Kole wetland agroecosystem. Farmers' perceptions about increase or decrease in ecosystem services benefits are assessed by using 10-point Likert scale data. By using Principal Component analysis, a composite weighted index was calculated and finally normalised the index with zero to one. The Ecosystem Services Demand Trade off Index (benefit index or perception index) was calculated by using the same method adopted in Ecosystem services supply trade off.

The mean log ratio of Ecosystem Services Demand Index between provisioning and regulating services (ETOBI_12) presented in Table 5.15 measures the association of ecosystem services benefits which indicates the domination of one service over another in terms of benefits received by farmers across Kole lands. The negative mean value ETOIB_12 in all blocks highlights the dominance of regulating services over provisioning services. But the low negative value indicates the synergy or mild trade off which reflects the role of provisioning services in their perception of benefits. Since the benefits from regulating services such as erosion control, water retention capacity, and nutrient regulation are dominant, the net benefits from provisioning services that rely on them in part, especially rice production, provide relatively better benefits to farmers on Kole farms. The lowest negative value in the perception index of benefits received by farmers in all blocks indicates that the services provided by the regulating ecosystem services are more beneficial than those provided by the provisioning services, but not at a significantly higher level. Similarly, the lower negative value across all blocks of the demand trade off index between provisioning and cultural ecosystem services reflects the argument that the benefits obtained from cultural ecosystem services are higher than those from provisioning services. The negative mean value of trade off index between regulating and cultural services suggests that benefits from cultural services are dominating than regulating services but not at a higher level. In summary, perceptions of the benefits of paddy cultivation in Kole fields are, from top to bottom, in the order of cultural services, regulating services, and provisioning services (Cultural services > Regulating services > Provisioning services).

Table 5.15

Spatial distribution of Ecosystem Service Demand Trade off

	ETOB1_12		ETOB1_13		ETOB1_23	
Block Wise	Mean	SD	Mean	SD	Mean	SD
Anthikad	-0.27	0.6129	-0.59	0.4688	-0.33	0.4951
Mullassery	-0.54	0.7432	-0.57	0.8008	-0.03	0.4159
Puzhakkal	-0.33	0.5046	-0.52	0.4261	-0.19	0.4686
North Kole	-0.35	0.6120	-0.56	0.5379	-0.22	0.4817
Cherpu	-0.15	0.5790	-0.46	0.4674	-0.31	0.5164
Irinjalakuda	-0.42	0.5106	-0.68	0.6340	-0.26	0.5631
Vellangallur	-0.11	0.3238	-0.54	0.1412	-0.43	0.3022
South Kole	-0.26	0.5543	-0.56	0.5446	-0.30	0.5279
All Farms	-0.32	0.5926	-0.56	0.5396	-0.25	0.4995

Source: Primary Survey

5.5.3 Spatial Distribution of Ecosystem Services Supply - Demand Trade off

Supply – Demand trade off tells the spatial lag between ecosystem supply and demand or supply and social benefits from Kole Wet lands agroecosystem. To assess the spatial trade-offs between ecosystem service (ESS) supply and stakeholder perception (DD), we constructed composite indices for both Ecosystem services Supply and farmers perceived benefits using Principal Component Analysis (PCA). The mean log ratio of Ecosystem services supply and Demand is calculated for three services to identify the trade-off are presented in Table 5.16.

The ecosystem services trade-off between supply and demand of provisioning services showed a negative value across all farms. This suggests a strong significant mismatch (trade off) between the potential of the ecosystem provisioning services than the perceived expectations of farmers. That is, perceived expectations of benefits from provisioning ecosystem services are higher than the potential supply of their services. Due to this overestimation, farmers put more pressures on Kole Paddy wetlands through over use of chemical fertilisers resulting the

degradation of lands and question the sustainability of Kole land paddy farming. The highest negative value (-2.24) and lowest yield per hectare (4866 Kg/ha) in Anthikad block is a clear indication of the unsustainable practices with highest expectation.

Table 5.16
Spatial Distribution of Ecosystem Services Supply – Demand Trade off

SS-DD	ETOI_SD_11		ETOI_SD_22		ETOI_SD_33	
Block Wise	Mean	SD	Mean	SD	Mean	SD
Anthikad	-2.24	1.9307	-1.21	0.9755	-0.60	0.3456
Mullassery	-1.56	0.9822	-0.36	0.4891	-0.61	0.3827
Puzhakkal	-1.77	0.7173	-0.27	0.9230	-0.58	0.5219
North Kole	-1.93	1.4404	-0.70	0.9858	-0.59	0.4230
Cherpu	-1.90	1.0433	0.11	0.4280	-0.77	0.6438
Irinjalakuda	-1.58	0.9167	-1.21	1.2295	-0.44	0.4468
Vellangallur	-1.54	1.5416	-0.06	0.2125	-0.66	0.6220
South Kole	-1.74	1.0238	-0.47	1.0783	-0.62	0.5835
All Farms	-1.87	1.3081	-0.62	1.0246	-0.60	0.4861

Source: Primary Survey

The mean log ratio of Regulating Ecosystem services of supply and demand showed mild trade off or synergy with a lowest negative or positive mean value in all blocks except Anthikad and Irinjalakuda. The highest negative value in Anthikad (-1.21) and Irinjalakuda (-1.21) blocks indicating a significant trade off or mismatch between the potential supply of regulating services and farmer's perceptions on benefits of regulating services. Specifically, Cherpu block region with positive log ratio (0.11) indicates that biophysical data supported by regulating services are higher than the farmers expectations (synergy). This underestimation of regulating services is due to the limited awareness of ecological services, access issues and the delayed ecological responses in Kole wetlands. Table 5.16 also indicates that farmers expectations of aesthetic, recreational and social relations in Kole lands are higher than the actual supply of cultural services. This higher mismatch between supply and demand of cultural services is resulting from the chemical contamination of Kole paddy wetlands which degrades the natural beauty of the Kole lands.

The study confirms that in Kole wetlands, expectations of benefits from provisioning services are much higher than the potential of the agricultural land. This over-expectation forces farmers to use large amounts of chemicals to meet these expectations, which in turn affects other ecosystem services. Similarly, underestimation of regulatory services puts excessive pressure on Kole wetlands beyond their carrying capacity through chemical use, which, combined with high expectations for cultural services, creates a significant supply-demand trade-off in ecosystem services.

5.6 Conclusion

The analysis made so far in this chapter reveals that paddy farming is profitable among all type of farmers. However, it is observed from the study that the profitability across Kole regions (South and North Kole regions) and size of holdings is different despite same farming practices were used. The analysis of input efficiency by using ecological production function revealed that both the farm inputs and ecosystem services are significant in paddy production, though their production efficiency follows diminishing returns to scale. The regression analysis about the relations between farm inputs and regulating services identified that excessive use of farm inputs affects the regulating services significantly. The pairwise correlation analysis between different ecosystem services revealed that there is no significant strong trade-off between provisioning and regulating services, while a strong trade-off exists between regulating and cultural services. However, it has been identified that a synergy exists between provisioning and cultural services. Using the average log ratio of the Ecosystem Services Trade-off Index, a spatial analysis of the correlation between ecosystem services distribution and farmer's perceptions of ecosystem service benefits showed a strong trade-off between supply and demand of ecosystem services across all blocks in the study area. This highlights that perceived benefits of ecosystem service exceed the actual distribution of estimated services in all block areas. Such patterns suggest an overestimation of farmer's service availability, which could result from short-term productivity gains, reliance on external inputs, or lack of awareness of underlying ecological processes. The spatial clustering of negative values in few Blocks was particularly important, pointing to areas where demand pressures or farmers expectations exceed ecological carrying capacity, posing risks to long-term sustainability. These findings highlight the need for targeted communication, extension services, and landscape planning strategies that better align perceptions with ecological realities. Under this scenario, the Chapter VI explores how the paddy farming and their implications on ecosystem services affects the wellbeing of the farmers.

Chapter VI
Capabilities on Ecosystem Services and Wellbeing

CHAPTER VI

CAPABILITIES ON ECOSYSTEM SERVICES AND WELLBEING

Sustainable agriculture, especially paddy farming in wetlands, plays a crucial role in promoting the wellbeing of farmers. The preceding chapter (Chapter V) of the study examined the economics of paddy farming and the impact of intensive farming practices on ecosystem services. It was observed that paddy farming in Kole wetlands is relatively profitable across *padasekharams* irrespective of size of land holding. Although rice cultivation on Kole wet lands is profitable, traditional agricultural inputs and ecosystem inputs are relatively inefficient and ecosystem service trade-offs or synergies occur due to intensive farming practices. The present study argues that farmers wellbeing is not only depends on farm income or profitability but more significantly on the benefits obtained from ecosystem services provided by the Kole wetlands. To explore this argument, integrating the Ecosystem Approach (MEA, 2005) and Capability Approach (Sen, 2008), this chapter examines how farmer's capabilities and their impact on ecosystem services of Kole land contribute to the attainment of wellbeing. This complex relationship between capabilities, ecosystem services, and wellbeing has been assessed using variance-based Structural Equation Modelling (SEM), applying the Partial Least Squares (PLS) path modelling method (Hair et al, 2017). PLS-SEM is a non-parametric method to analyse the explained variance in latent dimensions. It is an appropriate statistical method for exploring the complex relationship between capabilities and wellbeing using an intermediate effect of ecosystem services provided by the Kole Wetland Agroecosystem. Structural Equation Modelling is a multivariate statistical method used to determine the association between influencing factors. SEM consists of a measurement model and structural model. Measurement model describes the relationship between observed variables and latent variables, while a structural equation describes the relationship between each pair of latent variables.

The equations of the measurement model suggested by Zhang et al. (2021) can be expressed as:

$$X = \Lambda_x \omega + \delta$$

$$Y = \Lambda_y \eta + \epsilon$$

where X represents a vector composed of exogenous variables; Y refers to a vector composed of endogenous variables; ω is a vector composed of exogenous latent variables; η is a vector composed of endogenous latent variables; Λ_x is the factor loading of variable X on ω and Λ_y

denote the factor loading matrix of Y on η ; and δ and ε are the random error terms of the measurement equations X and Y.

The equation of the structural model suggested by Zhang et al. (2021) can be expressed as:

$$\eta = \alpha\eta + \beta\omega + v$$

where, α is the structural coefficient matrix of the endogenous latent variable, β is the structural coefficient matrix of exogenous latent variables and v is the residual of the structural equation. In SEM, it is analysed with regard to direct effects and indirect effects, in which case direct effects denote path coefficients between cause variables (exogenous/endogenous variables) to result variables (endogenous variables), while indirect effects are represented by products of path coefficients forming a path between cause variables to result variables via one or more mediator variables (endogenous variables). The path coefficient between cause variables to result variables in this analysis is represented by the structural variable.

The measurement model, one element of the PLS path model, which is used to measure the latent variables (i.e. constructs) is presented in the first part of this chapter. The other part of the PLS path model, that is, the structural model (relationship between the constructs) is presented in the second part of this chapter. The end part of this chapter provides the overall analysis of the interrelationship between different influencing variables of the study through PLS path model.

6.1 Measurement Model

The measurement model represents the relationships between constructs and their corresponding indication variables. This part of the chapter presents the detailed description of the indication variables and the development of measurement model based on conceptual framework proposed in Chapter II by using PLS-SEM statistical technique. The measurement model can be either formative or reflective or a mix of both models (Hair et al., 2017). However, reflective model is chosen to develop the measurement model in this study. In a reflective measurement model, all indicators are caused by the same construct¹⁷, and so, indicators of a particular construct should be highly correlated with each other, and can be interchangeable (i.e. any single indicator of a construct can be left out without changing the meaning of the construct, providing that the construct has sufficient reliability). Based on the conceptual model

¹⁷ The ‘construct’ is a latent variable used in Structural Equation Model, which cannot be directly observed or measured but can be inferred from multiple of indicators.

framed in the Chapter II, the study presents Capabilities, Ecosystem Services and Wellbeing are the higher order constructs¹⁸. These are useful in modelling complex, multidimensional constructs. Capabilities are higher order constructs which are formed by other several latent constructs formed from Sen (2008) and Nussbaum (2016) approach. Similarly, Ecosystem Services have several dimensions or latent constructs as adopted by Millennium Ecosystem Services approach. Wellbeing has also multiple of dimensions or constructs advocated by several researchers. The indicators of constructs are presented in the section 6.1.1 of this chapter.

6.1.1 Indicators of Constructs

This section deals the several indicators of latent variables used in the measurement of the conceptual model of the present study. In the repeated indicator approach in Smart PLS, a higher-order construct uses all indicators of its lower-order components while all constructs are reflective.

6.1.1.1 Indicators of Farmers Capabilities

The farmers' capabilities are assessed in this study, in terms of Capability approach advocated by Sen (1985) in response to conventional utilitarian view of wellbeing. Sen asserts that wellbeing should be understood in terms of capabilities people have and the actual achievements or functioning's they are able to realise (Sen, 1985; 1999; 2008). Sen does not have a list of reference capabilities based on the belief that it is contextual, and only possible through a democratic process. But Nussbaum prefers a list of capabilities that explain the content of capabilities in more detail (Robeyns, 2005b). The basic capabilities are those which people are born into, like gender, and basic or innate capabilities to which people are supposed to attain—are the stable personality elements of individuals' intelligence, health, and social emotions. Gender, age, equity, access to land and credit, education, and income all affect the capability of the farmer which focus on the real freedoms individuals have to achieve wellbeing (Sen, 1999). Moreover, house property ownership and per capita income offer security and stability to the farmers as additional ability to access resources. In this view, a farmer's capability to achieve wellbeing is shaped not just by available resources, but by their ability to convert those resources into meaningful outcomes. Freedom manifests itself in the act of choice. People's preferences and ideals of the good life influence choices, which are shaped by their

¹⁸ In Smart PLS, Higher Order Constructs (HOCs) are used when a latent variable (construct) is formed by other latent variables, rather than directly by indicators.

broader social and cultural context. Contextual situation (of farmers) affects their ability to transform essential goods and services into valuable skills and activities. According to Polishchuk et al. (2012), the capabilities of individuals directly influence both the extent and type of use of natural resources for agricultural production by farmers. This is supported by the instrumental role or concept emphasized by Robeyns (2005a) as essential for turning goods and resources into valuable capabilities and ultimately functioning. Based on the above description of capabilities in literature, three constructs of Capabilities as a latent variable have been selected. These three dimensions of Capabilities are: Basic Capabilities, Farmers Knowledge and skill, Ecosystem service Knowledge.

To measure the basic capabilities as a latent variable of measurement model, the selected indicators for the study are: Gender, Age, Education, Ownership of Farm land, Ownership of House property and per capita Income from farming. The average median value of all these indicators and their normality test are presented in Table 6.1.

Null Hypothesis: The data set of indicators of capabilities and ecosystem services follows a significant Normal distribution

Alternative Hypothesis: The data set of indicators capabilities and ecosystem services does not follow a significant Normal distribution

Table 6.1

Descriptive Statistics and Tests of Normality of Basic Capabilities

Basic Capabilities	Median	Inter Quartile Deviation	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
			Statistic	df	Sig.	Statistic	df	Sig.
Gender	1.00	1.00	0.467	393	0.000	0.540	393	0.000
Age	60.00	11.00	0.100	393	0.000	0.985	393	0.000
Size of the Family	4.00	2.00	0.158	393	0.000	0.940	393	0.000
Years of Schooling	12.00	5.00	0.187	393	0.000	0.938	393	0.000
Per capita House property (Ha)	0.027	0.04	0.263	393	0.000	0.499	393	0.000
Per capita Kole land owned (Ha)	0.108	0.14	0.166	393	0.000	0.800	393	0.000
Per capita Income from Paddy (Rs)	12110	20279	0.242	393	0.000	0.499	393	0.000

Note: a. Lilliefors Significance Correction

Source: Primary survey

As the p-values of Shapiro-Wilk test of all indicators of basic capabilities are 0.000 which is lower than 5 per cent level of significance suggesting that the distribution of basic capabilities data set is not normal and hence suggest the use of non-parametric test.

