MIXED FARMING AND ITS SUSTAINABILITY: A STUDY ON PALAKKAD DISTRICT IN KERALA

Thesis Submitted to University of Calicut for the award of the degree of

Doctor of Philosophy in Economics

By

SATHYAVATHI M

Under the Supervision of

Dr. K V Ramachandran
Professor (Retd.)
Department of Economics
University of Calicut
Dr. John Matthai Centre
Aranattukara, Thrissur.

Department of Economics, University of Calicut,

Dr. John Matthai Centre, Aranattukara, Thrissur-680618

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CERTIFICATE

This is to certify that the thesis entitled, **"Mixed Farming and its Sustainability: A Study on Palakkad District in Kerala "** submitted to the University of Calicut in partial fulfillment of the requirements for the award of the Degree of Doctor of Philosophy in Economics, is a record of original work done by Ms. Sathyavathi M under our supervision and guidance and the thesis has not formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title to any candidate in any university. She is allowed to submit the thesis to the University for Evaluation.

Dr. K V Ramachandran

(Supervising Guide)

Professor (Retd.)
Department of Economics
University of Calicut
Dr. John Matthai Centre
Aranattukara, Thrissur.

Dr. Muneer Babu M

(Co-Guide)

Assistant Professor
Department of Economics
University of Calicut
Dr. John Matthai Centre
Aranattukara, Thrissur.

Place: Thrissur

Date: 16/7/2025

DEPT. OF ECONOMICS, Dr. JOHN MATTHAI CENTRE ★ THRISSUR-680 618 ★ UNIVERSITY OF CALICUT

CERTIFICATE

This is to certify that corrections are made as per suggestions by the adjudicators in the thesis of our research scholar, Sathyavathi M titled "**Mixed Farming and its Sustainability: A Study on Palakkad District in Kerala**."

Dr. K V Ramachandran

(Supervising Guide)

Professor (Retd.)
Department of Economics
University of Calicut
Dr. John Matthai Centre
Aranattukara, Thrissur.

Dr. Muneer Babu M

(Co-uide)

Assistant Professor
Department of Economics
University of Calicut
Dr. John Matthai Centre
Aranattukara, Thrissur.

Place: Thrissur

Date: 16/7/2025

DEPT. OF ECONOMICS, Dr. JOHN MATTHAI CENTRE ★ THRISSUR-680 618 UNIVERSITY OF CALICUT

DECLARATION

I hereby declare that the work presented in the thesis **"Mixed Farming and its Sustainability: A Study on Palakkad District in Kerala"** submitted to the University of Calicut for the award of the degree of Doctor of Philosophy in Economics is based on the original work done by me under the guidance of Dr. K V Ramachandran, Professor of Economics (Retd.), Department of Economics, Dr. John Matthai Centre, Aranattukara, Thrissur and Dr. Muneer Babu M, Assistant Professor, Dr. John Matthai Centre, Aranattukara, Thrissur 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.

Sathyavathi M
Research Scholar in Economics
Dr. John Matthai Centre
Aranattukara, Thrissur.

Dr. K V Ramachandran
(Supervising Guide)
Professor (Retd.)
Department of Economics
University of Calicut
Dr. John Matthai Centre
Aranattukara, Thrissur.

Dr. MuneerBabu M
(Co-Guide)
Assistant Professor
Department of Economics
University of Calicut
Dr. John Matthai Centre
Aranattukara, Thrissur.

Place: Thrissur

Date: 16/7/2025

DEPT. OF ECONOMICS, Dr. JOHN MATTHAI CENTRE ★ THRISSUR-680 618

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Sathyavathi M

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MIXED FARMING AND ITS SUSTAINABILITY: A STUDY ON PALAKKAD DISTRICT IN KERALA

Abstract

Mixed farming is a farming system which combines crop production with livestock rearing conducted by households which together forms integrated components of a single farming system. In the study mixed farming is defined as farming which practices paddy cultivation along with cattle rearing. The study aimed to explore the complementary relationship between two components such as paddy cultivation and cattle rearing within mixed farming system. The study also tried to understand as whether mixed farming system could contribute to the attainment of three sustainability dimensions that is economic social and environmental and to what extent. The study also focused on determinants of sustainability in mixed farming. For analyzing the stated objectives, the study is conducted in Palakkad District of Kerala and data is collected from 394 farmers practicing paddy cultivation along with cattle rearing. Two important indices are computed such as Complementarity Index – to measure the complementary relationship between paddy cultivation and cattle rearing and Sustainability Index – to measure the economic, environmental and social sustainability of mixed farming. To measure the sustainability of mixed farming, the FAO's approach to Sustainable Agriculture served as the basis with some modifications. To trace out the determinants of sustainability in mixed farming, the Tobit regression model is employed.

Complementarity refers to the synergistic relationship between paddy cultivation and cattle rearing where their combined activity leads to higher net farm income than if they were managed independently. The findings from the Complementarity Index (CI) which is computed by combining the methodology adopted by Choi et al., 2008 and Lee, 2011, indicates that 88.1% of mixed farms demonstrated complementarity between paddy cultivation and cattle rearing, enhancing both productivity and resource efficiency. Sustainability Index evaluates a mixed farm's ability to balance environmental health, economic profitability and social well-being. From the study it can be concluded that, 65.7% of mixed farms are demonstrating sustainable practices. This suggests that most mixed farms are either meeting or nearing sustainability standards, reflecting a positive trend in sustainable farming. The sustainability of mixed farming is influenced by several key factors, each playing a vital role in the overall resilience and efficiency of the system. The study of sustainability determinants in mixed farming reveals that factors like cattle output share and farming experience positively influence sustainability, while mixed farming output and contribution of family labour negatively affect the sustainability index. By examining these factors, the study aims to identify practices that can improve the economic, environmental, and social sustainability of mixed farming. In summary, the study on mixed farming and its sustainability emphasizes the significance of implementing methods that strike a balance between social well-being, environmental health, and economic viability.

Keywords: Mixed farming, Economic Sustainability, Environmental Sustainability, Social Sustainability, Complementarity.

സമ്മിശ്ര കൃഷിയും അതിന്റെ സുസ്ഥിരതയും: കേരളത്തിലെ പാലക്കാട് ജില്ലയെക്കുറിച്ചുള്ള ഒരു പഠനം

സംഗ്രഹം

സമ്മിശ്ര കൃഷി എന്നത് വിള ഉൽപാദനവും കന്നുകാലി വളർത്തലും സംയോജിപ്പിച്ച് ഒരു കൃഷി സമ്പ്രദായത്തിന്റെ സംയോജിത ഘടകങ്ങൾ സൃഷ്ടിക്കുന്ന ഒരു കൃഷി രീതിയാണ്. പഠനത്തിൽ സമ്മിശ്ര കൃഷിയെ കന്നുകാലി വളർത്തലിനൊപ്പം നെൽകൃഷി ചെയ്യുന്ന കൃഷി എന്നാണ് നിർവചിച്ചിരിക്കുന്നത്. സമ്മിശ്ര കൃഷി സമ്പ്രദായത്തിനുള്ളിൽ നെൽകൃഷി, കന്നുകാലി വളർത്തൽ എന്നിങ്ങനെ രണ്ട് ഘടകങ്ങൾ തമ്മിലുള്ള പൂരക ബന്ധം പര്യവേക്ഷണം ചെയ്യുന്നതിനാണ് പഠനം ലക്ഷ്യമിടുന്നത്. സമ്മിശ്ര കൃഷി സമ്പ്രദായത്തിന് സാമ്പത്തിക, സാമൂഹിക, പാരിസ്ഥിതിക എന്നീ മൂന്ന് സുസ്ഥിര മാനങ്ങൾ കൈവരിക്കാൻ കഴിയുമോ എന്നും എത്രത്തോളം എന്നും മനസ്സിലാക്കാനും പഠനം ശ്രമിച്ചു. സമ്മിശ്ര കൃഷിയിൽ സുസ്ഥിരതയുടെ നിർണ്ണായക ഘടകങ്ങളിലും പഠനം ശ്രദ്ധ കേന്ദ്രീകരിച്ചു. പ്രഖ്യാപിത ലക്ഷ്യങ്ങൾ വിശകലനം ചെയ്യുന്നതിനായി, കേരളത്തിലെ പാലക്കാട് ജില്ലയിലാണ് പഠനം നടത്തിയത്, കന്നുകാലി വളർത്തലിനൊപ്പം നെൽകൃഷി പരിശീലിക്കുന്ന 394 കർഷകരിൽ നിന്ന് ഡാറ്റ ശേഖരിച്ചു. നെൽകൃഷിയും കന്നുകാലി വളർത്തലും തമ്മിലുള്ള പൂരക ബന്ധം അളക്കുന്നതിന് പൂരക സൂചികയും സമ്മിശ്ര കൃഷിയുടെ സാമ്പത്തിക, പാരിസ്ഥിതിക, സാമൂഹിക സുസ്ഥിരത അളക്കുന്നതിന് സുസ്ഥിരതാ സൂചികയും പോലുള്ള രണ്ട് പ്രധാന സൂചികകൾ കണക്കാക്കി. സമ്മിശ്ര കൃഷിയുടെ സുസ്ഥിരത അളക്കുന്നതിന്, എഫ്എഒയുടെ സുസ്ഥിര കൃഷിയോടുള്ള സമീപനം ചില പരിഷ്കാരങ്ങളോടെ അടിസ്ഥാനമായി വർത്തിച്ചു. സമ്മിശ്ര കൃഷിയിലെ സുസ്ഥിരതയുടെ നിർണ്ണായക ഘടകങ്ങൾ കണ്ടെത്തുന്നതിന്, ടോബിറ്റ് റിഗ്രഷൻ മോഡൽ ഉപയോഗിച്ചു.