The farming knowledge acquired through years of experience in rice cultivation in the Kole lands is the inherent capability of the farmers. The sowing methods, seedlings, fertilizer application, and plant protection methods adopted by most farmers in their paddy fields are evidence of the farming knowledge of the farmers. Farmers as a group have the knowledge, skills, and ability to efficiently operate their farms to produce paddy and other related products for better wellbeing. Their farming knowledge is assessed on the basis of their ability and awareness about paddy farming practices by using Likert scale type data are presented in Table 6.2. The median value 6.50 indicates that all farmers have moderate capability to operate paddy farming efficiently. However, as per the significant p-value of the Shapiro-Wilk test ($p = 0.000$) shows the non-normality of the distribution of indicators and suggesting a non-parametric test.

Table 6.2

Descriptive Statistics and Tests of Normality of Farming and Ecological Knowledge

Descriptive Statistics and Tests of Normality								
Capabilities	Median	Inter Quartile Range	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
			Statistic	df	Sig.	Statistic	df	Sig.
Farming Knowledge	6.50	1.50	0.122	393	0.000	0.953	393	0.000
Ecological Knowledge	8.00	1.00	0.248	393	0.000	0.848	393	0.000

Source: Primary survey

Farmers have the ability to understand the ecosystem services provided by wetlands. Ecological knowledge, or ecosystem knowledge, plays a crucial role in achieving their wellbeing in terms of ecosystem services provided by their farmlands. The knowledge about the provisioning, regulation, and cultural services of Ecosystem services provided by their farmlands addresses the issue of how to acquire these on the basis of environmental justice. The knowledge from local ecological services related to their awareness about the access to required resources for food and income to achieve a better living, provisioning of a clean environment for living, awareness about the capacity of Kole lands to provide adequate nourishment, and also their

knowledge about the capacity of the Kole land to prevent diseases. The knowledge about regulating services like water recharging capacity, carbon sequestration, and soil stability of Kole lands provides better capabilities to farmers to acquire wellbeing from their paddy farming. Additionally, farmers have several opportunities and freedom to engage in recreation, enjoying aesthetic beauty and receiving environmental education from their paddy fields. The median values of the capability indicators assessed by using 10-point Likert scale type questions and their normality test result of their data distribution are presented in Table 6.2. The results showed that farmers are more likely agree about their understanding of ecological knowledge or capability. The median value is 8.00 and their Inter Quartile Range (IQR) is only 1.00. As per the normality test by Shapiro-Wilk suggesting the p value 0.000 means that it is less than 1 percent level of significance and data distribution is not normal.

6.1.1.2 Indicators of Ecosystem Services

Ecosystem Services are the tangible and intangible benefits provided by Kole wetland Paddy fields to farmers for achieving their wellbeing. The study makes use of ecosystem services as a higher order construct and provisioning; regulating and cultural service are their lower order constructs or dimensions. Based on their capabilities, farmers can obtain these services regularly in assisting the paddy farming and maintain a better level of wellbeing. Ecosystem services are provisioning, regulating and cultural services. These services are treated as latent constructs based on their importance and trends on wellbeing of the farmers. The importance and trends of ecosystem services are measured in terms of perception of the farmers living around the Kole wetland area about ecosystem services. The present study assesses the perception of the farmers about the changes in ecosystem services contributed by Kole paddy wetlands during the last twenty years. The perception about increases or decrease of the access of provisioning, regulating and cultural services (Manzoor, et al. 2019) since last twenty years is operated as a mediating variable to assess the relationship between capabilities and wellbeing of the farmers. According to Harrison (2018), research on perceptual valuation has contributed to the development of comprehensive approaches to ecosystem service assessment. The perceived importance and trends of ecosystem services are the indicators of the dependence of people living near these services for their livelihoods and wellbeing (Sodhi et al, 2010). Based on their perception about increase or decrease of ecosystem services, a 10-point scale questions included in the questionnaire and data collected relating the variable value description from ‘1 equals strongly decrease to 10 equals strongly increase’.

By analysing the perceptions about increase or decrease of provisioning ecosystem services, the study revealed a “little more decrease” (median value = 3.00) of the provisioning services (Table 6.3). It is also noted that, as the p value of Shapiro-Wilk Test is 0.000 for provisioning services which is less than 5 per cent level of significance, we reject the hypothesis of normality and confirm the hypothesis that data distribution is not normal. So, we will choose non parametric test.

Table 6.3

Descriptive Statistics and Tests of Normality of Ecosystem Services (Increase or Decrease)

Ecological Services	Median	Inter Quartile Range	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
			Statistic	df	Sig.	Statistic	df	Sig.
Provisioning Services	3.00	1.00	0.163	393	0.000	0.955	393	0.000
Regulating Services	5.50	1.50	0.126	393	0.000	0.977	393	0.000
Cultural Services	6.50	2.50	0.138	393	0.000	0.968	393	0.000
Note: a. Lilliefors Significance Correction								

Source: Primary survey

The perception about the importance and trends of provisioning services is limited to paddy production, fish production and straw as a byproduct of paddy. Additionally, duck rearing, livestock and lotus cultivation are the other provisioning services provided by the Kole wetlands. Recently, the production trend and importance of duck rearing, livestock and lotus cultivation decreased substantially. Therefore, farmers do not perceive these services as highly significant in their wellbeing aspect. Hence, in the study of assessment of provisioning services, only three indicators are significantly measured.

Although wetlands provide many regulating services, many of these services are not experienced by farmers due to erratic weather patterns, droughts, and untimely rainfall. Therefore, the contribution of regulating services to rice cultivation is limited to water retention, carbon sequestration, and soil erosion, which are used as a comprehensive indicator to understand the actual level of regulating ecosystem services used by farmers. The overall median value of all regulating services together is estimated as 5.50 indicating a mid of

“partially increase” to “partially decrease” of the variable description. The results clearly indicate that though Kole wetlands are highly productive naturally fertile land, but recently due to climatic variability and anthropogenic reasons, the capacity to provide regulating services decreased significantly. The p-value of the Shapiro-Wilk Test ($p = 0.000$) of regulating services suggests a non-normal data distribution and hence a non-parametric test can be suggested.

Kole wetlands provide opportunities to farmers for recreational facilities such as fishing, swimming, bird watching, and kite diving; facilities for exploring the aesthetic beauty through photography and nature observation; opportunities for celebrating numerous cultural festivals related to religious and other festivals and also chances for education and information through the *Padasekharams*. From the analysis, it is identified that, average median value is 6.50 indicating “mildly increase” in cultural services (Table 6.3). Among these cultural ecosystem services, swimming, fishing, and kite flying are rarely available to farmers due to environmental pollution caused by excessive use of chemicals in agriculture. However, exploration of aesthetic beauty, bird watching, and educational information are available on a much larger scale today. Therefore, recreation, aesthetic beauty, and environmental education are the three indicators that farmers consider as increased cultural services.

6.1.1.3 Indicators of Wellbeing

The capabilities approach to the study of human well-being was identified in terms of links between ecosystem services and wellbeing (Costanza et al., 2007; Polishchuk & Rauschmeyer, 2012). The approach to wellbeing in the current study develops from Sen’s (1999) capabilities theory to the effect that how a person thinks and feels about what they have, what they can do, and what they can do for both. According to Millennium Ecosystem Assessment, changes in ecosystem services deeply affect the wellbeing components including necessary material for a good life, health, good social relations, security, and freedom and choice. The present study used these five components as latent construct to assess the wellbeing of the farmers in Kole wetlands. 10-point Likert scale typed questions have been used to collect the data to assess the achievements of these five sets of components. The valuation scale used in data set is ranged from “1 for extremely dissatisfied to 10 for extremely satisfied” about their achievements of functioning data set. The descriptive statistics and their test of normality are presented in Table 6.4.

Table 6.4

Descriptive Statistics and Tests of Normality of Wellbeing Components Achievements
(Satisfaction)

Wellbeing Dimensions	Median	Inter Quartile Range	Kolmogorov-Smirnov ^a			Shapiro-Wilk			Value Description
			Statistic	df	Sig.	Statistic	df	Sig.	
Basic Materials for Life	5.00	2.00	0.208	393	0.00	0.922	393	0.000	Partially Dissatisfied
Health	8.00	2.00	0.236	393	0.00	0.872	393	0.000	Little more Satisfied
Security	4.50	0.50	0.176	393	0.00	0.869	393	0.000	Partially Dissatisfied
Social Relations	6.50	2.00	0.111	393	0.00	0.958	393	0.000	Mildly Dissatisfied
Freedom of Choice	5.00	1.50	0.178	393	0.00	0.903	393	0.000	Partially Dissatisfied

Note: a. Lilliefors Significance Correction

Source: Primary survey

The basic material for good life including income and assets, enough food and water at all times, shelter, ability to have energy to keep warm and cool, and ability to access goods. The provisioning services supplied by the Kole wetlands are paddy, fish, livestock, straw, and clean water. Changes in these provisioning services have very strong impacts on the adequacy of material for a good life. For example, increased production of paddy and fisheries has been associated with growth of food and income of the farmer. Similarly, the management of farming provides employment and sufficient revenue to access goods and services. The availability of straw as a byproduct of paddy significantly assists livestock feeding. The combined overall average median value of basic materials for life (median value equals 5.000) indicates “partial dissatisfaction”, which means that paddy farming does not provide required sufficient basic materials for their wellbeing. The provisioning services of Kole paddy farming are not capable to provide adequate food and other resources for life to the farmers. The modification and maintenance of canals and waterbodies are useful for paddy farming which help to supply

sufficient water recharge and clean water for drinking. The pollution of water through chemical input use and declining per capita availability of water negatively impact the basic materials for life. Cultural services do not directly contribute anything to the achievement of basic materials for life. The socio-economic conditions of the farmers as their basic capabilities as well influence the accessibility of materials goods for life.

Health is both a product and a determinant of wellbeing (MEA, 2005). Health refers to the ability of a human feel well and be strong. This depends upon the adequate nourishment from food and free from disease. Health also has to do with having access to enough clean air and drinking water, as well as having enough energy to be warm and cool. Food, water, and medicinal plants are provided by Kole wetlands' provisioning services; air quality, water quality, disease control, and waste treatment are provided by their regulating services; and recreational, artistic, and spiritual possibilities are provided by their cultural services, which have an impact on health. The overall median value of health is 8.00 with IQR of 2.00 (Table 6.4). Hence, it means that majority of the farmers are "little more satisfied" as to obtaining better health through paddy farming.

Social cohesiveness, respect for one another, and the ability to help others and look after children are all components of healthy social relationships. Social interactions can be impacted by changes in the providing and regulation of environmental services, primarily through their direct consequences on security, health, and material well-being. Social relationships may be greatly impacted by changes in cultural services, particularly in cultures that have close links to their local surroundings. The farmers' households and other local residents are regularly visit the Kole wetlands and enjoy the opportunities of recreational activities like fishing, bird watching, swimming etc., Recently, photo shooting, video creation, sightseeing, enjoy natural beauty are very common in society. The Kole wetlands are the best place for exploring the aesthetic beauty of nature. In addition, farmers and local residents celebrate many festivals and cultural programmes in connection with harvesting and other religious aspects. Along with education and training given by the Kole *Padasekharams*, these cultural services could help to create good social relations among farmers, their friends, relatives, neighbours and even distant tourists. However, the majority of the farmers are remarked "mildly dissatisfied" (median value is 6.5) with the performance of Kole wetland paddy farms to provide social relations.

Security is another important dimension of wellbeing. The safety of people and their belongings, safe access to essential resources, and defence against man-made and natural

calamities are all considered aspects of security. Farmers' security has been significantly impacted by regulatory services such as flood, disease, and climate control. The degradation of food and water provided by the provisioning services leads to loss of access to essential resources. Similarly, the social bondage and social network provided by the cultural services of Kole lands enhance the safety and security of the living conditions of the farmer. Kole wetlands protect the local farmers and their household from excessive flood and drought occur regularly. Moreover, each farmer has equal chance to engage in farming and utilise the resources effectively, which provide a good security and justice among farmers. The descriptive statistics presented in Table 6.4 shows that majority of the farmers opined “partial dissatisfaction” with security services of Kole paddy farming (median equals 4.5 and IQR equals 0.50).

Freedom of choice and action refers to a person's ability to direct their own destiny and accomplish the things they find meaningful (MEA, 2005). Generally, this construct of wellbeing exists only with other elements of wellbeing discussed above. However, in Kole land farming, each farmer has equal freedom to choose their own cropping pattern. Moreover, farmers can influence the decision of the authorities in a democratic way related to paddy farming and other related social issues. They have freedom to choose a good house in cop up with the environment and also to choose additional job along with farming. The descriptive statistics presented in Table 6.4 illustrated that median score on the perception of the farmers on freedom of choice obtained was 5.00 (IQR=1.50) indicating that majority of the farmers are “partially dissatisfied”.

All the dimensions of wellbeing except health of the farmers are in the value description of dissatisfactory and health as a dimension of wellbeing have an amount of satisfaction. It means that farmers are not satisfied with their wellbeing in terms of different dimensions. The study shows that although farmers have significant levels of capabilities, they are unable to fully translate that into wellbeing. Why the farmers cannot fully translate their capabilities into wellbeing? The study argues that, this is because of the role of ecosystem services in the paddy fields as mediator role in achieving the wellbeing of farmers, especially those living in and around paddy fields. It is identified from the study that each dimension of wellbeing significantly depends on the ecosystem services provided by the Kole lands. It is also identified that wellbeing dimensions decreases with dissatisfactory level of ecosystem services. Thus, the following sections (section 6.2) examines the causative interrelationship between these potential variables in the assessment of wellbeing by using Structural Equation Model (SEM). The Shapiro-Wilk normality test of all dimensions of wellbeing which is presented in Table 6.4

identified that, all dimensions are distributed at significant level ($p < 0.05$) and hence it is not normally distributed. The non normality of data suggest the non-parametric test of each dimension with grouping of variables. To examine the differences in wellbeing dimensions of farmers in different locations of Kole lands, we have used a two independent sample non-parametric test with grouping of location of Kole lands such as North Kole and South Kole. Our research hypothesis for this is that North Kole farmers are more satisfied than South Kole farmers in achieving wellbeing dimensions.

Null Hypothesis: The two populations are identical

Alternative Hypothesis: The two populations are not identical

Table 6.5
Non-Parametric Test Results (Ranks)

Location of the Kole		N	Mean Rank	Sum of Ranks
Basic Materials for Life	North Kole	252	195.80	49341.50
	South Kole	141	199.15	28079.50
	Total	393		
Health	North Kole	252	177.12	44633.50
	South Kole	141	182.54	25738.50
	Total	393		
Security	North Kole	252	194.92	49119.50
	South Kole	141	200.72	28301.50
	Total	393		
Social Relations	North Kole	252	191.35	48219.00
	South Kole	141	207.11	29202.00
	Total	393		
Freedom of Choice	North Kole	252	187.59	47273.50
	South Kole	141	193.81	27327.50
	Total	393		

Source: Primary survey

Table 6.6
Non-parametric Test Statistics

Test Statistics ^a					
	Basic Materials for Life	Health	Security	Social Relations	Freedom of Choice
Mann-Whitney U	17463.50	12755.50	17241.50	16341.00	15395.50
Wilcoxon W	49341.50	44633.50	49119.50	48219.00	47273.50
Z	-0.29	-4.83	-0.50	-1.33	-2.23
Asymp. Sig. (2-tailed)	0.78	0.07	0.62	0.18	0.06
Note: a. Grouping Variable: Location of the Kole					

Source: Primary survey

As the p-value of Mann Whitney U test of all dimensions (Table 6.6) is greater than 5 per cent level of significance ($p > 0.05$) so we fail to reject the null hypothesis that two populations are identical. It means no significant difference between Kole locations whether North or South Kole in the case of all dimensions of wellbeing. The output indicates the result, with correction of ties and Z-score was significant. The mean rank of North Kole and South Kole farmers about all dimensions are nearly same (Table 6.5) indicating the presence of similar opinion. Hence the study focuses only at the aggregate level of interrelationship between potential variables by using Structural Equation Modelling with Smart PLS-SEM.

In the conceptual model, Capabilities as a construct is treated as dependent variable and basic capabilities, Farming Knowledge and Ecosystem Knowledge are their independent variables. Similarly, Ecosystem services are treated as dependent variable and their indicators like provisioning, regulating and cultural services are their independent variables. Lastly, Wellbeing as a dependent variable and their indicators such as basic material for good life, health, good social relations, security and freedom of choice and action are independent variables. However, in a structural model, capabilities (three variables) are independent variables, wellbeing constructs are dependent variable (five dependent variable) and ecosystem services (three variables) are mediating variable. Each variables have their own constructs and each construct has their own multiple of indicators in the model presented in Figure 6.1.

6.1.2 Assessment of Measurement Model

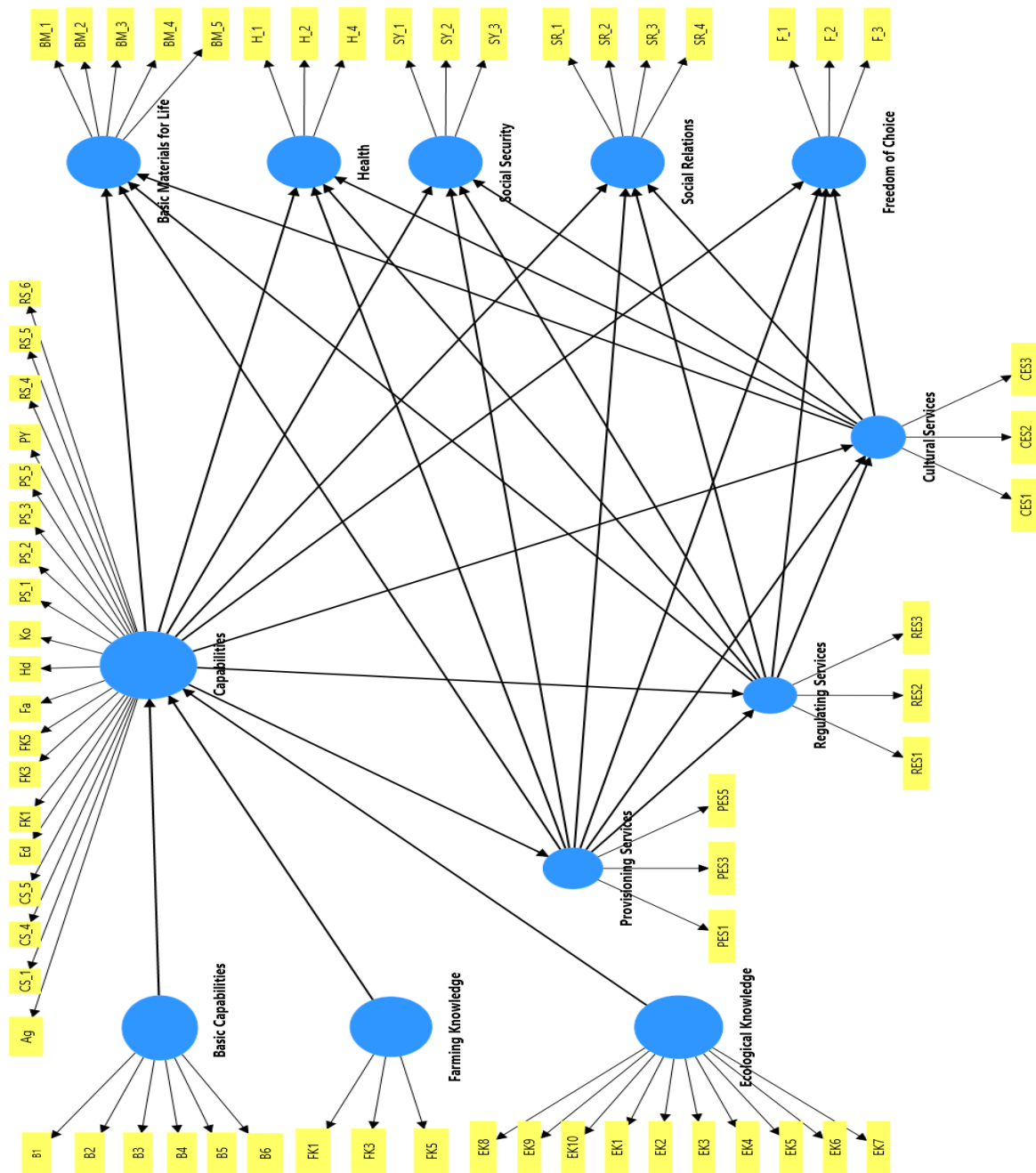
On the basis of the theoretical model designed and explained in Chapter III and the estimation of measurement model indicators presented in the foregoing section, it is attempted to determine what path model, as shown in Figure 6.1, is tested using PLS-SEM method. PLS-SEM is a non-parametric method that relies on the variance explanation of latent dimensions which cannot be directly observed. This is considered most appropriate for dealing with intricate models designed for carrying out a study as presented. The indicator variables of the construct's measurement model can make use of data that is in the metric scale (ratio or interval scale of measurement), for example, age and income, and also make use of data using scales that are of an ordinal nature (for instance, like the Likert scale) (Hair et al., 2017; Ringle et al., 2023). The first step in the assessment of measurement model is to assess the statistical significance of the indicators of the latent construct or the outer model. Various methods have been used to calculate the reliability and validity of the outer model study, as suggested by Hair et al. (2017).

The reliability refers to the consistency of scale tools. The individual item in the measurement indicator's reliability is tested by factor loading. The factor loading measures the absolute contribution of an indicator to its assigned construct (Cenfetelli and Basseller, 2009). Each of the factors or indicators had values of "Standard factor Loading" that were greater than 0.70, which provided that the study dimensions have satisfactory level of reliability. The internal consistency is tested by latent variable composite reliability (CR), rho_A and Cronbach's alpha. The recommended value of these tests is to be greater than 0.70. The rho_a value lies between the Cronbach's alpha and composite reliability (Sarstedt et al., 2017) indicating good reliability. The validity refers to the correctness of the scale tools. The measurement indicators validity is tested with convergent validity and discriminant validity.

The convergent validity is used to measure the correlation between items with the same dimensions and to detect the Average Variance Extracted (AVE). The recommended value of AVE is greater than 0.50 (Hair et al, 2017). The discriminant validity measures the correlation between items with different facets. The criteria used to measure discriminant validity includes Fornell-Larcker criterion method and the Heterotrait-Monotrait Method Ratio (HTMT). The Fornell-Larcker method using the square root value of AVE to test the discriminant validity. If the square root value of the diagonal AVE is greater than the correlation coefficient value of the horizontal and vertical column, which is an indicative of high discriminant validity (Fornell and Larcker, 1981). Finally, the HTMT value, state by Leguina (2015) should be under 0.90.

Figure 6.1

PLS Path Model



Source: computed by the author

Finally, the collinearity of indicators also assessed for measurement model by using VIF values of indicators. The threshold VIF value of all indicators are less than 5 which indicates no multicollinearity among indicators. The study results of these tests are presented in the following section (6.1.2.1). By running the PLS-SEM algorithm and bootstrapping procedure for the model estimation, the following evaluation of measurement model results obtained are presented in Table 6.7, 6.8 and 6.9.

6.1.2.1 Reliability and Validity of Indicators of Dimensions of Capabilities

Based on the conceptual model, Capabilities of the farmers are assessed in terms of three dimensions like Basic capabilities, Farming practice knowledge and ecosystem knowledge. Each dimension or constructs of Capabilities have different indicators. The indicator variables selected in the outer model of capabilities have factor loading values greater than 0.70 are considered highly satisfactory (Henseler et al., 2009). All the indicators of basic capabilities collected through questionnaire are included in the model due to higher outer loading values ranges between 0.722 and 0.936 are presented in Table 6.7. The indicators of basic capabilities are the demographic and background variables of the farmers in wellbeing assessment. The AVE, Cronbach's Alpha, rho_a and Composite Reliability (CR) are 0.665, 0.902, 0.912 and 0.932 respectively. All these values are higher than the threshold limit. The highest value of VIF of multicollinearity among indicators of basic capabilities are 4.426 indicates that all the VIF values of the indicators are below the threshold of 5.

Based on Capabilities approach, Robyn's model and MEA approach, ecological or ecosystem knowledge is a crucial factor for the determination of farmers' capabilities in the wellbeing assessment. Due to low factor loading (less than 0.70) and low AVE (less than 0.5), few indicators are omitted from the indicator list and the remaining 10 indicators with higher than factor loading of 0.70 related to provisioning, regulating and cultural services knowledge and skill of farmers are included and their reliability and validity are presented in Table 6.7. The AVE of ecological knowledge are 0.582 and Cronbach's alpha, rho_a and CR are higher than 0.70 showed the highest reliability and validity of the indicators in the measurement model. All VIF values of ecological knowledge are lies between 1.287 and 1.815 indicate no collinearity issues in the latent constructs.

Farming Knowledge are significant in the capabilities of farmers due to their skill and efficiency in paddy production with years of experience. Farmers are knowledgeable in cropping pattern under various seasons. Farmers are well aware about the application of fertilisers in time bound manner and the use insecticides and weedicides as and when required to overcome the crop diseases. These farmers knowledge are the real capabilities in the assessment of their wellbeing. followed in those activities in all Kule lands together at a time. Hence, these indicators are excluded from the measurement model. Though tilling, harvesting, and transportation are the other farming practices, but the study does not factor loaded significantly (less than 0.70) sometimes due to a common practice. The AVE of omitted indicators are lower than 0.5.

Table 6.7

Evaluation of Outer Measurement Model of Capabilities as Independent Variable & VIF of Multicollinearity

Capabilities Indicators (IV)		Indicator	Outer loadings	Cronbach's Alpha	rho_A	CR	AVE	VIF
Basic Capabilities	B1	Age	0.895	0.902	0.912	0.932	0.665	1.283
	B2	Years of Schooling	0.821					1.042
	B3	Family Size	0.799					2.064
	B4	Gender	0.722					1.896
	B5	House Property	0.763					1.283
	B6	Land Ownership	0.936					4.426
	B7	Per capita Income	0.751					1.846
Ecological Knowledge	EK1	Access of Resources and food	0.755	0.895	0.902	0.933	0.582	1.520
	EK2	Clean environment	0.746					1.311
	EK3	Adequate nourishment	0.789					1.555
	EK4	Avoid Diseases	0.738					1.287
	EK5	Water Recharge	0.732					1.371
	EK6	Carbon sequestration	0.739					1.815
	EK7	Soil Stability	0.737					1.572
	EK8	Recreation	0.749					1.208
	EK9	Aesthetic beauty	0.789					1.170
	EK10	Environmental Education	0.845					1.188
Farming Knowledge	FK1	Cropping Pattern under Weather condition	0.897	0.798	0.813	0.827	0.618	1.006
	FK2	Crop diseases	0.712					1.079
	FK3	Apply fertiliser and insecticides	0.736					1.125
Capabilities		All Indicators	0.786	0.924	0.946	0.970	0.618	2.156

Source: Primary survey

The remaining indicators outer loading value range between 0.897 and 0.712. Their AVE, Cronbach's alpha, rho_a and CR are higher than required level (0.618, 0.798, 0.813 and 0.827 respectively). The overall capability as a latent construct in the reflective measurement model is highly factor loaded with indicators by 0.786. The reliability of the construct Capabilities

was assessed by using Cronbach's alpha (0.924), rho_a (0.946), and Composite reliability (0.970) which are statistically significant with high value.

6.1.2.2 Reliability and Validity of Indicators of Mediating Variables (Ecosystem Services)

Ecosystem Services presented in the conceptual model have three dimensions including provisioning, regulating and cultural services. The changes in each service independently affect the wellbeing components of farmers. The drivers of ecosystem services are basic capabilities, farming practice (or knowledge) and ecosystem knowledge in the conceptual model. The conceptual model treated ecosystem services as a mediating factor between capabilities and wellbeing of the farmers. The changes in mediating factors due to farming practices have a trade-off or synergy have been analysed and presented in chapter V.

Provisioning services, as a first-order construct of ecosystem services, have three indicators: paddy production, fish production, and straw production from paddy. The factor loading of these indicators has a value of 0.70 or more, indicating the statistically significant content validity of the model. The variables such as duck production and livestock have non-significant factor loadings (less than 0.70) and non-significant AVE (less than 0.5), so these variables are dropped from the construct. Reliability and validity of the indicators in the provisioning services are presented in Table 6.8. It is observed that the Cronbach's alpha value was 0.846, rho_a was 0.854, Composite reliability was 0.860 and Average Variance Extracted was 0.674, indicating that the provisioning services indicators has acceptable internal reliability and validity. It is also observed that the issue of multicollinearity is not present in the model as VIF values for the observed indicators are between 1.003 and 1.134.

Water Retention, Carbon sequestration and Soil erosion are the indicators of regulating services. These variables or indicators have the factor loading values of 0.713, 0.809 and 0.805 respectively. Each indicators have significant factor loading value of greater than 0.70, observed that the study dimension of regulating services has satisfactory level of reliability. The convergent validity of the regulating services ensures AVE value of 0.604. The value of Cronbach's alpha, rho_a and Composite Reliability of regulating services are above the threshold value of 0.70.

Table 6.8

Evaluation of Outer Measurement Model of Ecosystem Services as Mediating Variable & VIF of Multicollinearity

Ecosystem Services (MV)	Indicator	Outer loadings	Cronbach's Alpha	rho_A	CR	AVE	VIF
PES1 <- Provisioning Services	Paddy Production	0.726	0.846	0.854	0.860	0.674	1.124
PES2 <- Provisioning Services	Fish Production	0.839					1.134
PES3 <- Provisioning Services	Straw	0.889					1.003
RES1 <- Regulating Services	Water Retention	0.713	0.811	0.813	0.820	0.604	1.199
RES2 <- Regulating Services	Carbon sequestration	0.809					1.287
RES3 <- Regulating Services	Soil erosion	0.805					1.324
CES1 <- Cultural Services	Recreation	0.786	0.824	0.835	0.844	0.644	1.111
CES2 <- Cultural Services	Aesthetic	0.836					1.165
CES3 <- Cultural Services	Environmental Education	0.785					1.011

Source: Primary survey

The significantly higher factor loading indicators of cultural services are recreation, aesthetic beauty and environmental education. All the indicators observed in the model have 0.70 and more value of factor loading, Cronbach's alpha and CR. It is observed that AVE is 0.644 and VIF value of all indicators are below the threshold value of 5. Therefore, it is clear that collinearity is not an issue for regulating services.

6.1.2.3 Reliability and Validity of Indicators of Wellbeing (Dependent Variables)

Wellbeing in the conceptual model is a higher order construct in PLS-SEM measurement model have five unobserved variables as dimensions. The wellbeing dimensions suggested by the Millenium Ecosystem Assessment are: Basic material for life; Health; Security; Good social relations and Freedom of choice and action which were analysed among farmers. The reliability and validity of all indicators of each dimension are presented in Table 6.9. The factor loading of all the items in the wellbeing dimensions incorporated in the model have a value range between 0.712 and 0.855 which is greater than the minimum acceptable value of 0.5. However, in the research process, few indicators have weaker factor loading (less than 0.70) removed after examining the composite reliability, content and convergent validity. Because the values for the construct were already over the suggested level, the removal of those indications significantly increased the composite validity and AVE. Additionally, none of the outer loadings in the items include a zero, according to an analysis of the loading's confidence interval in the current model.