നെൽകൃഷിയും കന്നുകാലി വളർത്തലും തമ്മിലുള്ള ആശ്രിത ബന്ധത്തെയാണ് പരസ്പരപൂരകം എന്ന് പറയുന്നത്, അവിടെ അവയുടെ സംയോജിത പ്രവർത്തനം സ്വതന്ത്രമായി കൈകാര്യം ചെയ്യുന്നതിനേക്കാൾ ഉയർന്ന അറ്റ കാർഷിക വരുമാനത്തിലേക്ക് നയിക്കുന്നു. 2008-ൽ ചോയി തുടങ്ങിയവർ സ്വീകരിച്ച രീതിശാസ്ത്രം സംയോജിപ്പിച്ച് കണക്കാക്കിയ പരസ്പരപൂരകം സൂചികയിൽ നിന്നുള്ള കണ്ടെത്തലുകൾ സൂചിപ്പിക്കുന്നത്, 88.1% സമ്മിശ്ര കൃഷിയിടങ്ങളും നെൽകൃഷിയും കന്നുകാലി വളർത്തലും തമ്മിലുള്ള പൂരകത്വം പ്രകടമാക്കിയെന്നും ഇത് ഉൽപ്പാദനക്ഷമതയും വിഭവ കാര്യക്ഷമതയും വർദ്ധിപ്പിച്ചെന്നും ആണ്. പാരിസ്ഥിതിക ആരോഗ്യം, സാമ്പത്തിക ലാഭക്ഷമത, സാമൂഹിക ക്ഷേമം എന്നിവ സന്തുലിതമാക്കാനുള്ള ഒരു സമ്മിശ്ര കൃഷിയിടത്തിന്റെ കഴിവിനെ സുസ്ഥിരതാ സൂചിക വിലയിരുത്തുന്നു. പഠനത്തിൽ നിന്ന് നിഗമനം ചെയ്യാൻ കഴിയുന്നത്, 65.7% സമ്മിശ്ര കൃഷിയിടങ്ങളും സുസ്ഥിര രീതികൾ പ്രകടിപ്പിക്കുന്നുണ്ടെന്നാണ്. മിക്ക സമ്മിശ്ര കൃഷിയിടങ്ങളും സുസ്ഥിരതാ മാനദണ്ഡങ്ങൾ പാലിക്കുന്നുണ്ടെന്നോ അടുത്തെത്തുന്നുവെന്നോ ആണ്, ഇത് സുസ്ഥിര കൃഷിയിലെ ഒരു പോസിറ്റീവ് പ്രവണതയെ പ്രതിഫലിപ്പിക്കുന്നു. സമ്മിശ്ര കൃഷിയുടെ സുസ്ഥിരതയെ നിരവധി പ്രധാന ഘടകങ്ങൾ സ്വാധീനിക്കുന്നു, അവയിൽ ഓരോന്നും വ്യവസ്ഥിതിയുടെ മൊത്തത്തിലുള്ള പ്രതിരോധശേഷിയിലും കാര്യക്ഷമതയിലും നിർണായക പങ്ക് വഹിക്കുന്നു. സമ്മിശ്ര കൃഷിയിലെ സുസ്ഥിരത നിർണ്ണയിക്കുന്ന ഘടകങ്ങളെക്കുറിച്ചുള്ള പഠനം വെളിപ്പെടുത്തുന്നത് കന്നുകാലി ഉൽപ്പാദന വിഹിതം, കൃഷി അനുഭവം തുടങ്ങിയ ഘടകങ്ങൾ സുസ്ഥിരതയെ പോസിറ്റീവായി സ്വാധീനിക്കുന്നു എന്നാണ്, അതേസമയം സമ്മിശ്ര കൃഷി ഉൽപ്പാദനവും കുടുംബ അധ്വാനത്തിന്റെ സംഭാവനയും സുസ്ഥിരതാ സൂചികയെ പ്രതികൂലമായി ബാധിക്കുന്നു എന്നാണ്. ഈ ഘടകങ്ങൾ പരിശോധിച്ചുകൊണ്ട്, സമ്മിശ്ര കൃഷിയുടെ സാമ്പത്തിക, പാരിസ്ഥിതിക, സാമൂഹിക സുസ്ഥിരത മെച്ചപ്പെടുത്താൻ കഴിയുന്ന രീതികൾ തിരിച്ചറിയുക എന്നതാണ് പഠനം ലക്ഷ്യമിടുന്നത്. സംഗ്രഹത്തിൽ, സമ്മിശ്ര കൃഷിയെയും അതിന്റെ സുസ്ഥിരതയെയും കുറിച്ചുള്ള പഠനം സാമൂഹിക ക്ഷേമം, പരിസ്ഥിതി ആരോഗ്യം, സാമ്പത്തിക നിലനിൽപ്പ് എന്നിവയ്ക്കിടയിൽ സന്തുലിതാവസ്ഥ സൃഷ്ടിക്കുന്ന രീതികൾ നടപ്പിലാക്കുന്നതിന്റെ പ്രാധാന്യം ഊന്നിപ്പറയുന്നു.

(*പ്രധാന* പദങ്ങൾ: സമ്മിശ്ര കൃഷി, സാമ്പത്തിക സുസ്ഥിരത, പരിസ്ഥിതി സുസ്ഥിരത, സാമൂഹിക സുസ്ഥിരത, പൂരകത്വം.)

CHAPTER 1
OUTLINE OF THE STUDY

1.1 Introduction

Food is the most important need for sustenance of human life. In the human history, people are always driven to search for food. Food is a fuel for societal organization, and development throughout the history. The main requirement of a country is to attain and sustain food security. Only a sustainable agricultural sector ensures a nation of long term food security.

Agriculture, the cultivation of land and breeding of animals, plays a vital role in sustaining life by providing food, fibre and other products. Every day, agriculture produces an average of 23.7 million tons of food, provides livelihoods for 2.5 billion people, and is the largest source of income and jobs for poor, rural households. (UNEP,2018) Agriculture accounts for 29% of GDP and 65% of jobs in developing countries. Mixed crop- livestock farms are widely spread in different tropical regions in the world, they contribute to food security, rural development, sustainability and poverty alleviation. (Rangel et.al.2017) Agricultural households in developing countries face substantial risk of farm income fluctuations. Farm income is subject to yield and price risk, both of which are significant because of the dependence of farming on weather. (Kurosaki, 1996) Due to low income and lack of insurance facilities, risk mitigation is more important for poor farmers.

Mixed farming provides farmers with an opportunity to diversify risk, promote greater bio-diversity, allow intensified farming, make the best use of crop residues and to maintain diversified agro ecosystem. Crop – livestock diversification is the best potential livelihood strategy for farm households. (Mekuria et.al. 2018) Mixed farming is a kind of farming which combines the cultivation of crops and rearing of livestock. Such agriculture occurs across Asia and in countries such as India, Malaysia, Indonesia, Afghanistan, South Africa, China, central Europe, Canada, and domestic consumption countries such as the United States and Japan now use it for commercial purpose. (Kumar et. al. 2024)

India has a long agricultural history. Undoubtedly, agriculture and its allied activities is the largest livelihood contributor in India, especially in rural areas. It also makes a significant contribution to the Gross Domestic Product (GDP). Economic Survey 2023-24 highlights that the Indian agriculture sector provides livelihood support to about 42.3 per cent of the population and has a share of 18.2 per cent in the country's GDP at current prices.(PIB, 2024) Agriculture plays a key role in the overall economy of the country. It offers raw materials to agro-based industries, generates employment, provides market for industrial products, contributes to national income etc and more important is provision of food for the ever increasing population. Relevance of agriculture is thus, not relegated but demands a mechanism to sustain it against all modern challenges. Mixed farming, combination of crop and livestock rearing is traditionally practiced in India with varying degrees as a means of livelihood for farmers.