Reliability of the model was assessed by Cronbach's alpha values with a range of 0.756 and 0.842. The value of Composite validity of all constructs is greater than 0.70 (range between 0.790 and 0.870). Similarly, the rho_a value lies between Cronbach's alpha and CR with value of more than 0.70. The convergent validity of the model was also acceptable because of the AVE value ranges between 0.539 and 0.628. According to the collinearity issue of the model presented in the table 6.3 that the highest VIF value is 1.516 for BM_1 for basic material for life. Hence, collinearity is not an issue in the measurement model of wellbeing.

6.1.2.4 Discriminant Validity of the Measurement Model

By comparing the correlations between the latent variables with the square root of AVE (Fornell-Larcker, 1981) and the Heterotrait-Monotrait ratio (HTMT) of correlations (Henseler et al., 2015; Leguina, 2015), the discriminant validity of the final model was evaluated. As depicted from Table 6.10 discriminant validity is established by Fornell-Larcker criteria which states that square root of AVE should be greater than correlation value with other constructs.

Table 6.9

Evaluation of Outer Measurement Model of Wellbeing as Dependent Variable & VIF of Multicollinearity

Wellbeing (DV)		Indicators	Outer loadings	Cronbach's Alpha	rho_A	CR	AVE	VIF
Basic Materials for Life	BM1	Food, cloth & living materials	0.731	0.842	0.854	0.870	0.572	1.516
	BM2	Drinking water, electricity & Gas	0.745					1.415
	BM3	Education and Training	0.736					1.398
	BM4	Comfortable housing	0.778					1.363
	BM5	Area of Arable Land	0.791					1.191
Health	H1	Nutritional Food	0.726	0.804	0.813	0.829	0.620	1.115
	H2	Regular Exercise and Stress management	0.855					1.281
	H3	Physical and Mental strength	0.775					1.177
Security	SY1	Peace of Mind and Safety	0.726	0.756	0.778	0.790	0.557	1.004
	SY2	Financial Resources	0.768					1.004
	SY3	Equal right to use resources	0.744					1.180
Social Relations	SR1	Aesthetic experiences and natural beauty	0.762	0.813	0.821	0.824	0.539	1.355
	SR2	Opportunities for relaxation and stress relief	0.714					1.233
	SR3	Engage in recreational activities	0.712					1.404
	SR4	Cooperate with social community	0.748					1.312
Freedom of Choice and Action	FC1	Influence decisions in farming and social issues	0.834	0.824	0.831	0.835	0.628	1.124
	FC2	Quality of housing with a good natural environment	0.775					1.042
	FC3	Quality health care	0.767					1.080

Source: Primary survey

Table 6.10
Fornell-Larcker Criterion of Measurement Model

Constructs	B	EK	FK	C	PES	RES	CES	BM	H	SY	SR	FC
B	0.790											
EK	0.632	0.767										
FK	0.550	0.607	0.810									
C	0.676	0.563	0.665	0.781								
PES	0.686	0.463	0.665	0.688	0.767							
RES	0.513	0.502	0.441	0.771	0.529	0.788						
CES	0.351	0.379	0.498	0.419	0.273	0.614	0.740					
BM	0.612	0.573	0.572	0.672	0.632	0.556	0.409	0.725				
H	0.677	0.632	0.538	0.558	0.577	0.572	0.587	0.466	0.811			
SY	0.395	0.362	0.388	0.543	0.352	0.326	0.603	0.328	0.594	0.763		
SR	0.682	0.334	0.612	0.456	0.599	0.638	0.532	0.620	0.578	0.541	0.709	
FC	0.623	0.511	0.327	0.614	0.424	0.442	0.528	0.598	0.602	0.693	0.561	0.754

Source: Primary survey

Abbreviations: B, Basic Capabilities; EK, Ecological Knowledge; FK, Farming Knowledge; C, Capabilities; PES, Provisioning Services; RES, Regulating Services; CES, Cultural Services; BM, Basic material for life; H, Health; SY, Security; SR, Good social relations; FC, Freedom of choice and action.

The diagonal and bolded values are the square root of AVE. Below the diagonal elements are the correlations between the construct's values. It is observed from Table 6.10 that the vertical and horizontal correlations values of each construct are lower than the square root value of AVE.

The heterotrait-monotrait ratio (HTMT) of correlations of constructs are presented in Table 6.11 observed that all values are under 0.90 (Leguina, 2015).

Table 6.11

HTMT ratio of Measurement Model

Constructs	B	EK	FK	C	PES	RES	CES	BM	H	SY	SR	FC
B												
EK	0.524											
FK	0.432	0.452										
C	0.76	0.82	0.79									
PES	0.688	0.735	0.691	0.842								
RES	0.366	0.41	0.83	0.799	0.519							
CES	0.478	0.695	0.612	0.701	0.843	0.442						
BM	0.487	0.587	0.629	0.704	0.756	0.518	0.854					
H	0.368	0.465	0.68	0.683	0.732	0.529	0.812	0.368				
SY	0.258	0.455	0.315	0.376	0.558	0.251	0.824	0.492	0.761			
SR	0.473	0.448	0.469	0.568	0.486	0.388	0.555	0.514	0.575	0.338		
FC	0.235	0.632	0.561	0.566	0.815	0.414	0.857	0.766	0.842	0.677	0.787	

Source: Primary survey

Abbreviations: B, Basic Capabilities; EK, Ecological Knowledge; FK, Farming Knowledge; C, Capabilities; PES, Provisioning Services; RES, Regulating Services; CES, Cultural Services; BM, Basic material for life; H, Health; SY, Security; SR, Good social relations; FC, Freedom of choice and action.

To sum up, in this research, it is clear that factor loadings of 95 per cent of the questionnaire items are all greater than 0.70 are included in the measurement model. The Cronbach's alpha, rho_a and CR values of all dimensions are higher than 0.70 and also rho_a lies between Cronbach's alpha and CR, indicating good reliability and internal consistency of the measurement model. The convergent validity of each dimension of the model is also good with more than 0.50 value of AVE. The discriminant validity test by Fornell-Larcker criterion have a significant higher square root value of AVE than correlation coefficient value matrix. Moreover, HTMT ratio of all values are less than 0.90 indicating good discriminant validity. All these indicates that research data's reliability and validity are acceptable and can proceed to evaluate structural model.

6.2 Structural Equation Model

The structural equation model (SEM)¹⁹ assesses the proposed hypothesis relationship in the research framework. SEM is suitable model to analyse complex direct and indirect effects of multiple observed and latent variables. It also helps to assess the mediating effect of a variable.

¹⁹ The logical link between seen variables (also known as manifest variables) and latent variables is described by SEM, a multivariate statistical technique. By providing a causal channel, it may handle several dependent and independent variables at once.

Thus, SEM is an appropriate statistical method for the analysis of this study, which examines the relationship between capabilities and wellbeing using an intermediate effect of ecosystem services provided by the Kol Wetland Agroecosystem. The explanatory power of the structural model presented in the section 6.2.1 is assessed on the basis of R^2 , and significance of β value (path coefficients). The predictive relevance of model was assessed in terms of Q^2 value. The assessment of the structural model with path coefficient determination is presented in this section and finally the mediation analysis illustrated in the last section.

6.2.1 Explanatory Power of the Structural Model

The goodness of fit of the dependent variables in each structural path is determined by R^2 value. R square statistics explains the variance in the endogenous variable explained by the exogenous variables. Simply, it explains the percentage variations in dependent variable on account of changes in one or more independent variable(s). The R square value measures the explanatory power of the variance of each endogenous construct. (Shmueli & Koppius, 2011). It is also referred to as in-sample predictive power (Rigdon, 2012). The R square ranges from 0 to 1, with higher values indicating a greater explanatory power. According to Cohen, (1988), acceptable R^2 values are based on context of research, though general acceptable rule of thumb is: 0.26 (substantial), 0.13 (moderate), and 0.02 (weak). Accordingly, study results presented in Table 6.6 show that R square value of all endogenous variables in model has above the recommended threshold score and representing the explanatory and predictive power of the collected data and the model specified. Although, the R square value of endogenous variable like “security” and “Freedom of choice” has comparatively lower, but the explanatory power of the model in terms of theory is above substantial (Cohen, 1988).

Likewise, Q square value establishes the predictive relevance of endogenous constructs. It assessed how well a model can predict out of sample data. The Q^2 value above zero indicates that our values are well structured and that the model has predictive relevance. Generally, 0.02, 0.15, 0.35 for weak, moderate, strong degree of predictive relevance of each effect (Hair et al 2013). But ideally, Q square is positive and not much lower than R square. All the Q square values of the structural model presented in Table 6.12 represent a strong degree of predictive relevance of the model excluding “security” and “Freedom of choice”. The moderate power of predictive relevance of “security” and “freedom choice” also admissible in terms of the theory of the model.

Finally, the model fit was assessed by using standard root mean square residual (SRMR) value and Normed Fit Index (NFI). The threshold value of SRMR should be less than 0.08 (Henseler

et al., 2014) and the NFI value should be more than 0.90 to achieve a good model fit to data (Hair et al., 2017). The SRMR value of the study model (0.032) presented in Table 6.12 was slightly lower than the required threshold value. The slightly too lower value of SRMR highlights the higher complexity and the large number of latent constructs in the model (Hair et al., 2016). The NFI value 0.932 (Table 6.12) is above the recommended threshold value and suggesting a good model fit.

Table 6.12

Explanatory Power, Predictive Power and Model Fit Indices of Structural Model

Endogenous Variables	R-square	R-square adjusted	Q ² predict
Capabilities	0.898	0.891	0.864
Provisioning Services	0.598	0.596	0.586
Regulating Services	0.599	0.597	0.565
Cultural Services	0.438	0.431	0.378
Basic Materials for Life	0.770	0.767	0.551
Health	0.454	0.448	0.392
Social Relations	0.609	0.605	0.536
Security	0.366	0.355	0.337
Freedom of Choice	0.244	0.243	0.153
Model Fit Indices			
SRMR	0.032		
NFI	0.932		

Source: Primary survey

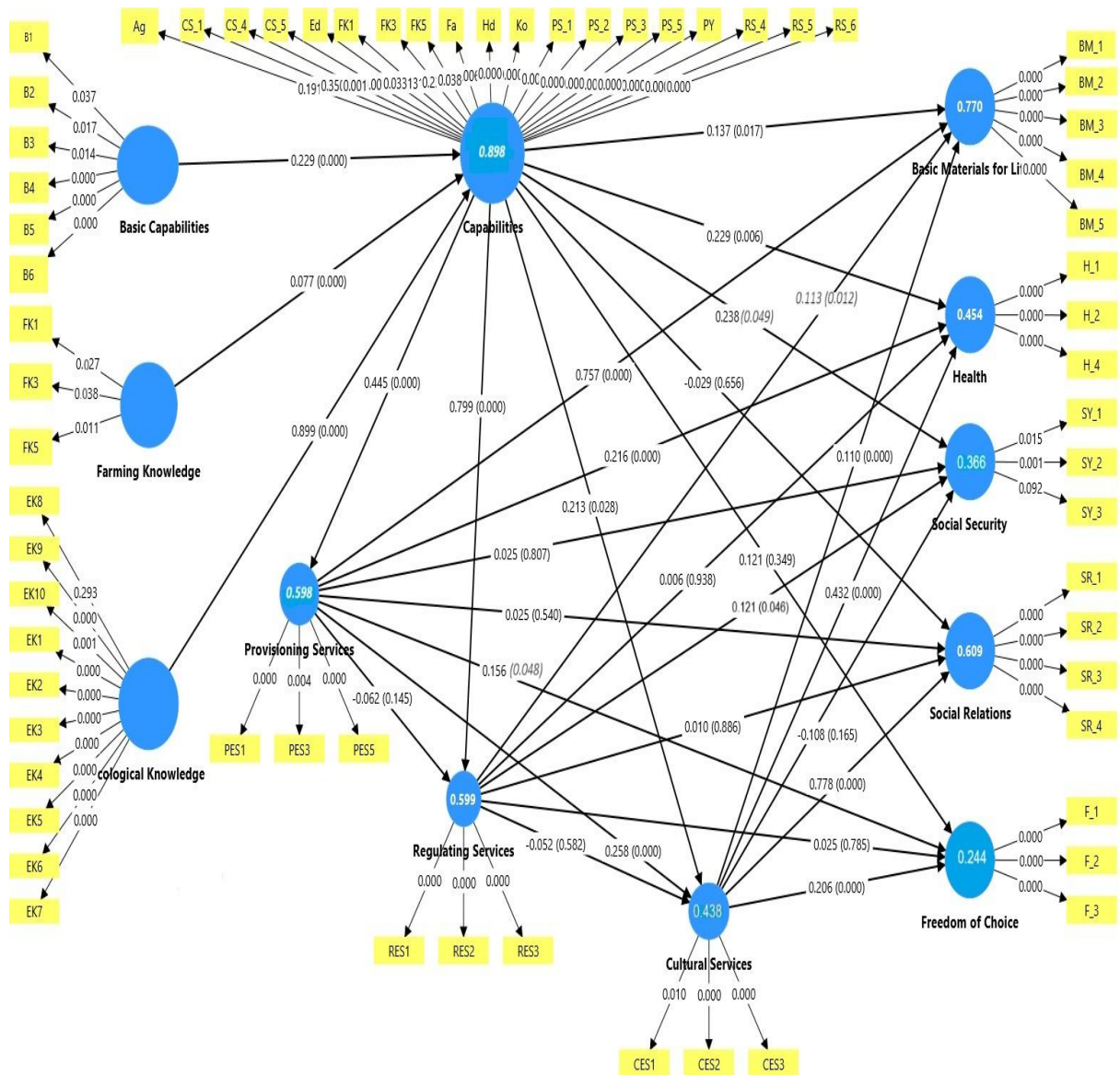
6.2.2 Assessment of Structural Model

The assessment of structural model involves the analysis of the interrelationship between potential variables or constructs defined by the model. Using PLS-SEM, a two tailed test type, and a significance level of 0.05 as advised by Hair et al., (2017) to assess and compare the path coefficients of different latent constructs. According to Aibinu and Al-Lawati, (2010), the highest β coefficient of the predictor latent constructs (exogenous variables) depicts the largest

effect on the endogenous variables. The β coefficients are evaluated with its statistical significance using t-test. To determine the significance of path coefficients and its associated t-value by using bootstrapping method in smart PLS 4. The study uses 5000 bootstrap samples to calculate both direct and mediating effects of relationship between potential variables. The structural model which shows the relationship between endogenous and exogenous variables is presented in Figure 6.2. The direct effects of all potential variables are presented in section 6.2.2.1 and Table 6.13 and the mediating effects of potential variable are depicted in section 6.2.2.2 and in Table 6.14.

Figure 6.2

Structural Path Model



6.2.2.1 Direct Effects of Potential Variables

The study examines the interrelationship between capabilities of the Kole land paddy farmers and their wellbeing with a mediating effect of ecosystem services provided by the Kole wetland agroecosystem. The analysis of direct effects of capabilities on wellbeing dimensions; capabilities on ecosystem services; ecosystem services on wellbeing dimensions; and interrelationship between ecosystem services are presented in Table 6.13 based on six main alternative hypotheses with 26 sub alternative hypotheses given below.

H1 There is a significant direct impact of Capabilities of farmers on different dimensions of Wellbeing (Hypothesis: H1a to H1e)

H2: There is a significant direct impact of Capabilities on different components of Ecosystem services including Provisioning, Regulating and Cultural Services (Hypothesis H2a to H2c)

H3: There is a significant direct impact of Provisioning ecosystem services on different Dimensions of Wellbeing (Hypothesis H3a to H3e)

H4: There is a significant direct impact of Regulating ecosystem services on different dimensions of Wellbeing (Hypothesis H4a to H4e)

H5: There is a significant direct impact of Cultural ecosystem Services on different dimensions of Wellbeing (Hypothesis H5a to H5e)

H6: There is a significant trade off or synergy between different ecosystem services (Hypothesis H6a to H6c)

The study results presented in Table 6.13 show that the direct effects on wellbeing dimensions including Basic Materials for Life, Health, and Security to farmers are significant. But no significant direct relationship exists between capabilities and other two dimensions of wellbeing such as Social Relations and Freedoms of Choice and Action. The VIF value (2.893) is below the threshold level of 5 shows no issue of multicollinearity in capability constructs. It is evident from Table 6.13 that the relationship between capabilities and basic materials for life ($\beta = 0.137$, $p = 0.017$) are significant at 5 per cent level and accept the alternative hypothesis (Hypo: H1a). Similarly, the relationship between capabilities and Health ($\beta = 0.229$, $p = 0.006$) are significant at 1 per cent level and thus accept the hypothesis (Hypo: H1b) that there is direct relationship between capabilities and health.

Table 6.13
Direct Effects of Potential Variables

Path Analysis	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (O/STDEV)	P values	VIF	Hypo.
H1a: Capabilities -> Basic Materials for Life	0.137	0.136	0.057	2.395	0.017	2.893	Valid
H1b: Capabilities -> Health	0.229	0.230	0.084	2.742	0.006		Valid
H1c: Capabilities -> Social Relations	-0.029	-0.026	0.065	0.445	0.656		Not Valid
H1d: Capabilities -> Security	0.238	0.244	0.121	1.967	0.049		Valid
H1e: Capabilities -> Freedom of Choice and Action	0.121	0.123	0.129	0.937	0.349		Not Valid
H2a: Capabilities -> Provisioning Services	0.445	0.452	0.047	9.416	0.000	1.000	Valid
H2b: Capabilities -> Regulating Services	0.799	0.799	0.029	27.404	0.000	1.247	Valid
H2c: Capabilities -> Cultural Services	0.213	0.222	0.097	2.197	0.028	2.841	Valid
H3a: Provisioning Services -> Basic Materials for Life	0.757	0.757	0.037	20.667	0.000	1.334	Valid
H3b: Provisioning Services -> Health	0.216	0.215	0.051	4.230	0.000		Valid
H3c: Provisioning Services -> Social Relations	0.025	0.022	0.041	0.613	0.540		Not Valid
H3d: Provisioning Services -> Security	0.025	0.025	0.104	0.244	0.807		Not Valid
H3e: Provisioning Services -> Freedom of Choice	0.156	0.156	0.079	1.975	0.048		Valid
H4a: Regulating Services -> Basic Materials for Life	0.113	0.112	0.045	2.511	0.012	2.497	Valid
H4b: Regulating Services -> Health	0.006	0.009	0.078	0.077	0.938		Not Valid
H4c: Regulating Services -> Social Relations	0.010	0.009	0.072	0.144	0.886		Not Valid
H4d: Regulating Services -> Security	0.121	0.119	0.060	2.010	0.046		Valid
H4e: Regulating Services -> Freedom of Choice	0.025	0.026	0.092	0.273	0.785		Not Valid
H5a: Cultural Services -> Basic Materials for Life	0.110	0.109	0.031	3.563	0.000	1.161	Valid
H5b: Cultural Services -> Health	0.432	0.430	0.047	9.128	0.000		Valid
H5c: Cultural Services -> Social Relations	0.778	0.780	0.030	25.984	0.000		Valid
H5d: Cultural Services -> Security	-0.108	-0.111	0.078	1.389	0.165		Not Valid
H5e: Cultural Services -> Freedom of Choice	0.206	0.209	0.058	3.541	0.000		Valid
H6a: Provisioning Services -> Cultural Services	0.258	0.259	0.056	4.643	0.000	1.257	Valid
H6b: Provisioning Services -> Regulating Services	-0.062	-0.065	0.042	1.459	0.145	1.247	Not Valid
H6c: Regulating Services -> Cultural Services	-0.052	-0.060	0.095	0.551	0.582	2.494	Not Valid

Source: Primary survey

The Capabilities and Security also have a significant relationship with original sample mean of 0.238 (β value) and p value is less than 0.05 or 5 per cent level of significance (Hypo: H1d). Thus, reject the null and accept the alternative hypothesis that the direct relationship between capabilities and security are valid.

Conversely, mean value of the relationship between capabilities with social relations and freedom of choice are -0.029 and 0.121 respectively are not significant (p value greater than 0.05) and hence reject the two-alternative hypothesis, H1c and H1e, and accept the null hypothesis that there are no significant direct relation exists between capabilities with social relations and freedom of choice. It is observed from the analysis that capabilities of the farmers cannot be fully directly translated in to all the components of wellbeing. It highlights the role of ecosystem services as a mediator to achieve all the dimensions of wellbeing.

According to Millennium Ecosystem Services Approach and capability approach, Capabilities are directly related to different components of ecosystem services (Sangha et al, 2015) such as provisioning, regulating and cultural services. The research analysis presented in Table 6.13 shows that Capabilities are significantly and directly related to three ecosystems services. The highest β coefficient value of provisioning, regulating and cultural services (0.445, 0.799 and 0.213 respectively) with significant t value and p value less than 0.05 (5 per cent level of significance) suggest to accept the alternative hypothesis and reject the null hypothesis which highlights that farmers capabilities are directly influencing the access of ecosystem services of Kole wetlands. Hence the Hypothesis H2a, H2b and H2c are valid. This highlights the significant role of ecosystem services as mediator in achieving different dimensions of wellbeing.

Among different ecosystem services, study results show that, provisioning services are directly and significantly contributed to achieving basic materials for life of the farmers (β coefficient = 0.757, and $p < 0.01$). Additionally, provisioning services directly contribute the access of Health ((β coefficient = 0.216 and $p < 0.01$) and freedom of choice and action ((β coefficient = 0.156 and $p < 0.05$). The significant t-value and p value suggesting the acceptance of hypothesis H3a, H3b and H3e and revealed that provisioning services directly contributed to basic materials for life, health and freedom of choice. The study result shows from Table 6.13 that the other two dimensions such as social relations and security are not significant. The means values of are 0.025 with p value greater than 0.05. Hence accept the null hypothesis that no significant relation exists between provisioning services with social relations and security. Thus

Hypo:H3c and H3d are not valid. It is evident that provisioning services cannot directly contribute security and social relations among farmers.

Regulating services as ecosystem services are primarily intangible benefits to farmers. However, farmers are aware about the access and importance of regulating services as a contributor of different dimensions of wellbeing. The direct impact of regulating services on different dimensions of wellbeing is examined and observed that it provides basic materials for life (β coefficient = 0.113 and $p = 0.012$) and Security to farmers (β coefficient = 0.121 and $p = 0.046$). The significant t- value with p value less than 0.05 or 5 per cent level of significance suggest the acceptance of alternative hypothesis that regulating services are directly related to basic materials for life and security. Hence hypothesis H4a and H4d are valid. On the other hand, the direct relationship of regulating services to Health (Hypo:H4b), Social Relations (H4c), and Freedom of choice and action (H4e) are not significant (their p value is greater than 0.05). Hence accept the null hypothesis that regulating services are not directly related to health, social relations and freedom of choice. These results are confirmed with the theory that regulating services contribute water as a basic material for life and protect farmers from flood and drought as a security directly.

The direct effect of Cultural services and the different dimensions of wellbeing are presented in Table 6.13. In terms of path coefficients, the direct effect of cultural services on social relations (β coefficient = 0.778, and $p = 0.000$) is significant. Similarly, relationship of cultural services with health (β coefficient = 0.432, and $p = 0.000$); freedom of choice (β coefficient = 0.206, and $p = 0.000$); and basic materials for life (β coefficient = 0.110, and $p = 0.000$) are significant with p value less than 0.01 or 1 per cent level of significance. Hence reject the null hypothesis and accept the alternative hypotheses (H5a, H5b, H5c, H5d) that the direct effect of cultural services on dimensions of wellbeing is valid. All the dimensions of wellbeing except security are significant and directly related to cultural services. The mean value (β coefficient) of the relationship between cultural services and security is -0.108 with p value greater than 0.05, fail to reject the null hypothesis that cultural services do not contribute directly to the security of farmers. Hence the hypothesis H5e is not valid.

Finally, the study examines the direct impact of provisioning services on regulating services and cultural services and vice versa. It is observed that in terms of perception about access and importance of provisioning services and cultural services are significant and maintain a synergy or positive relation (β coefficient = 0.258 and $p < 0.01$). Hence reject the null hypothesis and

accept the alternative hypothesis that provisioning and cultural services are positively related (Hypothesis: H6a is valid). However, it is evident that trade-offs exist between provisioning services and regulating services (β coefficient = - 0.062) but not significant ($p > 0.05$). Similarly, regulating and cultural services also contributed negatively (trade off with β coefficient = -0.052) but not significant ($p > 0.05$). Thus, accept the null hypothesis that regulating services are not related to cultural services significantly. Hence H6b and H6c are not hold true.

6.2.2.2 Mediation Analysis

The mediation analysis was performed to assess the mediating role of Ecosystem Services on capabilities and wellbeing. According to Palomo et al. (2016), individual capabilities are a key factor influencing farmers preferences for and access to ecosystem services. The capabilities have indirect impact on their wellbeing by influencing ecosystem services (Liu et al., 2024) contributed by Kule Wetland farms. These indirect impact on wellbeing dimensions are assessed by using PLS-SEM bootstrapping method. Mediation analysis involves three step method suggesting how endogenous variable (capabilities) directly impact dependent variables (wellbeing dimensions), how the independent variables indirectly influence the dependent variables through mediator variables (ecosystem services) and how the mediator influence the dependent variable. Baron and Kenny (1986) argued that the indirect effect is greater than direct effect or both are statistically significant results a mediation effect of intermediary variables. According to Zhao et al., (2010), the intermediary effect is detected by the significant t-value of indirect effect (t-value greater than 1.96). Furthermore, size of the intermediary effect is assessed in terms of the 'variance accounted for' (VAF value). If the VAF value lies less than 20 percent, it indicates slight intermediary effect, or between 20 to 80 per cent means a partial intermediary effect and $VAF > 80$ per cent indicates the complete intermediary effect. The specific indirect effect result in PLS-SEM indicates the mediating effect of the structural model. In a structural model, mediations are classified as either full mediation or partial mediation effects. The significant direct and indirect effect of potential variables measure the partial mediation, while significant indirect effect and non-significant direct effect shows the full mediation of potential variables. Meanwhile, a significant direct effect and a non-significant indirect effect measure the non-mediation effect of potential variables.

The analysis of mediation effect is based on following main hypothesis and fifteen sub hypotheses.

H7: The Components of Ecosystem Services mediates the relationship between Capabilities of the farmers and their different dimensions of Wellbeing.

The study result presented in Table 6.14 illustrate the specific indirect effect (mediation effect) between capabilities and basic materials for life through provisioning (β coefficient = 0.337, t value = 9.023) and regulating services (β coefficient = 0.136, t-value = 2.667). Therefore, mean value of mediating effect of provisioning and regulating services is accept at 1 per cent level of significance ($p < 0.01$). Hence, accept the hypothesis H7a, and H7b. It is also observed that the VAF value indicates 65.44 per cent of mediation through provisioning services and 26.41 percent mediation through regulating services. It is evident from Table 6.13 that provisioning and regulating services act as a mediator to link between capabilities and basic materials for life. The direct effect between capabilities and basic materials for life are significant (β coefficient = 0.137, t-value = 2.395). Additionally, direct effect of capabilities with Provisioning, and regulating services are also significant. Therefore, the significant direct and indirect effect together suggesting the partial mediation effect between capabilities and basic materials for life through provisioning and regulating services. But the partial mediating effect between capabilities and basic materials for life through cultural services ($\beta = 0.023$, t value = 1.734 and $p = 0.083$) presented in Table 6.14 suggest to accept the hypothesis that there is no significant specific indirect effect between capabilities and basic material for life through cultural services. Though cultural services and basic material for life have significant direct effect (Table 6.13), the mediating effect (Table 6.14) of cultural services is not significant and their VAF value is less than 20 per cent (VAF = 4.47 per cent). Hence hypothesis H7c is not valid and indicating no mediating effect of cultural services on basic materials for life. Therefore, the study highlights that there are partial mediation effect of provisioning and regulating services between capabilities and basic materials for life.

The specific indirect effect or mediation effect of ecosystem services on health is presented in Table 6.14. It is observed that specific indirect effect of capabilities and health through all the three ecosystem services are significant. The original mean value and p value of the indirect effect of provisioning services on health ($\beta = 0.096$, $p = 0.000$), regulating services on health ($\beta = 0.065$, $p = 0.036$) and cultural services on health ($\beta = 0.092$, $p = 0.036$) suggesting significant specific indirect effect of capabilities and health through all the three ecosystem services. So, the hypotheses H7d, H7e, and H7f are accepted with 5 per cent level of significance. Additionally, the VAF value are 21.15, 14.32 and 20.26 per cent for mediating effect of provisioning, regulating and cultural services respectively. This indicates that the mediation

effect of provisioning and cultural services are partial ($VAF > 20$) and regulating services have slight intermediary effect. Hence there is a partial mediation effect between capabilities and health through provisioning, regulating and cultural services as mediators. It is evident from Table 6.13 that the direct effect of capabilities, provisioning and cultural services on health are significant but regulating services on health are not significant. Therefore, it is evident that provisioning and cultural services are partially mediate between capabilities and health, while no mediating effect of regulating services on capabilities and health.

Social relations as a wellbeing dimension are indirectly depending on capabilities via cultural services. The mean value of this specific or indirect relationship is 0.165 and their p value is less than 0.05. Therefore, accepted the hypothesis that capabilities are indirectly depends on social relations through the mediating effect of cultural services (Hypothesis H7i is significant). It is also observed from Table 6.14 those cultural services contributed 77.10 percent VAF value indicating the partial mediation effect to social relations. The specific indirect effect of capabilities through provisioning and regulating services on social relations have no significant mean value ($p > 0.05$). Therefore, reject the hypothesis that capabilities and social relations are indirectly related through provisioning (Hypothesis H7g) and regulating services (Hypothesis H7h). It is also noted that the VAF value of these two relations are 5.14 and 3.74 respectively which is below 20 indicating no mediating effect. Thus, it is evident from study that capabilities, provisioning and regulating services have no significant direct and indirect relation with social relations, but only cultural services have significant direct relation (Table 6.13) and indirect relation (Table 6.14). Therefore, study highlights that capabilities are not directly contributed to social relations but cultural services have full mediation effect on social relations.

The original mean value (β coefficient value = 0.117) of specific indirect effect of capabilities and security through regulating services is significant with 5 per cent level of significant ($p = 0.042$). Hence accept the hypothesis H7k that regulating services have a mediating effect on security. The VAF value of 49.79 per cent suggest the partial mediating effect of regulating services on security. But the mean value of the mediating or specific indirect effect of other two services including provisioning ($\beta = 0.011$) and cultural services ($\beta = -0.023$) on security are not significant ($p > 0.05$). Hence the hypotheses H7j and H7l are not valid. The VAF value of provision and cultural services are less than 20 indicating the least mediation effect. The direct effect between capabilities and security are statistically significant (Table 6.13 and the specific indirect effect through regulating services is significant (Table 6.14). Thus, it is noted that capabilities and security are partially mediated only through regulating services.