In India mixed farming implies dovetailing of crop production and animal husbandry to the best advantage of the farmer. The relationship between the two is expressed as a complementary use of livestock and crops. This enables a full utilization of by-products of crops and their regeneration to useful livestock products. Thus, manure from livestock becomes available, and the spare time of the farmer and his family is entirely used. Mixed farming is not new to the Indian cultivator. Today mixed farming is practiced as a tradition handed over to him by his ancestors in which superstitions and sentiments rather than up to date technology and commercial farm approach. . (ICAR, Mixed Farming in India, 1957)

"The most flourishing farmers in India are the 'Jats of Punjab, Delhi, and western part of Uttar Pradesh and enterprising Kisans of Bombay State, Konkan and Kerala.(ICAR, Mixed Farming in India, 1957) Most of the farmers in Kerala go in for mixed farming. Traditionally, agriculture in Kerala is characterized by for every pair of draught animals the farmers rear two or more milch animals. The milk and milk products obtained from milch cattle supplement their income and provide them with a wholesome diet. The manure obtained from cattle goes to enrich the paddy fields. The improved diet of the farmer gives them a sturdy physique suited to agricultural work. So it is in mixed farming the key to prosperous agriculture lies.

Mixed farming represents a type of farming in which crop production and livestock production are combined to sustain and satisfy as many needs of the farmer as possible. According to the Food and Agricultural Organization (FAO) (Livestock, Environment and Development Initiative – LEAD website),Mixed Farming System(MFS) are defined as farming systems conducted by households or by enterprises where crop cultivation and livestock rearing together form integrated components of a single farming system. The FAO considers mixed farming systems as "The best known form of mixed farming is when crop residues are used to feed the animals and the excreta from the animals are used as nutrients for the crops." Mixed farming is considered by the FAO as probably the most benign agricultural production system from an environmental perspective because it is, at least partially, a closed system (Schiere and Kater, 2001). The waste products of one enterprise (crop residues), which would otherwise be loaded on to the natural resource base, are used by the other enterprise, which returns its own waste products (manure) back to the first enterprise. As mixed farming provides many opportunities for recycling and organic farming and for a varied, more attractive landscape, it is the favourite system of many agriculturalists and environmentalists.

1.2 Significance of the Study

As the world faces growing challenges related to climate change, food security, and rural development, it is crucial to identify farming strategies that not only ensure economic profitability but also promote environmental conservation and social well-being. Farmers engaged in mixed farming are economically better off than others because uncertainties in crop production can be reduced by integrating livestock with that of crops. They contributes to household income and provides full time occupation with better utilization of human resources which have otherwise zero opportunity cost. This research will contribute valuable insights into how these different sustainability pillars can be integrated into farming practices, offering a holistic approach that can guide policy-makers, farmers, and researchers in the development of more sustainable agricultural models.

Additionally, the study focus on the complementarity of farming practices provides an opportunity to explore how paddy cultivation and cattle rearing can work together to strengthen overall farm sustainability. By understanding how economic, environmental, and social factors interact and support each other, this research can help identify synergies that improve resilience, productivity, and the livelihoods of farmers. The findings will be significant in informing policy decisions, shaping future agricultural practices, and promoting sustainable rural development, ultimately contributing to long-term food security and environmental stewardship.

1.3 Scope of the Study

The scope of the study covers comprehensive analysis of the economic, environmental, and social aspects of mixed farming system, with a focus on their sustainability and complementarity. The study examines various characteristics of mixed farming system and how they contribute to or hinder sustainability across these three dimensions. The study also seeks to comprehend how combining methods such as paddy cultivation and cattle rearing can enhance the overall sustainability of mixed farming systems.

The study geographically focused on different regions of Palakkad district providing a comprehensive view of mixed farming practices in different settings. The study focuses on one specific combination within the mixed farming system, which is the integration of paddy cultivation and cattle rearing. It considered the perspectives of farmers and rural communities to gain a holistic understanding of how mixed farming is perceived and implemented on the ground. The research has generated findings that can inform policies, improve farming practices, and contribute to sustainable agricultural development in various regions.

1.4 Statement of the problem

Agriculture lays the foundation for human Civilization. Modern agriculture support 8.2 billion World Population through substantial increase in yields resulting from intensified farming with high level of Input and chemical fertilizers and pesticides as well as advanced crop and livestock production technologies. Due to increased demand for food chemical fertilizers is applied to squeeze more yields from land which may lead to environmental degradation such as soil matter depletion, nutrient loss, soil degradation etc. Intensive livestock and crop (separated) production has resulted in soil fertility loss and environmental pollution. It is a challenge before us to increase food production without compromising the integrity of environment. In such context, idea of sustainable agriculture arises to pursuit for balancing food production and environmental welfare as a double-edged strategic goal. To achieve this goal, farming system might be designed with due consideration of economics and environment and society. Recently mixed farming system receives increasing attention for its self sustainable feature. Thus there is a need to understand better as whether mixed farming system could contribute to the attainment of three sustainability dimensions that is economic social and environmental and to what extent.

1.5 Research questions

1. How paddy cultivation and cattle rearing support each other in mixed farming system?
2. How far mixed farming contributes towards sustainable agriculture?
3. What are the determinants of sustainability in mixed farming?

1.6 Objectives of the Study

The primary objectives of the study are following

- **To assess the complementarity of mixed farming**

The study aims to explore the complementary relationship between two components such as paddy cultivation and cattle rearing within mixed farming system. The study focuses on complementary synergy, that is, benefit from producing two or more outputs jointly rather than producing them separately in mixed farming because of inherent production activities such as the crop residues as livestock feed, especially during the dry season and likewise manure from cattle is used as fertilizer for paddy cultivation

- **To analyse the economic, environmental and social sustainability of mixed farming**

The study aims to assess the economic, environmental, and social sustainability of mixed farming which is crucial to ensure that mixed farming practices are profitable, resource-efficient, and beneficial to communities. If Mixed Farming System (MFS) should be maintained or re-introduced, they would need to demonstrate significant economic, environment and social benefits. There is thus a need to understand better if MFS could contribute to the three sustainability dimensions of farming and to what extent. Measuring sustainability of mixed farming is crucial for ensuring that farming practices do not harm the environment and can continue to meet the needs of future generations.

- **To trace out the determinants of sustainability in mixed farming**

The sustainability of mixed farming is influenced by several key determinants, each playing a critical role in the systems overall resilience and efficiency. In constructing a sustainability index for mixed farming, several determinants are typically considered to provide a comprehensive assessment of sustainability. In addition to the commonly recognized factors, features of mixed farming itself influence the sustainability of mixed farming and the researcher aims to identify those determinants of sustainability of mixed farming. Moreover, the study also aims to assess how each determinant impacted to the sustainability of mixed farming.

1.7 Hypothesis

The central hypotheses are given below:

Hypothesis1: Mixed farmers maintain an acceptable level of economic, environmental and social sustainability.

Hypothesis 2: There is no significant difference among the determinants with respect to their impact on sustainability of mixed farming.

1.8 Data Sources and Methodology

The research design, nature and sources of data, sampling design, the sample size determination, and the research methods are described in detail under this head.

- **Research Design**

The research design of the study is exploratory, descriptive and analytical in nature. The study is exploratory aiming to explore new insights into mixed farming, complementarity and gain deeper understanding on different aspects of sustainability of mixed farming. The study has also developed working hypotheses from operational point of view. The study has followed the methods like surveying the available literature and experience survey. The study has surveyed farmers who have practical experience with mixed farming. The study is descriptive in nature aiming to provide a detailed account of the characteristics of mixed farmers and also focuses on current state of sustainability of mixed farming. The research design of the study is also considered analytical because in the context of sustainability of mixed farming, the study examine and interpret data pertaining to sustainability and also assess how different determinants influence the level of sustainability in mixed farming.

- **Nature and Source of data.**

The study is based on both primary and secondary data. The present study mostly depends on the first hand information collected by the researcher. Primary data is collected through direct interview with a pre structured schedule among the farmers practicing mixed farming i.e.. both paddy production and cattle rearing. So the mixed farmers are respondents of the study. The sample frame is list of farmers who are members of Padasekharams or Polders. The required data and information are also collected from various study reports, magazines, newspapers, and other internet sources. The major sources of the secondary data include the data from Department of Economics and Statistics, Government of Kerala and Department of Animal Husbandry and Dairying, Government of India. No accurate data is available regarding the total number of mixed farmers in Kerala.