Table 6.14
Mediating Effects of Potential variables

Specific Indirect Effect (Mediating Effects)	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (O/STDEV)	P value	VAF (%)	Hypo.
H7a: Capabilities -> Provisioning Services -> Basic Materials for Life	0.337	0.342	0.037	9.023	0.000	65.44	Valid
H7b: Capabilities -> Regulating Services -> Basic Materials for Life	0.136	0.137	0.051	2.667	0.000	26.41	Valid
H7c: Capabilities -> Cultural Services -> Basic Materials for Life	0.023	0.024	0.013	1.734	0.083	4.47	Not Valid
H7d: Capabilities -> Provisioning Services -> Health	0.096	0.097	0.026	3.747	0.000	21.15	Valid
H7e: Capabilities -> Regulating Services -> Health	0.065	0.065	0.031	2.097	0.036	14.32	Valid
H7f: Capabilities -> Cultural Services -> Health	0.092	0.095	0.044	2.103	0.036	20.26	Valid
H7g: Capabilities -> Provisioning Services -> Social Relations	0.011	0.01	0.019	0.598	0.550	5.14	Not Valid
H7h: Capabilities -> Regulating Services -> Social Relations	0.008	0.008	0.058	0.144	0.886	3.74	Not Valid
H7i: Capabilities -> Cultural Services -> Social Relations	0.165	0.173	0.076	2.183	0.029	77.10	Valid
H7j: Capabilities -> Provisioning Services -> Security	0.011	0.011	0.046	0.243	0.808	4.68	Not Valid
H7k: Capabilities -> Regulating Services -> Security	0.117	0.116	0.052	2.250	0.042	49.79	Valid
H7l: Capabilities -> Cultural Services -> Security	-0.023	-0.024	0.021	1.100	0.271	9.79	Not Valid
H7m: Capabilities -> Provisioning Services -> Freedom of Choice and Action	0.069	0.071	0.029	2.379	0.017	33.17	Valid
H7n: Capabilities -> Regulating Services -> Freedom of Choice and Action	0.020	0.021	0.073	0.272	0.785	9.62	Not Valid
H7o: Capabilities -> Cultural Services -> Freedom of Choice and Action	0.044	0.046	0.025	1.753	0.080	21.15	Not Valid

Source: Primary survey

The mediating effect of capabilities and freedom of choice and action through provisioning services are significant ($p = 0.05$) with mean value of 0.069 and t value of 2.379. But the mean value of regulating services ($\beta = 0.020$) and cultural services ($\beta = 0.044$) are low and not significant with p value greater than 5 per cent ($p = 0.785$ and 0.08 respectively). Hence, accept the hypothesis H7m and reject the hypotheses H7n and H7o. The specific indirect effect of provisioning services between capabilities and freedom of choice are significant and their

mediation effect are partial ($VAF = 33.17$ per cent). Thus, it is clear that capabilities cannot be directly translated into freedom of choice and action. That is, the direct effect of these two are insignificant (Table 6.13). But capabilities are indirectly translated into freedom of choice and action through mediating effect of provisioning services. Although freedom of choice is directly related to provisioning services and cultural services, no significant specific indirect relation exists with cultural services. So, the study highlights the full mediation of provisioning services on freedom of choice and action.

6.3 Conclusion

The ecosystem services like provisioning services, regulating services and cultural services have a significant mediating role to achieve all dimensions of wellbeing including basic materials for life, health, social relations, security and freedom of choice and action. The capabilities of farmers, including basic capabilities related to their socio-economic dimensions and demographic conditions, as well as their farming knowledge, encompass their ability, skills, and experience in farming, and their knowledge of ecosystem services, including their ability and opportunity to access these services, are not fully directly translated into different dimensions of wellbeing. Still, the role of ecosystem services provided by the wetlands are significant in achieving all dimensions of wellbeing. In short, the wellbeing of the farmers depends heavily on the indicators of capabilities and the mediating power of ecosystem services provided by the Kole wetlands paddy fields. The ecosystem services are mediate either partially or fully to achieve different dimensions of wellbeing.

The direct effect of capabilities on wellbeing dimensions including basic materials for life, health and security are significant, while some dimensions like social relations and freedom of choice are not significant. On the other hand, the indirect effect of capabilities via provisioning services and regulating services on basic materials of life are significant whereas indirect effect through cultural services is not significant. The indirect effect through provisioning, regulating and cultural services on health are significant. Moreover, indirect effect through regulating services on security is significant but not significant through provisioning and cultural services. Similarly, the intermediate effect of cultural services on social relations are valid but no significant intermediate relation exists through provisioning and regulating services. Likewise, provisioning services play a mediating role on freedom of choice and action, but regulating and cultural services have no active mediating role to achieve freedom of choice and action.

The study confirmed the role of wetland ecosystem services on wellbeing of farmers living in and around the Kole wetlands. All the three ecosystem services, either directly or indirectly influence the five dimensions of wellbeing of the farmers. The provisioning services directly and indirectly provide the wellbeing dimensions of basic materials for life, health and freedom of choice. On the other hand, regulating services also directly and indirectly provide basic materials for life and security to farmers, and also indirectly influence health to farmers. Moreover, cultural services provide basic materials for life, health, social relations and freedom of choice and action directly and influence health and social relations of the farmers indirectly. Thus, the study establish that wellbeing of the farmers not only depends on capabilities but also on the ecosystem services provided by the wetland agroecosystem. The study results supported the use of Structural Equation Modelling (SEM) as a multivariate statistical method to confirm the mediating role of ecosystem services from the complex interrelationships of several variables in the wellbeing analysis. Moreover, the study of wellbeing of the farmers has received only less attention in the field of the study of conservation of wetlands. Most of the studies focus on the characteristics and role of ecosystem services of wetlands on ecological protection of the society. The current study contributes to the body of academic literature on the role of paddy wetland agroecosystem services for promoting wellbeing to the farmers. In our future research, multiple analytical methods need to be integrated to illustrate complex relationships between ecosystem services and wellbeing.

Chapter VII
Summary of Findings and Conclusions

CHAPTER VII

SUMMARY OF FINDINGS AND CONCLUSIONS

Ecosystem services, particularly wetland agroecosystem services, have a dominant role in our economy to encompass food security and sustainable wellbeing. The Kole lands in the Thrissur district is one of the important paddy producing wetland agroecosystems in the state which provide multiple functions to the regions for their wellbeing. As paddy fields are being degraded through intensive farming practices, input efficiency is decreasing, leading to a decline in farm income, and livelihood activities. This leads to affect their overall wellbeing. In this context, the present research primarily aims to investigate the role of ecosystem services in providing wellbeing of the farmers in relation with paddy farming. In order to achieve this primary aim, study initially explores the changes in the land use pattern and their impact on production and productivity of paddy crops in Kerala particularly Thrissur Kole lands. Secondly, study analyse the impact of farming operations on ecosystem services provided by the Wetland agroecosystem of Kole lands of Thrissur. Finally, the role of capabilities of farmers to achieve their wellbeing in relation to ecosystem services is analysed. To achieve this aim and objectives, the study applied a conceptual model developed on the basis of theoretical framework of Millennium Ecosystem Assessment and Capability Approach. The variables adopted in the study to analyse the objectives have been collected from theoretical literature. The study relied on both primary and secondary data. Secondary data were collected from Department of Economics and Statistics, Kerala, was used to analyse trend of the land use pattern, cropping pattern, compound annual growth of area, production and yield of paddy crops of Kerala and particularly Thrissur district. The literatures were used to examine the pattern of ecosystem services in Kerala. Using descriptive research design, the study collected primary data from 393 paddy farmers in Kole lands in Thrissur district of Kerala using a structured questionnaire with direct face to face interview. The primary data were used to assess the economics of paddy farming through Net Returns Approach, and Benefit-Cost Ratio Analysis. The role of ecosystem services and their associations such as trade off or synergy were analysed by using Ecological Production Function and Mean Log Ratio of Ecosystem Services Trade off Index. The Structural Equation Modelling was employed to estimate the interrelationship between capabilities, ecosystem services and wellbeing of the farmers by using PLS-SEM.

7.1 Summary Findings of the Study

The study consists of seven chapters. The first chapter consists of an introduction followed by background of the study, the review of literature, statement of the problem, significance of the study, research gap, objectives, research hypothesis, data source and sampling methodology, method of analysis, and limitations of the study. The second chapter examines theoretical framework and concepts. The third chapter gives a brief description of the dynamics of paddy land use in Kerala and particularly Thrissur district, in line with area, production and productivity. The characteristics and role of study area with socio-economic profile of the sample households are examined in detail in chapter four. The fifth chapter explores the economics of paddy cultivation in terms of benefit-cost and resource use efficiency. Additionally, this chapter covers the ecosystem services association in Kole paddy wetlands. Sixth chapter assesses the role of ecosystem services to achieve wellbeing of the paddy farmers.

The **first objective** of this research study was to examine the dynamics of paddy land use in Kerala with special focus to the Kole Paddy wetland agroecosystem in Thrissur. This objective aims to examine the trend and pattern of land use and cropping pattern, particularly paddy crops in Thrissur, in comparison with Kerala average. Area, production, and yield per hectare of paddy crops in comparison with Kerala and the Thrissur district with the Kole Land area of Thrissur have been examined. The importance of Kole wetland agroecosystem of Thrissur Kole lands in Kerala is also analysed. To analyse the land use pattern of Kerala, a Bai-Perron test was conducted and identified four structural breaks during the entire period of 1980-81 to 2021-22 and estimated the compound annual growth rate of each break period. The study found that the net sown area showed a slight positive growth during the earlier break periods, but then turned to a peak decline of growth from 1998-99 to 2007-08, and continued the contraction. Furthermore, the study found that the compound annual growth rate of land use for non-agricultural use showed moderate growth in the earlier break periods but increased sharply in the later break periods since 2008-09. The study showed that while the net area sown has decreased by 0.27 per cent annually and 6.89 per cent in total, the area of land for non-agricultural purposes has increased by 1.44 per cent annually and 72.54 per cent in total. It was evident that the decrease in fallow land, wasteland, and other uncultivable land has been completely added to non-agricultural purposes. It is found out that net sown area in Kerala state declined while non-agricultural use of land increased substantially. Although the overall sharp decline in paddy area (75.81 per cent) showed clear evidence of paddy area shifting to other crops such as coconut, banana, and rubber, the study has identified positive signs of recovery

in the paddy sector during the last break period of 2013-2022. The season wise percentage variation of paddy area has revealed that a substantial increase in *Puncha* crops cultivation at the cost of *Autumn* and *Mundakan* crops still continued with a constant rate. The study found that the overall compound annual growth rate of area, and production declined whereas productivity increased at a marginal rate. However, the study also identified that since 2013-14, area, production and productivity of *Puncha* crops have grown at a better rate.

As compared to Kerala, the study found that the reduction in net sown area and increase in non - agricultural use of land in Thrissur district was much higher than the state average. As far as the trend in cropping patterns is considered, the area under paddy cultivation in Thrissur has decreased significantly compared to the state average, but the area under coconut, rubber and banana crops has increased relatively, as per the state average. The analysis on the compound annual growth rate of area, production, and productivity of paddy growing seasons in Thrissur confirms that district underwent a sharper decline in area and production than state of Kerala. In contrast, the productivity of paddy suggests a relatively stronger improvement in Thrissur than the state average, indicating greater efficiency in paddy within the shrinkage of area and production. Thrissur district performs well in overall productivity while Kerala state as a whole performs well in production and productivity during *Puncha* season. Surprisingly, since 2013, Thrissur district has recorded better growth in area, production and productivity of paddy in *Puncha* seasons compared to other seasons, as similar to the state overall growth. It is found that, although Kole wetland paddy fields have high value in monetary terms, this land converted significantly for built land and mixed crops. However, since 2013, contrary to state and district averages, the study found that, the Kole wetland paddy area increased, but production and productivity declined. The decline in productivity is an alarm for the need of the revival of paddy production in a multifunctional productive wetland ecosystem.

The **second objective** of this study was to analyse the paddy farming practices and their impact on wetland agroecosystem services association in the study area. This objective aims to assess the economics of paddy farming operations in Kole lands and their influence on ecosystem services including provisioning, regulating and cultural services. Furthermore, this objective evaluates the tradeoff and synergy of different ecosystem services through farming practices. To study the economic viability of paddy cultivation, net returns approach and the ratio of gross value of output and cost were estimated. Similarly, input efficiency and ecological efficiency were assessed by using Ecological Production Function. Ecosystem Services Tradeoff Index

and correlation analysis was used to estimate the trade off or synergy among ecosystem services.

The examination of overall economics of paddy cultivation observed that among all inputs, chemical fertilizers constitute the single largest item in average quantity and cost of total inputs applied across farm categories. The chemical fertilisers used (between 512 kg and 746 kg/ha) across size categories were six times higher than the prescribed rate suggested by the authorities, and a significant mean difference of 195 kg/ha was identified between marginal and medium holders. It was identified that out of total cost, 21.59 per cent of the cost incurred for chemical fertilizers, and their cost increases with decrease in size holding. The average quantity of weedicides and pesticides used for plant protection was much higher than the prescribed average whereas lime application is much lower than the prescribed rate. Inappropriate mixing, over dose with inefficient spraying by unskilled labour is very common in Kole lands. The overall cost incurred for nutrients and plant protection was significantly higher (34 to 39 per cent of the total cost) across farm categories. Furthermore, it is evident that cost of nutrients and plant protection decrease with increase in size holding and vice versa.

Human labour is replaced substantially by machines in the major field of operations of paddy cultivation. This decrease in labour days in paddy cultivation has helped to decrease the cost of cultivation substantially. Also, it was found that family labours and domestic workers were completely absent from paddy farming and were replaced by migrant workers. In monetary terms, the average cost of working input was lower in medium-sized farmers and in large *padasekharams* than in all other farm sizes, while the proportion of working input cost out of the total cost was higher than in all other farms. Among size of *padasekharams*, medium and small earned highest productivity and gross returns per hectare. But in operational holdings, inverse relations between size – productivity existed, with small farms performed well than other farms. In total, it was found that smaller and medium holdings were economically more efficient than others. In terms of overall profitability and production efficiency of paddy cultivation, medium-sized *padasekharams* as well as medium-sized farm holdings outperformed with the highest net returns and benefit-cost ratio. Marginal and small farms also performed well on a small scale.

It was found out that irrespective of size of Kole *padasekharams* or size of operational holding, majority operate economically efficient with better cost return balance. But it was also revealed

that 46 per cent of the sample farmers have only low level of profitability and an eight percent incur heavy loss.

In spatial comparison, the study found that farming operations in both North and South Kole are same, but they are dissimilar in terms of their ecological efficiency. In terms of productivity and net return from paddy, South Kole farms are more productive than North Kole farms.

The study results found out that paddy, fish, duck, vegetables, livestock, and straw are the significant provisioning services supplied by the Kole lands. From principal components analysis of the chemical and biological characteristics of the soil, the study identified that soil compaction, soil carbon sequestration, soil salinity, nutrient retention, and water retention are the major factors loading regulating services provided by the Kole paddy lands. Major significant cultural services identified from the Kole lands are aesthetic and social relations. Based on the provisioning services index comparison between different Kole areas, the study revealed that provisioning services in South Kole were far better than in North Kole farms. The regulating services index were found to be fair level with lowest value in all farm areas except Anthikad Block area in North Kole. Cultural services in Kole area were found to be relatively lower but more or less same in all farm areas.

The tradeoff and synergy between different ecosystem services were found to be assessed by using ecological production function with multiple regression, correlation analysis and ecosystem services tradeoff Index. Multiple regression equations have been fitted with yield per hectare as dependent variable and farm inputs and ecological inputs as independent variable indicating farm inputs including chemical weedicides, lime and labour affect positively on yield while seed, ploughing, chemical fertilisers and insecticides affect inversely on yield per hectare. It highlighted the overuse of seed, ploughing, chemical fertilizers and insecticides. The negative and positive regression coefficient values of ecological services were theoretically valid and significant. The regulating services such as, soil compaction, acidity, and salinity were negatively affecting the yield, while nutrient retention and water retention had a positive impact on the yield. While regulating services, such as soil compaction and soil acidity, showed a tradeoff with provisioning services, water retention and nutrient retention exhibited a synergistic relationship with yield per hectare.