There are no authentic sources of data regarding mixed farming. However, from the literature review, one common type of mixed farming identified is the combination of paddy cultivation and cattle rearing, particularly found in Kerala. For this study, Palakkad is selected to focus on this specific combination of mixed farming—paddy cultivation and cattle rearing. So the study is conducted in Palakkad district. Palakkad is the land of Palms and Paddy fields. It is a part of the Malabar District of Madras Presidency. The District accounts for about 11.53% of the total land area of the State of Kerala with its share of population as 8.2%. Palakkad is a major paddy growing area of the State. (Kerala State Planning Board)

Palakkad District, in the southeastern part of the former Malabar district, is one of the 14 districts of the Indian state of Kerala. It is located right in the middle of the state. Also, it is the largest district in Kerala since 2006. The city of Palakkad is the district headquarters. Palakkad is bordered on the northwest by the Malappuram District, on the southwest by the Thrissur District, on the northeast by Nilgiris and on the east by Coimbatore district of Tamil Nadu. The district is nicknamed "the granary of Kerala".

Paddy, the primary crop extensively cultivated in Kerala follows a unique three-season pattern: Autumn (July-October), Winter (November-February), and Summer (March-June). (Agricultural Statistics, 2024) In wet land paddy cultivation, Palakkad district secure the 1st position in 2022-23 with 73,400.72 hectares, contributing to 38.6% of the total wet land paddy area in the state. In the year 2021-22, it was 76,361.21 hectares. (Agricultural Statistics, 2024). District wise analysis of paddy area (Wet & dry) during the year 2022-23, Palakkad secure the 1st position with 73,462.43 hectares, contributing to 38.3% of the total paddy area in the state. In the previous year 2021-22, it was 76,503.68 hectares. Season wise –paddy area in Kerala during 2022-23, Palakkad district occupies first position in Autumn and Winter season. Palakkad district maintained its position as the highest producer of rice. (Agriculture Statistics, Government of Kerala, 2022-23).According to 20th Livestock census, Palakkad occupies first position in district wise cattle population 2019. (20th Livestock Census, Report of Kerala, 2021)

The sampling method used by the study is random sampling method.There are 13 blocks in Palakkad district. Amongst these 13 blocks, 7 blocks were randomly selected. They are Malampuzha, Alathur, Kuzhalmannam, Kollenkode, Nemmara, Thrithala and Sreekrishnapuram. In these 7 blocks there are 49 Krishi Bhavans and within these, there are 829 Padasekhara Samithies. In these Padasekhara Samithies there are 50930 paddy farmers. Data was collected from the secretaries of Padasekhara Samithies specifically for number of farmers who practice paddy cultivation along with cattle rearing. As a result, there are 6471 mixed farmers who practice both paddy cultivation and cattle rearing in these 7 blocks. Thus the farmer practicing both paddy cultivation and cattle rearing is the sample unit of the study. Using the Krejcie and Morgan Formula, the minimum sample size is 364. (Krejcie &Morgan, 1970) But the final sample size is 394 which is above sample size. Amongst these 6471 mixed farmers, 394 samples are randomly selected.

Table 1.1 Sampling Design

Blocks	Number of Krishi Bhavans	Number of Padasekhara Samithies	Number of paddy farmers	Number of mixed farmers	Minimum Sample size	Number of Data collected	Number of errors	Final Sample size
Malampuzha	6	77	4073	532	30	34	1	33
Alathur	8	124	10389	1239	69	75	3	72
Kuzhalmannam	7	195	13124	1245	70	82	5	77
Kollenkode	7	99	6800	852	48	55	4	51
Nemmara	7	150	8730	1430	81	100	7	93
Thrithala	7	94	4444	510	29	33	4	29
Sreekrishnapuram	7	90	3370	663	37	41	2	39
Total	**49**	**829**	**50930**	**6471**	**364**	**420**	**26**	**394**

Source: Primary Survey

The researcher has collected data from 420 samples. But 26 of them have errors. So remaining 394 samples is the final sample size of the study. (Based on the experience the researcher gained out of the pilot study.) The samples are selected using random sampling method.

- **Period of Primary Survey:** The primary survey was conducted from November 2023 to May 2024. The data collected from the farmers covers the period of July 2022 – June 2023.
- **Research Methods**

The study has used quantitative methods for analysis. Relevant statistical tools are used to analyse the stated objectives of the present study, along with descriptions and explanations. For explaining the complementary relationship between paddy cultivation and cattle rearing, the researcher combined the methodology adopted by Choi, 2008 and Lee, 2011 to compute the complementarity index and it has been tried to assess whether activities and practices in mixed farming system are mutually complementary and so tend to be adopted together, with each enhancing the contribution of the other. After computing the complementarity index, the significance of mean difference has been tested with respect to complementarity index across various agricultural characteristics of mixed farming. Independent-Samples Kruskal-Wallis Test and Independent-Samples Mann-Whitney U Test is performed to test the distribution of complementarity index across various agricultural characteristics of mixed farming.

For studying the second objective the methodology of Food and Agriculture Organisation (FAO) was adopted with some modifications. FAO has developed an Indicator 2.4.1 which gives overall measure of sustainable agriculture. There are three dimensions of sustainability: economic, environmental and social along with 11 sub indicators. From an environmental point of view, the indicator primarily examines the direct impacts of mixed farming practices, farmer decisions, and methods on the environment. From a social perspective, the focus is on mixed farming as a means of livelihood, emphasizing its impact on household income and food security. Economically, the scope is centered on mixed farm holdings, addressing aspects such as net profitability, risk management strategies, and related factors.

The sub-indicators used for assessing economic sustainability are farm output value per hectare, net farm income of mixed farms and risk mitigation mechanisms followed by mixed farms. The sub-indicators used for measuring environmental sustainability are prevalence of soil degradation, variation in water availability, management of fertilizers, management of pesticides and use of agro bio diversity supportive practices. The social sustainability is assessed using the sub-indicators wage rate in agriculture, food insecurity experience index and secure tenure rights to land. Sustainability criteria that is Critical/thresholds values against which the performance of each sub indicator is assessed to classify the mixed farm in terms of the sustainability level-Desirable, Acceptable and Unsustainable. Using these 11 sub indicators sustainability index is computed for measuring sustainability of mixed farming. With some adjustments, the FAO's approach to evaluating Indicator 2.4.1 Sustainable Agriculture served as the basis for these 11 indicators and techniques for evaluating the sustainability of mixed farming.

Each dimension score of economic, environmental and social is computed and these scores are converted into Z scores. Then three dimension indices are calculated. The UNDP method of HDI calculation is used to construct the Sustainability Index of mixed farming. The sustainability index is the geometric mean of standardized indices of the three dimensions. A traffic light approach is adopted in which three sustainability levels are considered for each indicator. Green for Desirable level of sustainability, Yellow for

Acceptable level of sustainability and Red for Unsustainable level of sustainability. After computing sustainability index, the significance of mean difference has been tested with respect to sustainability index across various agricultural characteristics of mixed farming. Independent-Samples Kruskal-Wallis Test and Independent-Samples Mann-Whitney U Test is performed to test the distribution of sustainability index across various characteristics of mixed farming.

The third objective is to trace out the factors that determine the sustainability of mixed farming and for that a regression analysis is employed. The Tobit Model of regression is suitable to explain the factors determining the sustainability Index. A Tobit regression model, where the Sustainability Index is the dependent variable and various features of mixed farming are considered as the explanatory variables in the regression model. The details of the regression models are presented in Chapter 6. The Chi-square test of normality is used to check the basic assumption of normality of the Tobit regression model. The Collinearity of the explanatory variables included in the Tobit regression model is checked using Variance Inflation Factor.

The data analysis was performed using SPSS because of its advanced statistical capabilities and Gretl for econometric modeling. Descriptive and summary statistics like percentages, measures of central tendency and measures of dispersion are used to know the average and spread of the data. Chi square Goodness of Fit Test, Independent-Samples Kruskal-Wallis Test, Independent-Samples Mann-Whitney U Test and modeling is done using Tobit Regression Approach. The data are presented using frequency tables, charts, pie diagrams, and bar charts.

1.9 Limitations of the study

The study is confined to one district, specifically Palakkad district in Kerala. Since it focused on a single combination of mixed farming, other combinations of mixed farming systems were not considered. Due to time and resource constraints, only a limited number of samples were covered, and an attempt was not made to include all mixed farmers in Palakkad district. Besides that, since sustainability is a long term process, the limitation of the study is that the data covers only limited period. As the study did not rely on secondary data, the population was drawn from selected blocks, which means the overall population of mixed farmers was not the focus of this study. Consequently, the information regarding the number of mixed farmers in Palakkad district may be subject to over reporting or underreporting due to personal bias. Additionally, the absence of adequate data on the accurate number of mixed farmers in the study area was a limitation. Time constraints also played a role in restricting the scope of the study. Despite these limitations, every effort was made to ensure the study remained a valuable and meaningful pursuit.

1.10 Chapter Scheme

The study consists of 7 chapters.

Chapter 1: An outline of the Study

The introduction chapter outlined an overview of the research study. The chapter presents the introduction, significance of the study, statement of the problem, objectives, hypothesis, Data source and methodology and chapter schemes as the key themes including the chapter priorities.

Chapter 2: Theoretical and Empirical Perspectives on Mixed Farming, Complementarity and Sustainability

The second chapter illustrates the developments in the theoretical and empirical literature related to the topic of research. It explores key concepts and frameworks that pinpoint different areas of mixed farming, building upon existing research and studies to provide a comprehensive understanding of how mixed farming practices, the complementarity between components of mixed farming system, and sustainability intersect.

Chapter 3: Mixed Farming Systems: Mechanisms, Technologies, and Practices in India and Kerala

The chapter 3 presents an overview of mixed farming. It explores the foundational concepts and definitions related to mixed farming, providing an in-depth understanding of the mechanisms, modes, and technologies that shape mixed farming practices. Additionally, the chapter examines the state of mixed farming in India, highlighting its diverse practices, challenges, and innovations. Special focus is given to farming in Kerala, exploring the unique agricultural landscape of the region and the specific factors that influence its mixed farming systems.

Chapter 4: Complementarity of Mixed farming

This chapter deals with Complementary synergy that is benefit from producing two or more outputs jointly rather than producing them separately in mixed farming because of inherent production activities such as the crop residues as livestock feed, especially during the dry season and likewise manure from cattle is used as fertilizer for paddy cultivation.

Chapter 5: Economic, Environmental and Social sustainability of mixed farming

Measuring sustainability of mixed farming is crucial for ensuring that farming practices do not harm the environment and can continue to meet the needs of future generations. This chapter deals with analysis of primary data for measuring the sustainability of mixed farming in Palakkad district of Kerala. The economic sustainability of mixed farming is covered in the first section. The environmental and social sustainability of mixed farming are covered in the second and third sections, respectively. Lastly, the economic, environmental, and social aspects of sustainability are combined to evaluate the sustainability of mixed farming.

Chapter 6: Determinants of Sustainability in Mixed Farming.

The chapter focuses on determinants of sustainability of mixed farming. The sustainability of mixed farming is influenced by several key determinants, each playing a critical role in the systems overall resilience and efficiency. In constructing a sustainability index for mixed farming, several determinants are typically considered to provide a comprehensive assessment of sustainability. Beyond the commonly recognized factors, other important determinants are studied in this chapter.

Chapter 7: Summary and policy implications

The seventh chapter presented the conclusions, which are drawn based on the finding of the study. The chapter includes a summary of the findings of the study, major conclusions and recommendations also drawn from best practices.

CHAPTER 2
THEORETICAL AND EMPIRICAL PERSPECTIVES ON MIXED FARMING, COMPLEMENTARILY AND SUSTAINABILITY

2.1 Introduction

The chapter presents both theoretical and empirical literature related to mixed farming, its complementarity, and sustainability. It explores key concepts and frameworks that pinpoint different areas of mixed farming, building upon existing research and studies to provide a comprehensive understanding of how mixed farming practices, the complementarity between components of mixed farming system, and sustainability intersect. The chapter aims to offer an extensive perspective on the subject by reviewing relevant literature and identifying gaps that the study looks to address.

2.2 Theoretical Background

T.W.Schultz is one of those economists who suggested ways and means to develop agriculture. One of his important contributions is The Poor But Efficient Hypothesis. The theory states that the farmers in conventional agriculture are generally able to allocate their resources in the optimal fashion and proves their efficiency in utilising their resources. In this hypothesis optimum allocation of available resources implies that no resources are left unemployed in the agriculture sector. Similarly in mixed farming system, we can see efficient and effective utilization of resources. Here waste products of one enterprise (crop residues) are used by the other enterprise, which in turn results its own waste product (manure) back to the first enterprise. Besides that, mixed farming system provides full time employment to labour.

A broad explanation for the variable adoption of sustainable agricultural practices comes from an agricultural anthropologist, Robert McC.Netting. He developed the theory of "The Ecology of Small Scale Sustainable Agriculture". He outlined a socio-ecological dynamic in which farmers and other members of their households engaged in laborious routines in which they cultivated an agro-biodiverse set of crops, recycled household, livestock, and agricultural wastes back into production processes, and made a large amount of improvements to their land, like terracing it, irrigating it, etc. From Netting's point of view, mixed crop-livestock livelihoods might not be essential for the practice of sustainable agriculture, but there was a clear association between crop-livestock product mixes and sustainable agricultural practices because these practices often necessitate the tight integration of animal wastes into crop production processes. For example, almost all of Netting's smallholders used manure from their animals to maintain the fertility of their crop cultivation. Netting advanced his argument through analyses of similar agro-ecologies in different places, rice cultivators in central China, potato growers in the Swiss Alps, and hill farmers in central Nigeria. A singular pattern runs through agriculture in all of these places. It involves labour intensive activities that, through biological controls and recycling of wastes, promote the long-term sustainability of agriculture. Netting's work provides implicit support for the contention that sustainable agriculture is scale dependent that it occurs most frequently on small farms.

Modern Portfolio Theory (MPT) is the technical finance theory equivalent to "Don't Put All Your Eggs in One Basket." Harry Markowitz developed portfolio theory and in 1990, earned the Nobel Prize for his contribution to financial economics. MPT assumes that investors are risk-averse, meaning they prefer a less risky portfolio to a riskier one for a given level of return. As a practical matter, risk aversion implies that most people should invest in multiple asset classes. Similarly, mixed farming helps in diversifying the sources of income by integrating both crop production and livestock rearing for resource poor farmers and landless labourers and thus offers considerable potential for poverty alleviation. Livestock act as a storehouse of capital and an insurance against crop production risks.

The capability approach of Amartya Sen is a theoretical framework that entails two normative claims. First claim the freedom to achieve well being is of primary moral importance and second that well being should understood in terms of people's capabilities and functioning. Sen argues, is a notion of what activities we are able to undertake ('doings') and the kinds of persons we are able to be ('beings'). Sen calls this notion capabilities. Capabilities are the real freedoms that people have to achieve their potential doings and beings. Real freedom in this sense means that one has all the required means necessary to achieve that doing or being if one wishes to. In this way, the capability approach changes the focus from means (the resources people have and the public goods they can access) to ends (what they are able to do and be with those resources and goods).Thus, in order to evaluate people's well-being, we need to not only consider the amount of resources they have, but also what they are able to do and be with those resources. Similarly an ideal mixed farming ensures recycling of residues ie the waste products of one enterprise (crop residues) are used by the other enterprise, which in turn results its own waste product (manure) back to the first enterprise. Therefore there is less reliance to outside inputs. According to Amartya Sen, one may be a pleasure wizard who gains a lot of utility from very little input. People living in deprivation may actually tend to lower their expectation as a coping mechanism. But just because they experience a bigger increase in well being from fewer resources. A mixed farmer also derive more utility from very little input by making maximum utilisation of resources. Mixed farming system provides an opportunity through organic supplementation through effective utilization of resources.

In his monumental treatise of 1798 entitled, "An essay on the principle of population" Malthus has interpreted scarcity as follows: society has only the ability to increase agricultural production at an arithmetic rate, while the number of mouths to be fed increases at a geometric rate. That is population will outstrip food supplies. Malthus argument presents the sophisticated concept of economic scarcity and its attendant effects on human well being. He argued that the quantity of arable land was fixed, so that land should be made more productive through intensive cultivation. With greater efforts farmers should squeeze more produce from the same fixed amount of land. If population pressure increases, if crop livestock systems are separated into specialised crop or livestock activities, the arable land part of system will experience increased rates of nutrient depletion and soil erosion. This can lead to a downward spiral of monoculture with lower quality food crops, increased under-nutrition and famine. So instead of separating crop and livestock, practicing mixed farming allows intensified farming with less dependence on natural resources and preserving more biodiversity than would be the case if food demands were to be met by crop and livestock activities undertaken in isolation.