Multiple regression equation fitted with regulating services as dependent variable and farm inputs as independent variable indicate that chemical fertilizers, insecticides and ploughing affect the regulating services negatively. The results accepted the theoretical argument of

excessive use of chemical inputs negatively affects the regulating services and in turn affects the paddy output.

The pairwise correlation among different ecosystem services indicated the insignificant tradeoff between provisioning and regulating services. But exist a strong significant tradeoff between provisioning and cultural services, while a significant synergetic relationship exhibited between regulating and cultural services.

The study used Ecosystem services Tradeoff Index to assess the supply tradeoff, demand tradeoff and supply-demand tradeoff between ecosystem services across blocks. The analysis on supply tradeoff showed a significant dominance of regulating services over provisioning services; dominance of cultural services over provisioning; and regulating services over cultural services across blocks. The ecosystem demand tradeoff was assessed in terms of benefits perceived by the farmers from the Kole lands. The study confirms that benefits from regulating services and cultural services were dominant over provisioning services across blocks. In terms of benefits, cultural services were dominant more than regulating services. The mean log ratio assessment of ecosystem services supply and demand found that perceptions of benefits from Kole farming were higher than the actual supply of services received, putting more pressure on the carrying capacity of Kole lands.

The **final objective** of the study was to assess the wellbeing of the farmers in terms of their capabilities and agroecosystem services contributed by Kole wetland paddy farming. This objective examines how the capabilities of the farmers are translated into wellbeing and the role of ecosystem services to achieve wellbeing as a mediator. The research hypothesises that ecosystem services influence directly and indirectly between capabilities and wellbeing of the farmers. To examine the hypotheses relationships, Structural Equation Modelling were applied by using PLS-SEM.

It is found out from the study that age of the farmers, education level, family and gender, house property, land ownership and per capita income from paddy are the reliable and valid indicators of basic capabilities of the farmers. The average value of these indicators is found to be significant. Each of these indicators are confirmed to be content valid as the outer loading value of all these indicators for determining basic capabilities is greater than 0.70. The study observed that, knowledge and understanding about ecosystem services of farmers act as another significant capabilities of the farmers to achieve wellbeing. The study revealed that farmers have a significant knowledge about the ability of the Kole lands to provide food and access to

other resources; their ability to provide a clean environment, ability to provide adequate nourishment and their ability to prevent diseases. Similarly, it is found out that farmers have significant knowledge about the regulating services like water recharge capacity, carbon sequestration, and the soil stability conditions of Kole paddy lands. The key ecosystem services identified by farmers in relation to cultural services are the aesthetic, recreational and educational information provided by Kole paddy lands. It is found out that the farmers are more likely to agree their overall capability to know the ecological services. Median value of ecological knowledge is estimated to be 8.00. The significant outer loading values of ecological knowledge is found to be in the range of 0.723 to 0.845. Furthermore, study estimated that knowledge, skill and experience of the farmers about how to employ inputs efficiently to produce paddy are valid capabilities of the farmers. The study finds that farmers awareness or capability level of paddy farming operations in Kole lands particularly cropping pattern, types of crop diseases affected and different nutrient and plant protection methods are moderate to apply efficiently. It was found that the median value of farming knowledge is 6.5 and outer loading value of all the identified indicators of these capabilities are 0.786 and their AVE is found out to be 0.618. The different reliability and validity test of these indicators identified as above the threshold limit prescribed in literatures. Therefore, it is concluded that farmers have a significant overall capability with outer loading value of 0.786.

Based on the observations and opinions of farmers, the present research examined level of changes (increase or decrease) in ecosystem services like provisioning, regulating and cultural services during the last 20 years in the realm of paddy farming in Kole lands. From the study, it was found that “a little more decrease” occurred in provisioning services during the period. Additionally, it is observed that among many provisioning services, only three services—paddy production, fish production, and straw—are significant, but their contributions to farmers have decreased. Furthermore, it was found that among the various regulatory services provided by Kole wetlands, water retention, carbon sequestration, and soil erosion are the significant services provided with high outer loading. However, these services were also found to be “partially decreased”. The study found that recreation, aesthetic beauty of nature and environmental education are significant cultural services which are “mildly increased” with higher outer loading. In this context, the study concludes that while cultural services are increasing mildly with paddy farming in wetlands, regulatory and provisioning services are decreasing.

The study examined the significance of different dimensions or indicators of farmers wellbeing based on the perception of achieved set of functioning. It is found from the study that there is “partial dissatisfaction” among farmers in case of achieving basic materials for life through paddy farming. Also, health as a wellbeing dimension is found to be “little more satisfied” among farmers in their achievement of wellbeing perception. The significant health indicators are found to be nutritional food, regular exercise and stress management capacity and physical and mental strength. Our study finds that farmers are “partially dissatisfied” with their personal safety and security from flood and drought, the availability of financial resources, and their equal right to use resources. It is also found that the farmers are “mildly dissatisfied” with the attainment of social relations among farmers through enjoying aesthetic beauty, opportunities for stress relaxation, cooperating social community, engage in recreational activities. Freedom of choice among farmers is found to be partially dissatisfied. Study observed that farmers are not satisfied with their democratic opportunities in decision making in farming issues, selection of good house, and their health care facilities. To conclude, farmers are mildly satisfied with the healthy living opportunities provided by Kole wetlands, while all other dimensions wellbeing do not satisfactorily provide wellbeing among farmers.

The study also examined the root cause of low or dissatisfactory levels of wellbeing dimensions among farmers and found that wellbeing dimensions are interrelated with the ecosystem services provided by the Kole wetlands and the capability of the farmers to perceive these services. This study found that the dimensions of wellbeing are directly and indirectly related to capabilities. This connection is indirectly associated with the services provided by wetland ecosystems.

The study found that farmers capabilities directly contribute to basic materials for life, with a significant β value of 0.137. In addition, all three ecosystem services directly contribute to the basic materials for life. Among these services, provisioning services ($\beta = 0.757$) were found to contribute more significantly than regulating ($\beta = 0.113$) and cultural services ($\beta = 0.110$). Additionally, the capabilities indirectly contributed to the basic materials for life through provisioning and regulating services, with respective β values of 0.337 and 0.136. In conclusion, study found that, provisioning and regulating services have a partial mediating effect on the relationship between capabilities and the basic materials for life.

The study found that capabilities of farmers directly contribute to health, with a significant β value of 0.229. Furthermore, among ecosystem services, cultural services ($\beta = 0.432$)

contributed more significantly than provisioning services ($\beta = 0.216$). Additionally, the capabilities indirectly contributed to health through provisioning, regulating, and cultural services, with respective β values of 0.096, 0.065, and 0.092 respectively. It is concluded that provisioning, regulating, and cultural services have a partial mediating effect on the relationship between capabilities and health.

The analysis revealed that the farmers' capabilities did not significantly contribute directly to their social relations. Similarly, provisioning and regulating services did not contribute significantly. However, only cultural services ($\beta = 0.778$) directly contributed to social relations among farmers. Hence, cultural services act as a full mediator to achieve social relations among farmers. The mediating effect was estimated to be 77 percent, and the significant β value was 0.165.

It was found that farmers capabilities directly contributed security to them. At the same time regulating services also contributed directly some security to farmers. Study revealed that regulating services played a partial mediating role in between capabilities and security.

It is ascertained that the capabilities of the farmers do not directly contribute to achieve freedom of choice, but indirectly, through provisioning services, can achieve some amount of freedom of choice. So, the full mediating role of provisioning services to achieve freedom of choice is identified in the study.

In conclusion, farmers have different capabilities, including basic capabilities, ecological knowledge, and farming knowledge, but these capabilities do not fully translate for wellbeing. In fact, farmer's wellbeing depends not only on their different capabilities but also on the ecosystem services provided by productive Kole paddy wetlands. The study concludes that all the wellbeing indicators proposed by the Millennium Ecosystem Assessment Report (2005), including basic materials for life, health, social relations, security, and freedom of choice, depend partly or wholly on farmer's capabilities and the ecosystem services provided by Kole wetlands. Hence the study remarks that the wellbeing of the farmers depends upon conservation of Kole wetlands and their related ecosystem services.

7.2 Implications and Recommendations of the Study

The present research study offers a significant multidimensional theoretical contribution by integrating the capability approach with ecosystem services approach to assess farmers wellbeing in paddy-based wetland agricultural systems. This study highlights the welfare

dimensions that farmers receive through the ecosystem services of the Kole wetland paddy farming ecosystem, rather than the income matrix of wellbeing. Conceptualizing ecosystem services not simply as ecological production structures but also as mediating factors that help farmers to achieve valuable activity, this study reconstructs wellbeing as an outcome shaped by ecological and socioeconomic dimensions. The study underpins the critical role of ecosystem services like provisioning, regulating, and cultural ecosystem services, such as soil fertility, water retention, and landscape aesthetics, in promoting capabilities of the farmers, particularly in the context of ecological vulnerability and economic uncertainty across paddy farming areas.

The study reminds us that wetland is a life supporting system that performs numerous ecosystem services and economic functions which are critical to achieve wellbeing. But such a life supporting system faces critical imbalances through overuse of resources. The overextraction of a natural ecosystem, such as the Kole wetland ecosystem, through various anthropogenic activities on farmlands, including man-made infrastructural expansion and the overuse of chemical inputs, creates severe stress and operates far beyond its carrying capacity. Within this scenario, to achieve sustainable wellbeing to farmers, study advocated following policy recommendations.

Firstly, study suggests that agricultural development strategies should be practically designed to achieve sustainable wellbeing pathways, by incorporating the role of ecosystem services in agricultural lands beyond yield specific strategies.

Secondly, at the policy level, this study advocates for integrated land use planning and participatory ecosystem service assessment by ensuring the voices of farmers, especially in Wetland agrarian regions, where ecological assets are deeply intertwined with livelihood security.

Thirdly, study suggests an integrated management plan exclusively for Thrissur Kole Wetland Paddy Fields. The conservation of wetlands can be restored naturally through a participatory-led management approach that balances the objectives of biodiversity conservation with the sustainable livelihoods and wellbeing of dependent communities.

Fourthly, the study traces out the unawareness among farmers about the carrying capacity of wetlands particularly paddy wetlands. Hence, the study suggests to raise awareness to farmers and chief executives of Padasekhara samithies about the role of ecosystem services to achieve livelihood and their carrying capacity as a wetland.

Fifthly, it is evident from the study that common public believe that Kole lands are waste lands and consider it as a real estate asset. Hence, it is recommended to raise public awareness about the role of wetlands as a food hub for all living organisms and initiate measures to conserve them in supporting of food security and the wellbeing of local people.

Sixthly, the study finds a significant difference in cost structure and, consequently, profitability among different land tenures and paddy field sizes. The survey shows that lands near coastal areas are experiencing severe salt intrusion, which adversely affects production. Therefore, irrespective of the size of the holding, the authorities should ensure cost efficiency by implementing proper management strategies. Similarly, taking into account the suggestions of farmers, urgent action is required to adopt improved and innovative methods such as smart sluice technologies to prevent salt intrusion.

Seventhly, the survey shows that lack of support from higher authorities during cultivation is the main reason for abandoning cultivation or leasing out agricultural land. Those who lease land use excessive amounts of chemicals and enjoy short-term benefits, which destroys the natural fertility of the soil in the future. Therefore, the study suggests that proper assessment should be made by the authorities regarding the soil test and application of chemicals in all types of agricultural land.

Finally, study proposes to raise and timely disbursement of all the existing incentive scheme to farmers to adopt sustainable farming practices which is more supportive to natural ecosystem services.

7.3 Limitations and suggestions for Future Research

The literature on ecosystem services and agricultural land use tends to be more descriptive and qualitative in nature. Moreover, it is challenging that Kerala has never conducted a quantitative study on ecosystem services, their trade-offs and the role of welfare distribution in paddy fields. This study is an initial step towards assessing ecosystem services and their trade-offs, which has several limitations particularly assessment of regulating services. Additionally, the dimensions of wellbeing in the proposed model are centred around the adopted theoretical framework. There are many other possibilities for the dimensions of wellbeing in other theoretical models that are not considered in this study. These limitations can be considered as an area for future research. Methodologically, this study demonstrates how ecosystem services act as mediating variables within the capability approach frameworks. Hence, it offers an innovative, replicable methodological model for future research in agroecological and human

development contexts. Similarly, the present study is confined to wetland paddy farming in the Thrissur Kole area alone due to time and financial constraints, indicating a wider scope for future research on how farming across states or districts in similar ecological contexts, as well as a comparative analysis with dry lands, shapes the nexus between capability, ecosystem, and wellbeing.

7.4 Conclusion

Farmers are the primary food producers in society. They feed us by taking on all the risks associated with farming, from climate change to pest infestation. The paddy farmers living around wetland areas continue to cultivate paddy because they are deeply attached to the land passed down from their ancestors. However, due to ongoing agricultural practices and the environmental hazards posed by climate change, the vast majority of farmers are concerned about whether they can rely entirely on paddy farming for their livelihoods and wellbeing. As a result, paddy cultivation is undergoing a significant structural and ecological transformation in Kole wetlands, and farmers have turned to other non-agricultural activities for livelihood, which poses a major threat to the state's food security. However, due to intensified input use and cost adjustments, there was a marginal improvement in profitability regionally, but these short-term gains are offset by the production risk arising from the degradation of ecosystem services, especially regulating services such as soil fertility maintenance, water retention, and carbon sequestration. Meanwhile, the excessive and unbalanced use of chemical inputs results trade-off between different ecosystem services which make great threat to the long-term livelihood strategies. Beyond these threats, the capabilities and functioning, the cornerstone of the wellbeing of many farmers who rely on agriculture and its allied sectors to sustain their families, are being questioned. The capabilities of the farmers do not directly translate into wellbeing, but can only be achieved through the ecosystem services provided by the Kole Wetland Agro-Ecosystem. However, these highly productive multi functioning Kole Wetland Ecosystems are on the verge of degradation due to anthropogenic activities, which is seriously affecting the wellbeing capabilities of farmers. The research partially endorses Sen's capability approach to wellbeing, but highlights the importance of ecosystem services in providing wellbeing to farmers living in an ecologically fragile wetlands, like paddy wetlands area along with their capabilities. Though engaging paddy cultivation is not sufficient to achieve their food security and livelihood, it is urgent to address the ecological importance of paddy wetland area and conserve these lands for sustainable wellbeing. An ecologically tailored strategies based on regional characteristics are needed to recoup the sustainable paddy farming. To achieve

wellbeing beyond yield and profit margin requires long-term sustainable policies that strengthen capabilities and functioning of farmers based on ecosystem services. Sustainable organic farming practices that combine spatial and size-specific efficient input use and appropriate technology should be promoted in compatible with soil health and ecological function.

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ANNEXURE 5.1

Minimum Data Set based on Principal Component Analysis

Particulars	PC-I	PC-II	PC-III	PC-IV	PC-V	PC-VI	PC-VII
Eigen value	6.388	4.390	3.260	2.550	1.689	1.341	1.228
Variance (%)	26.62	18.29	13.58	10.65	7.04	5.59	5.12
Cumulative variance (%)	26.62	44.91	58.49	69.12	76.16	81.74	86.86
Factor Loadings							
Bulk density	0.919						
Porosity	-0.845						
Available P	-0.827						
Dehydrogenase activity	0.708						
Available Mn	0.681						
Available N		0.835					
Soil Moisture		0.774					
Organic Carbon		0.757					
Microbial Biomass Carbon		0.659					
Available K		-0.633					
ECEC			0.867				
EA			0.762				
Available Ca			-0.733				
Particle Density			-0.679				
Available Zn				0.918			
Available Fe				0.851			
Available S				0.611			
EC					0.946		
PH					-0.742		
Available Cu						-0.835	
Max. Water holding Capacity							0.838
Mean Weight Diameter							-0.601

Source: Primary Survey

ANNEXURE 5.2

Weights of Each Principal component

Principal Components	PC-I	PC-II	PC-III	PC-IV	PC-V	PC-VI	PC-VII
Weights (Wi)	0.31	0.21	0.16	0.12	0.08	0.06	0.06

Source: Primary survey

ANNEXURE 5.3

Distribution of Principal Component Analysis based on Literature

Component	Main Interpreted Factor	Supporting Literature / Citation
PC-I: Soil compaction & nutrient mix	Bulk Density, Avail.P, Dehydrogenase	Bulk density and porosity are common soil compaction indicators influencing root penetration and nutrient availability (<i>Lal, 2015; Reeves, 1997</i>).
PC-II: Carbon Sequestration, Organic & microbial soil health	OC, Avail.N, Soil Moisture, Biomass Carbon	Soil organic matter, N, and microbial biomass are primary indicators of soil fertility and carbon cycling (<i>Anderson & Domsch, 1993; Lal, 2004</i>).
PC-III: Cation exchange, nutrient retention	ECEC, EA, Avail.Ca	Effective cation exchange capacity and exchangeable acidity regulate soil nutrient balance and buffering capacity (<i>Thomas, 1982; Brady & Weil, 2016</i>).
PC-IV: Micronutrient availability	Avail. Zn, Avail. Fe	Zn and Fe availability are key micronutrients that influence plant growth and nutrition (<i>Alloway, 2008; Marschner, 2012</i>).
PC-V: Salinity / salt concentration	EC	Electrical conductivity is a direct measure of soil salinity (<i>Rhoades et al., 1999</i>).
PC-VI: Acidity & heavy metal binding	pH, Avail. Cu	Soil pH governs Cu solubility and bioavailability; low pH increases metal mobility (<i>McBride, 1994; Kabata-Pendias, 2011</i>).
PC-VII: Water Retention capacity	Maximum Water Holding Capacity	Water retention is a core soil physical property supporting regulating ecosystem services (<i>FAO, 2015; Millennium Ecosystem Assessment, 2005</i>).

Source: Secondary Survey

ANNEXURE 5.4

Soil Quality Range

Sl No.	Range of SQI value	Soil quality class
1	0.80 - 1.00	Very good
2	0.60 - 0.79	Good
3	0.40 - 0.59	Fair
4	0.20 - 0.39	Bad
5	0.00 - 0.19	Very bad

Source: Partoyo (2005)

APPENDIX - I

INTERVIEW SCHEDULE FOR COLLECTING PRIMARY DATA

TOPIC: ECOSYSTEM SERVICES APPROACH TO THE INTERLINKAGES BETWEEN KOLE WETLAND FARMING AND HUMAN WELLBEING IN KERALA

A. General Information

Name of the respondent:

Type of Respondent: ☐Farmer (1) ☐ Fisherman (2) ☐Both (3)

1. Age of the respondent

2. Gender: ☐Male (1) ☐Female (2)

3. Caste: ☐Hindu (1) ☐Christian (2) ☐Muslim (3) ☐Others (4)

4. Size of the Family: ☐Nuclear (1) ☐ Joint (2)

5. Family Composition:

Sl. No	Name of the Family Members	Age	Sex	Education	Year of Schooling	Occupation	Monthly Income (In Rupees)
1							
2							
3							
4							
5							

6. Primary source of Income of the family:

☐Paddy Cultivation (1) ☐Govt. Service (2) ☐Private Job (3)
☐Business (4) ☐Agriculture and Livestock (5)

7. Other Source of Income:

8. Do you have Kisan Credit Card? ☐Yes (1) ☐No (0)

9. Main Source of Drinking Water: ☐Own Well (1) ☐Public Tap (2)

☐Home Tap connection (3) ☐Others (4)

10. Source of Drinking water during summer period:☐Own Well (1)

☐Public Tap (2) ☐Home Tap connection (3) ☐Others (4)

11. Type of the house: ☐Concrete (1) ☐ Thatched (2) ☐Other (3)

12. Size of the land area owned (In Acres)

(a) Dry land (pady+ homestead property):

(b) Kole Land in Acres (cultivable+ fallow+water logged+waste):

13. Area of the land taken as lease for paddy cultivation (in Acres):

14. If leased, amount of rent of the leased land:

15. Distance away from Kole lands:☐ < than ½ km (1) ☐ ½ km to 1 km (2) ☐ 1km to 1 ½ km (3) ☐ >1½ km (4)

16. Generation of the farmer: ☐First (1) ☐Second (2) ☐Third (3) ☐Fourth (4) ☐Fifth (5)

17. How long you are living in this area: ☐ >50 years (1) ☐Between 30-50 years(2) ☐30-10 years (3)

☐ <10 years(4)

B. Particulars of Kole land Farming

18. Name of the Padasekhara Samithi:

19. Area, production and cost of crops grown

		Before 15 years			2022		
Sl. No	Types of Crops	Area (In Acres)	Production (in Kilograms)	Cost of farming (In Rupees)	Area (In Acres)	Production (in Kilograms)	Cost of farming (in Rupees)
1	Paddy						
2	Fish						
3	Duck						
4	Lotus						
5	Livestock (cow, Buffalo in Nos)						
6	Other Crops(specify) (Herbal vegetation)						

20. Area of Kule land kept as fallow (in Acres):

21. Reasons why the cultivable area kept as fallow: ☐ Lack of irrigation (1) ☐ waterlogged (2) ☐ fear of crop failure (3) ☐ No active members in the family (4)

22. Do you make any change of paddy crops grown since last 10 years:

☐ Yes (1) ☐ No (2)

23. If yes, reason why do you make change?: ☐ suggested by padasekharam (1)

☐ own interest (2) ☐ other reason (3)

24. Rank your order of interest on the basis of the usage of chemical inputs and modernisation in Kule paddy farming (Rank from 1 to 7)

	Attributes	Rank
1	Earn better production	
2	Earn profit	
3	Follow the predecessors	
4	Conserve wetland	
5	Provide food to society	
6	Enjoyment and time pass during old age	
7	Social interest	

25. Particulars of Fertilisers applied in single farming period:

	Before 15 years				2022			
Sl. No	Name of the chemical fertilisers used	Number of times used	Total quantity used (in Kg)	Cost (in Rs/-)	Name of the chemical	Number of times used	Total quantity used (in Kg)	Cost (in Rs/-)

					fertilisers used			
1	Urea							
2	Potash							
3	Ammonium Sulphate							
4	Paddy Mixture							
5	Super phosphate							
6								
7								
Sl. No	Name of the Organic fertilisers /Bio fertilisers used	Number of times used	Total quantity used (in Kg)	Cost (in Rs/-)	Name of the chemical fertilisers used	Number of times used	Total quantity used (in Kg)	Cost (in Rs/-)
1	Cow dung							
2	Lime							
3	Green Manure							
4	Oil Cake/							
5	Bone meal							
6								
7								

26. Particulars of Insecticides/pesticides used:

	Before 15 years				2022			
Sl. No	Name of the chemical Pesticides used	Number of times used	Total quantity used (in Kg)	Cost (in Rs/-)	Name of the chemical pesticides used	Number of times used	Total quantity used (in Kg)	Cost (in Rs/-)
1								
2								
3								
4								
Sl. No	Name of the Organic pesticides used	Number of times used	Total quantity used (in Kg)	Cost (in Rs/-)	Name of the organic pesticides used	Number of times used	Total quantity used (in Kg)	Cost (in Rs/-)
1								
2								
3								

28 a. Particulars of weedicides used:

	Before 15 years				2022			
Sl. No	Name of the chemical weedicides used	Number of times used	Total quantity used (in Kg)	Cost (in Rs/-)	Name of the chemical weedicides used	Number of times used	Total quantity used (in Kg)	Cost (in Rs/-)
1								
2								
3								
4								

Sl. No	Name of the Organic weedicides used	Number of times used	Total quantity used (in Kg)	Cost (in Rs/-)	Name of the organic weedicides used	Number of times used	Total quantity used (in Kg)	Cost (in Rs/-)
1								
2								
3								

27. Other input Particulars:

	Before 15 years				2022		
	Items	Qty/hours	Cost	Procured/available	Qty/hours	Cost	Procured/available
1	Seed/seedling Cost						
2	Ploughing & Levelling						
3	Pumping engine charge						
4	Bund preparation- Labour						
5	Planting cost: Labour/Machine						
6	Harvesting: Labour						
7	Harvesting: Machine						
8	Transportation/Marketing						
9	Weeding Labour charge						
10	Miscellaneous cost (specify)						
11	Post harvesting cost						
12							

30. Total Labour hours used:

Family labour: ☐

Hired Labour: ☐

31. Area of Double crops grown:

32. Quantity of production in double crops:

33. Do you have ownership of following assets/equipment?

Sl. No	Name of the Equipment	Yes (1)	No (0)
1	Ploughing Machine		
2	Seedling machine		
3	Harvesting		
4	Sprayer		
5	Any Other (specify)		

34. Reasons for Crop damage experienced in last five years:

☐ Untimely rain (1)

☐ Heavy Rainfall (2)

☐ Drought (3)

☐ Salt water intrusion (4)

☐ Attack of pest and diseases (5)

- ☐ Breaking of Bunds (6)
- ☐ Any other (specify) (7)
35. Post-harvest particulars:
- a. Sold at farm level (in Kg):
- b. Usage as seed (in Kg):
- c. Own consumption (in Kg):
- d. Quantity/price of paddy straw produced/sold:
36. Are you believe that the spread of mosquito in house is due to the canal system in Kole lands? ☐ Yes (1)
☐ No (2)
37. Are you notice severe illness like cancer, Asthma, Malaria, Brochities etc., affected many people in the locality.
☐ Yes (1) ☐ No (2)
38. Are you feel that these health problems in and around Kole land area is due to the misuse and overuse of chemical inputs?
☐ Yes (1) ☐ No (2)
39. Are you feel any breathing problem during farming period/at the time of applying chemical inputs?
☐ Yes (1) ☐ No (2)
40. Are you believe that tourism is an added value to Kole lands?
☐ Yes (1) ☐ No (2)
41. Extend of damage to crops:

Capabilities- (1) Provisioning services: Strongly Agree = SA, Strongly Disagree=SD

	Capabilities	SA 10	9	8	7	6	5	4	3	2	SD 1
1	Do you know Kole land farming enable you to access resources and earn food/income and gain livelihood?										
2	Do you know Kole land enables you to live in a clean environment?										
3	Do you know Kole land provides you an adequate nourishment?										
4	Does Kole land provide you adequate drinking water?										
5	Do you believe that Kole lands keep you from avoidable diseases?										
6	Does Kole lands provide sufficient employment?										
(2) Regulating Services		10	9	8	7	6	5	4	3	2	1

1	Does Kole land reduce your vulnerability to ecological shocks and stress?										
2	Do you know Kole lands maintain water regulation?										
3	Do your Kole lands and canal system enable ground water recharge?										
4	Does Kole land farming produce carbon sequestration										
5	Does the Kole lands farming enable to maintain Soil Stability?										
6	Do you know plant protection chemical inputs produce GHGs (damaging environment)										
(3) Cultural Services											
1	Do you know Kole lands contain enough recreation facilities such as fishing, sports, picnic?										
2	Do you realise the aesthetic value of Kole lands?										
3	Do you know the ability of Kole lands to express cultural and spiritual values such as festivals, ceremonies?										
4	Does the Kole land enable to provide the environmental education (learn from nature)										
5	Does the Kole land avoid tension and conflict over resource scarce?										

C_Farming Knowledge

1	I can independently adapt my farming practices based on weather conditions.										
2	I am capable of make decisions about which inputs to use (seeds, fertilizers, etc.).										
3	I can identify and respond to early signs of crop disease and the use of insecticides.										
4	I am capable of applying new techniques (trillers/harvesting machine, HYV seeds) learned through experience.										
	I know how to correctly apply fertilizers and pesticides										
6	I am capable of keeping Labour skill efficiently										

C. Wellbeing (Satisfaction Level) – Highly Satisfied=HS, Highly Dissatisfied=1

	Indicator statement	HS 10	9	8	7	6	5	4	3	2	HD 1
Basic material for a good life											
1	I can secure basic goods and services (e.g., food, cloth, living materials, transportation) for a good life										
2	I have a regulated life environment (sufficient drinking water during summer, electricity, gas etc.,)										
3	I have good access to education and training (access to schools, training centres)										
4	My households have comfortable environment to live										
5	I have satisfied area of arable land/Kole land										
6	I have a satisfied number of livestock										
7	I have sufficient availability to Paddy husk for feeding livestock										
Health											
1	Your household can afford/have enough food with nutrition to keep alive and healthy										
2	I engage in healthy behaviours such as regular exercise and stress management.										
3	Securing clean air and temperature control										
4	Access to safe drinking water										
5	Keep away the physical and mental illness										
Security											
1	I can live with peace of mind and safety										
2	Getting the access to financial resources for daily life										
3	I have equal right to use natural resources and energy appropriately										
4	Protected from flood or drought										
Good social relations											
1	I got opportunities for aesthetic experiences and enjoyment of natural beauty										

	(photography, watching nature)										
2	I often got opportunities for relaxation and stress relief from kole land										
3	Promoted me for enhance community and social connectedness among the local residents										
4	I and my family frequently engage in recreational activities (fishing, swimming, bird watching, kiting etc..)										
5	Able to support me by giving information (Padasekharams)										
6	It provided me many opportunities to meet and cooperate with the social community (festivals)										
Freedom of choice and action											
1	A fair chance is given to everyone to succeed in farming										
2	I have an opportunity to influence decisions in farming and social issues										
3	I have freedom to choose between different options										
4	I have full freedom and opportunity to choose satisfied another/secondary job										
5	You have affordability to quality of housing with a good natural environment										
6	You have affordable access to quality health care										

D. Your perspective/opinion about of changes (increase or decrease) in Ecosystem Services provided by Kole lands in the last 20 years. (10=strongly increase, 1=strongly decrease)

	Provisioning Services	SI 10	9	8	7	6	5	4	3	2	SD 1
1	Paddy production										
2	Availability of Clean water										
3	Fish varieties (Natural) and other species (frog, snail, tortoise)										
4	Duck rearing										
5	Quantity of Straw or Husk										
6	Number of Livestock										
(2) Regulating Services		10	9	8	7	6	5	4	3	2	1
1	Natural fertility of the soil and Nutrients										
2	Flood control capacity										

3	GHG Emission through chemical inputs										
4	Water retention or recharge capacity										
5	Carbon sequestration										
6	Soil Erosion										
(3) Cultural Services											
1	Kole lands provide Education and information (padasekharams)										
2	Recreation like fishing, swimming, bird watching, sky flying etc)										
3	Explore Aesthetic beauty (photography, nature watching)										
4	Cultural Festivals (religious, festivals, etc)										

- c. Point out your perceptions about positive and negative impacts of fish farming in kole lands.

Sl. No	Positive impacts	Tick	Negative	Tick
1	Additional income to farmers (1)	☐	Delay in dewatering (1)	☐
2	Additional income to padasekhara samithi (2)	☐	Delay in agricultural operations (2)	☐
3	Organic manure (3)	☐	Risk of rain due to delay (3)	☐
4	Less weeds (4)	☐	Others (specify) (4)	☐

- d. Mark your perceptions about positive and negative impacts of Duck penning

Sl. No	Positive	Tick	Negative	Tick
1	Additional income (1)	☐	Increase variety of weeds through excreta (1)	☐
2	Destroy pests and insects (2)	☐	Spoil bunds (2)	☐
3	Organic Manure (3)	☐	Spoil rice (3)	☐
4	Increase soil fertility (4)	☐	Any other (specify) (4)	☐
5	Clean up weeds and wastes (5)	☐		

- e. Your perception about double farming (Advantages and challenges)

- f. Problems and challenges faced during farming period related to water management, harvesting and farming practices:

- g. Comment your opinion about the role of Padasekhara samithis to support paddy farming:

- h. Your opinion and suggestions about to conserve Kole wetland paddy farming to promote food security and employment