Kenneth Boulding's 1966 essay "The Economics of the Coming Spaceship Earth," on sustainability has relevance today for fostering economic policies that consider planetary boundaries. Since its publication, this essay has had a keen influence on much of the thinking about the global economy and sustainability. It has been recognized that there is a relationship of interdependence between economics and environment. He has described the necessary changes to economic science that from "cowboy economy" towards "spaceman" economy. Spaceship is a circular system where there is a need to concentrate our efforts in the recycling of materials, waste reduction, maintenance of exhaustible sources of energy and in the exploitation of renewable energy sources such as solar etc. Mixed farming is the most benign agricultural production system from an environmental perspective because it is partially, a closed system. The waste products of one enterprise are used by the other enterprise, which return its own waste product back to the first enterprise. It provides many opportunities for recycling and organic farming and for a varied, more attractive landscape, Mixed farming is the favourite system of many agriculturists and environmentalists because it maintain soil fertility by recycling nutrients, minimises soil erosion, and allows biodiversity.

2.3 Mixed farming and Complementarity

In many parts of Asia and Africa, especially in developing countries livestock is integrated to crop and it cannot be separated and they are complementary. There is marked complementarity in resource use in integrated crop- livestock system, with inputs from one sector being supplied to others. (Devendra, 2002) The fact that in much of the world, field and pasture, animal and vegetable, and literally, cereal and milk, still exist in close proximity and will continue to do so for decades to come.(Thornton, 2015)

Livestock are often criticized for their negative externalities to environment. However, in the mixed farming systems followed in India, the livestock help in saving natural resources through their synergistic relationship with crop production. There are positive environmental externalities associated with livestock production in India's mixed farming systems. These are land saving due to recycling of agricultural by-products as animal feed and also due to use of dung- cake as domestic fuel; saving of chemical fertilizers due to use of dung as manure and prevention of carbon dioxide emission due to use of animal energy in agriculture. (Dikshit, 2013). Likewise, use of animal energy as a substitute for mechanical energy has potential to save diesel consumption to the extent of 13 Mt and prevents greenhouse gas emission due to burning of diesel. (Dikshit,2013)

Smallholder farmers have been integrating their limited resources which is a part of sustainable farming system. Mixed Crops and Livestock (MCL) Farming becomes the most popular approach in developing countries and there arises a question in MCL farming system, whether farmers apply this farming practice as an income generating activity or a survival strategy. The study conducted in Indonesia explores the determinant factors of MCL practice among farmers. A cross-sectional data of the Indonesia Family Life Survey (IFLS) in 2014 was used by involving 3,702 farm household (2,957 of non-MCL farmers and 745 of MCL farmers). A binary choice model was employed to estimate the probability of practicing MCL farming in Indonesia. The results showed that the cultivated land size and age of farmers negatively explained the choice of practicing MCL among farmers in Indonesia. This indicated that MCL farming tends to be practiced by younger farmers with smaller land size. The livestock asset is insignificant within the MCL farming. It indicates that crop farming is the primary farming while keeping livestock is more complementary activity among farmers in Indonesia (Putra, 2019)

A study was conducted in Tunisian rain fed areas to measure technical efficiency and also to explore the complementarities, synergies and economies of diversification among the mixed crop- livestock small holder producers using the cross partial derivative framework of output variables in the distance function. The data was collected from 59 farmers and analyzed using a stochastic input distance function to estimate the synergies based on second cross-partial derivative concept of output variables in the distance function. The findings of the study revealed that there are significant technical inefficiencies among the mixed crop livestock smallholders and the study also highlights that economic diversification act as productivity shield against climate change threats. Thus the integrated system that is mixed crop livestock system can be considered as sustainable intensification strategy. (Dhehibi, 2023)

2.4 Mixed farming and Economic Sustainability

Practicing mixed farming is more beneficial than crop farming for all the farmers irrespective to the size of land holding.(Bharati, 2007). Mixed farming system was a better option than the single activity as it generates more income.(Pomishahbaz et. al.2017, Rai1994, Bharati 2007). Even though it is a better option it was found that the yield shocks & adjustment for input costs result in a much larger variability of net profits.(Kurosaki 1997). The areas of Punjab have developed into granaries that provide other regions with excess food grains. In Punjabi agriculture, dairy production is very significant. Also, livestock can provide a buffer against losses in a particular season. For example, selling a few sheep or goats can help a family overcome a poor grain harvest. (Thornton, 2015)There are two types of cow feed: dry feed made from crop wastes and green feed produced in arable land. The study in Punjab highlights how green fodder limits the production of other cereals, such as wheat during the Rabi season and basmati paddy during the Kharif season. The market for green fodder in the research area is underdeveloped. Household participation is also lower. According to the report, even if they had to buy shortfall wheat, smaller farms would rather be self-sufficient in green fodder. The cost of green feed is the cause of this. (Kurosaki, 1996).

A study conducted in India during 2007-2011, it is apparent from the data that the arecanut based mixed farming system had positive effect on gross and net profits. The variations in cash inflows were due to variations in prices of inputs and labour. (Sujata, 2015) The economic vulnerability is comparatively less on mixed crop-livestock systems due to more crop and livestock interactions, which allows for less reliance on markets and more flexibility. (Sneessens, 2019). Introducing spatial grazing has the potential to increase the profitability of livestock in the system, and increase farm profit. (Llewellyn 2017)

Another study investigated that dairy contributes to the farm income on one end & supplement to the crop husbandry by supplying organic manure and on the other, milch animal is more remunerative than crop production and provide high level of employment to family members.(Singh,2006) The study carried out in Sikkim with special reference to the mixed farming of La Chan & La-Chung Valleys of North Sikkim, concludes that mixed farming provides a means of livelihood for the tribals , even though they face many physical & economic hardships.(Rai, 1994). A study in South Gujarat compared the gross and net income of marginal, small and medium farmers from mixed farming and the study concluded that income of marginal farmers was low as compared to that of small and medium farmers and higher amount of income was found in middle part farmers than that of upper and lower part of South Gujarat farmers. (Thakker, 2001)

The main challenge for farmers is to ensure low vulnerability and to maintain a high annual income within an ever-changing context of production (climate, prices, and sanitation issues). The vulnerability refers to the extent to which a farmer is affected by negative economic impacts and it corresponds to its susceptibility to be harmed, reflecting its inability to cope with adverse effects. A study was conducted in France to determine the economic vulnerability of farming systems considering their social dimension, and to identify farming management profiles that are likely to be less vulnerable. The vulnerability levels was defined on the basis of four quantitative indicators reflecting the 'behaviour' of the economic results per labour unit in the long term: the relative standard deviation of the economic result per worker, the relative mean distance of the economic result to a minimum threshold, the number of economic disruptions over a specified period, and the economic recovery time after disruption. The study was conducted among sample of 208 farms in France, and the results indicated that diversification alone is not enough to manage risks. Less vulnerable mixed crop-livestock systems are characterised by more crop-livestock interactions, allowing for less dependency on markets and more flexibility. Larger farms and farms with more livestock tend to be less vulnerable. (Sneessens 2019)

Mixed farming or an integrated crop-livestock farming system is one of the farming system that incorporate the concept of sustainable agricultural development. Integrated crop-livestock farming system is highly appropriate in a dry field area, which is scarce in agricultural resources. In Gunung Kidul Regency, a study was conducted to compare financial feasibility and technical efficiency among farmers who have adopted an integrated crop-livestock farming system and those who employ non-integrated crop-livestock systems and to describe factors determining the adoption of an integrated crop-livestock system. Primary data was collected 65 farmers who applied integrated crop-livestock farming and 47 farmers who applied non-integrated crop-livestock farming. Financial feasibility methods used were analysis of cost-return and B/C ratio and, for measuring technical efficiency, a stochastic frontier approach. A logit model was used to determine factors affecting adoption. According to the study, integrated crop-livestock farming is more efficient and profitable than non-integrated farming practices on dry landscapes. Integrated crop-livestock farming system can lower production costs, boost yield, and improve farming income on dry landscape. The findings also reveals that the primary factors that affect farmers' adoption of integrated crop-livestock technology were family members, educational attainment, the number of cows, income, training, and frequency of interaction with extension agents. (Widadie, 2015)

Over the last few years, structural transformation in the agricultural sector of developing countries has seen the spread of mixed farming with special emphasis on livestock products in particular. A study conducted in India emphasized the gaps for smallholder livestock producers to gain sustainable livelihood more efficiently. The livestock products discussed include milk, eggs and meat. The high-value livestock products for big markets have not been related to the vast majority of smallholders. The rural smallholder livestock producers mainly rely on informal market institutions to trade their products. It is argued that this blazing gap in smallholder livestock farming be addressed by focusing on S&T interventions like Telemedicine, VSAT, and more skill development centers, more number of para-vets and technical people as a part of valuable rural asset management. (Biswas,2008).

The two mixed-farming systems of southern Ethiopia (viz. Adilo and Kofele) was studied to evaluate the household income contribution and the profitability of traditional small ruminant enterprises. The integral part of mixed systems in the Ethiopian highlands is small ruminant production. Data on economic indicators was collected from 155 homes between September 2005 and August 2006 and gathered information on the income and spending details of small ruminant and other agricultural operations. In Adilo and Kofele, small ruminant keepers' sales accounted for 39% and 23% of their overall farm cash income, respectively. Chickens, ducks, pigs, hair sheep and guineapigs were commonly found on small-scale farms in subtropical Bolivia and were monitored over a full year. Chickens and guinea-pigs were reared for home consumption, while ducks and pigs reared mainly for sale. Sheep were reared for both purposes, depending upon the family requirements. Pigs contributed the greatest gross return, but received the large amount of supplementary feed, while, ducks and sheep all gave similar gross returns per breeding female, although chickens produced better returns and made a large contribution to the family diet. Mortality due to disease was a major problem in poultry, while internal parasites appeared to be important limiting factors in pigs and sheep and Guinea-pigs showed no problems apart from theft. Small animal species currently make significant contributions to the livelihoods of poor people in terms of both income and food security, and this could be greatly increased by improvements in animal husbandry. (Paterson, 2001)

Three mixed grain–livestock farms in Eastern Australia were examined for the possibility of enhancing on-farm conservation outcomes using a straight forward scenario and modeling approach to farm design. Given the present policy frameworks controlling agriculture and natural resource management in Australia, as well as the growing emphasis on the various advantages of land management in agricultural landscapes, farmers are expected to bear a large portion of the cost of conservation. When it comes to production opportunity costs, which are primarily disregarded (and underpaid) in landscape design, this is especially true. After applying fundamental landscape ecology design principles to existing farm configurations in a scenario approach to improve the preservation and connectivity of the landscape's natural elements, the direct (infrastructure) and indirect (loss of output) costs were calculated. To create scenarios, a three-stage process was used: (1) identify the main processes that pose a threat and take steps to mitigate them in order to stop the further depletion of natural resources; (2) find ways to improve the layout of the landscape while adhering to the landscape ecology principles listed below; and (3) investigate agricultural opportunities to make up for conservation costs. The use of conservation-based scenarios results in significant opportunity revenue losses, and there are few options to make up these losses using modified agricultural methods that don't cause additional environmental issues. Depending on the ecological state of farms and the particular mix of agricultural activities, small changes to the production base can have a significant impact on the profitability of farm enterprises. (House et.al, 2008)

A study was conducted in India to investigate sustainability, profitability, interdependence, and ecosystem services of crop-livestock integration in an arecanut plantation. It was a eight-year experiment from 2007 to 2014. In every year, arecanut showed comparable kernel yields in both single and intercropped systems. Compared to intercropped Napier Bajra Hybrid (NBH), the yield of green fodder from the single (NBH) was significantly higher. In various plantations, the yield of intercropped NBH was 5–47% lower than that of solo NBH per unit area. Compared to arecanut sole and fodder sole, the arecanut + fodder system had significantly greater total standing carbon reserves (210–228 t ha−1). Compared to ABMS (1178–1546 m3), arecanut sole (2340–3280 m3) used 47–50% more water per unit area. Livestock made up a significant portion of all outflows. The study highlighted that on an average, organic waste recycling potential of arecanut + dairy unit was 13.7 t ha−1 and dairy unit alone contributed to 87% of the manure production. Total nutrient supply from arecanut based mixed farming after recycling to the system was estimated at 218 kg N, 51.8 kg P and 33 kg K that can meet N and P demand of 1.7 and 2.2 ha of arecanut, respectively and this enables farmers to earn higher profits. The study recommended to include livestock components in arecanut ecosystem to adapt to climate change scenario, to provide ecosystem services and to reduce ecological imbalances arising due to continuous cultivation of perennial crop.(Sujata,2015)

In order to solve a mixed crop-livestock farm design challenge in New York, a multi objective MINLFP model was created to determine the trade-offs between profit, water productivity, and organic matter accumulation. For developing a model, economic aspects, agricultural cultivation, livestock output, water requirements, and soil organic matter were all considered. The study developed the optimal design of mixed crop-livestock farming systems for resource efficiency, economic profitability, and environmental sustainability and the trade-offs among profit, water productivity, and organic matter accumulation are considered. For that purpose, a case study on a 100 ha organic mixed crop-livestock farm with 19 types of crops, 22 types of crop products, 3 type of livestock, and 2 types of animal products was examined to demonstrate the relevance of the proposed model and solution methods. The study results suggest that it is more profitable to produce more high value cash crops and milk; it is more water efficient to grow cash crops than fodder; and it generates more soil organic matter accumulation by growing more crops with larger amount of root stubble and enlarging the heard size. (Liang, 2018)

Agriculture is the main stay of Indian economy. Since the majority of people depend on agriculture for making a living, it is the primary source of income in the country. However, because agriculture is susceptible to risk due to extreme climate change and highly fluctuating agricultural markets, this source of income is in risk. The allied activities of Indian agriculture, including horticulture, livestock, and fisheries, is dealing with a unique set of issues. The recommended solution is the mixed farming system, which increases production and gives farm owners better financial returns. The mixed farming could be in the form of the crop-livestock, crop-forestry, crop-horticulture fish-pig, fish-duck, and paddy-fish etc. Mixed farming system is helpful in decreasing the cost of production per unit area, increasing income and productivity and reducing the risk of farmers. (Ray, 2020)

The environment and economic sustainability of farmers are threatened due to specialization and intensification of agriculture despite its improvement in productivity. The combination of livestock and crops is considered as an alternative to specialised livestock or cropping systems because mixed crop-livestock systems can improve nutrient cycling while reducing chemical inputs and generate economies of scope at farm level. A study was conducted in France to compare the environmental and economic performance of mixed farming and specialized farming. Half of the farms in the study area practice mixed farming which is a combination of beef cattle and cash crops and another half specialize in either crops or cattle. Data were collected from 48 farms through an exhaustive survey and economic performances were evaluated using three criteria such as total gross margin, production costs; and an examination of how sensitive gross margins are to changes in input and output prices. The environmental performance was analysed by the criteria such as crop management strategies, the diversity of farm land use and nitrogen farm-gate balance. Mixed crop-livestock farms were less susceptible to changes in input and output prices than dairy and crop farms, and have greater overall gross margins than specialized farms. Mixed crop-livestock farms were less expensive than crop farms. The study also revealed crop management practices, has a shift from low to high input farming systems. Mixed crop-livestock farms were very heterogeneous with respect to the use of inputs and the study also revealed a lower potential for nitrogen pollution in mixed crop-livestock and beef production systems than in specialized farms like dairy and crop farming systems. Mixed crop-livestock systems appear to be a way for an environmental and economical sustainable agriculture despite its wide variability within system. (Ryschawy, 2012)

2.5 Mixed farming and Environment Sustainability

The foundation of African agriculture is comprised of mixed crop-livestock systems, which offer hundreds of millions of people options for livelihood and food security. Mixed farming system support risk management, intensification, and diversity in an environment friendly manner. The crop livestock interactions offer some buffering ability to help smallholders adjust to climate change. (Thornton, 2015) There are many ways in which the mixed systems may be able to adapt to climate change in the future, including via increased efficiencies of production that sometimes provide important mitigation co-benefits as well. But effective adaptation will require an enabling policy, technical, infrastructural and informational environment, and the development challenge is daunting. (Thornton, 2014)

There are trade-offs between different climate adaptation strategies for farmers who practice mixed farming. Mixed Farmers can obtain more fertile soil by composting crop waste and manure. Crop resilience and yields can be raised by employing legumes for natural nitrogen fixation, controlled release, and placement technology. As rainfall becomes unpredictable, mixed farming systems might employ water collection and retention strategies such building dams, pools, and roof-water harvesting. Both agricultural and non-agricultural diversification is seen to be crucial for helping mixed-system farmers adapt to climate change.

The risks related to mixed farming system can be managed by use of weather forecasts and index-based insurance products. Farmers have very little information about various risk mitigation mechanisms against climate change but unable to select which options is best for their mixed farm and also difficult for them to understand the full range of potential impacts these options might have on their food production, adaptation opportunities, and how feasible they are to implement i.e. what adaptation barriers may occur. The geographical and socioeconomic context of mixed farming system determines what works in a particular situation. The option a farmer finds the best also depends on what he wants to achieve in the end. (Schubert, 2014)

Mixed farming systems meet the demand for food for more than half of the world's population. These systems require transformative adaptations because they are vulnerable to climate change. A study in the wheat belt of Western Australia, a range of systemic and transformative adaptation options, were designed for the modelled climate change projected to occur in 2030 in collaboration with farmers. Using coupled crop and livestock biophysical models, the effectiveness of the adaptation options was evaluated within an economic and environmental framework at both the enterprise and farm scales. Under the impact of projected climate change, the economic returns of the current farms without adaptation and when the adaptations were made for 2030, profit increased, but such profit gains were connected with increase in greenhouse gas (GHG) emissions. Even though there may be challenges in terms of environmental sustainability and in particular with soil conservation, the current systems would be more resilient with the adaptations. A shift toward a greater livestock enterprises (stocking rate and pasture area) could be a profitable and low-risk approach and may have most relevance in years with extremely low rainfall (Ghahramani, 2018)

The most significant household asset for hundreds of millions of smallholder farmers worldwide today is the livestock — a few cattle or perhaps a small herd of goats and a flock of chickens. Furthermore, these animals usually reside on a small farm that is a hectare or two acres in size, where raising crops and cattle are intertwined. Livestock provide a vital source of fertilizer. Cattle pull ploughs for moving crops to markets. The leaves and stalks left over after harvest - "stover" is a vital source of nutrition for farm animals. Including crop waste and agricultural byproducts in the diet of ruminants may help reduce the methane production and the nitrogen outflow through the urine, two major environmental concerns. (Rangel et.al. 2017)

It is incredible to think that smallholder farmers can reduce their greenhouse gas emissions without having simple, practical, and easily attainable ways to deal with how global warming is affecting their operations. Climate projections indicate that throughout the next three decades, some parts of sub-Saharan Africa may experience high temperature and short growing seasons to support the types of important staple crops like maize that are currently in use. However, how these climatological shifts affect individual African farmers the way they produce food. Most of them depend on interactions between animals and crops, which can make them both improve and hinder climate change resilience.

The intermingling of crops with livestock production often leads to a more efficient use of natural resources which could make farmers more resilient to climate change. Also, livestock can provide a hedge against losses in a particular season. For example, a family overcome a poor grain harvest by selling a few sheep or goats. There emerges a need to help the mixed farmers to adopt climate smart options. (Schubert, 2015)

South Africa, the dual agricultural economy is made up of smallholder, frequently subsistence farming and a thriving commercial industry. Using the Ricardian cross-sectional paradigm, the study in this area investigated the effects of climate change on a national sample of commercial farming systems, including crop, horticultural, animal, and mixed systems. If precipitation and temperature decline simultaneously, it was discovered that productivity will be lowered, and that increase in temperature have a greater detrimental impact on agricultural output than precipitation decreases. The strongest conclusion is that there is disparity in the degree to which various commercial production systems will be affected. The most affected farms due to climate change is specialized commercial crop farming systems, but at the same time, mixed farming systems appear to be the least affected. This finding is compatible with studies on small-holder farms in sub-Saharan Africa. Although commercial farms have benefits derived from economies of scale, these farms are equally vulnerable to climate change. The study recommends that mixed farming methods will enhance the resilience of commercial farms to climate change and additionally access to insurance and irrigation is likely to reduce the risks. (Tibesigwa, 2015) And when it comes to dealing with the causes and consequences of climate change, the livestock-crop mix could make farmers more resilient to climate change because intermingling crops with livestock production often leads to a more efficient use of natural resources.

Integration of dairy, fishery, poultry components with diversified cropping in coastal lowland ecosystem is essential to offset the ecological imbalances arising due to continuous cultivation of rice crop in India.(Paramesh 2019) It is found that there exists strong association between mixed crop livestock operations & sustainable practices. The presence of animals on farms where people also cultivate crops encourages cultivators to recycle animal wastes into croplands & these practices seem to encourage farmers to adopt other practices like the rotation of cover crops, minimum tillage that also enhance agricultural sustainability.(Rudelet,2016)

In Cuba, a high external input dairy production model was applied widely from the 1960’s onwards. But this model collapsed by 1990’s as it was inefficient from both a financial & energetic point of view. As a result of this, a search for more sustainable approaches, such as low external input-mixed farming systems was stimulated. The study found that after conversion to mixed farming system, there is an increase in soil fauna biodiversity and soil biota activity (diplopods and worms). And also increase in milk yield per unit forage area. High extra crop production is linked to the highest energy and protein yields. The total labour input was also lower due to smaller cropping area during the six years. More intensive use of the available natural resources at the farming system level, through diversified MFS in terms of both crop & milk production, contributes to food, self-sufficiency & to efficient production of marketable products that contribute without degrading the resource base.(Funes,2009)

The challenges faced by smallholder farmers in mixed farming system is that of insufficient dry season livestock feed whilst crop production is mainly constrained by poor soil fertility and unpredictable rains. A potential solution to declining soil productivity is Conservation agriculture (CA) which is premised on three main principles namely minimal soil disturbance, crop rotations and mulching. However, farmers implementing CA in mixed crop-livestock systems are conflicted by the use of crop residues either as livestock feed or as mulch under crop production. In Murehwa, a sub humid region of Zimbabwe, a study was carried from 2012 to 2015 season, to evaluate the effects of maize-legume cropping systems on forage, maize grain yield and gross margins. The forage refers to the grass or hay harvested for livestock feeding. The cropping systems involved one conventional tillage practice with continuous sole maize (CT), four CA treatments consisting of continuous sole maize, maize-mucuna intercrop, maize-cowpea intercrop and maize groundnut/ soybean rotations. (Mutsamba, 2019) Farmers can grow legumes as intercrops with maize without any loss in maize grain yield. Maize-mucuna intercropping was the best of the tested cropping systems with respect to forage yield and gross margins in mixed crop-livestock systems of Murehwa. (Mutsamba, 2019)

The West African mixed farming system faces a major limitation of nutrient availability. Traditionally, the fertility was maintained by fallowing, and nutrient transfers by livestock from savanna to croplands. The agro-ecological intensification of these systems is demanded by demographic growth and socio- economic constraints. A meta-ecosystem model of nitrogen stocks and fluxes is built and examined different scenarios of fallow management with or without livestock to understand how agricultural practices and landscape management affect crop production. The results suggest that crop production is highly dependent on the source-sink dynamics of nitrogen. The study highlights a trade -off between space devoted to production (cropland) and space devoted to fertility restoration (fallow) because without livestock, maximum crop production is obtained for an intermediate duration of fallowing. Crop production is higher in presence of livestock than without livestock for a shorter duration of fallowing. This result highlights the conversion of savanna rangeland to cropland, and from fallow land to cropland, respectively due to the positive roles of livestock and fallows as pumps (vectors) of nitrogen. However, it also highlights tradeoff between the livestock presence and fallowing, suggesting that the best mix of livestock and fallow management is highly context-dependent. (Bissona, 2019)

Shortening crop rotations, simplifying cropping systems, and segregating livestock from cropping enterprises have generated high yields while creating high environmental cost. Improvement in soil health, reduction of financial risk, increase yields, and reduction in many negative environmental externalities can be achieved through diversification, including integrated crop/livestock systems and the use of cover, forage, and perennial crops. The effects of four different dryland farming methods on overall production, financial performance, and soil quality are investigated in eastern Washington State in a five-year study. According to this study, adding perennial crops to organic farming systems—like alfalfa and forage grasses—can improve soil quality, increase profitability, and provide nitrogen for grain crops that come after.(2019, Wachtera) Cattle are kept by individual keepers in sub-Saharan Africa, but they often come into contact with animals from other herds when they graze the same pasture, use watering stations, or use the same bulls for breeding and ploughing. Although these connections are not extensively documented, they may have significant implications for the transmission and control of illness.

A study was conducted in a mixed farming area of predominately smallholder farmers among 329 farms from Kimilili sub-county of Bungoma County. Over the past four weeks through grazing and watering contacts, between 45.6 and 100% of the farms in each study village had been in contact. Over the past 12 months, between 88.9 and 100% were considered to have been in contact. Effective disease control and surveillance must take into consideration the frequency and range of contacts that occur between farms within a single village. (Ogola,2018)

Together with population growth, coastal systems are undergoing both natural and man-made alteration. Understanding how socioecological drivers at the various hierarchical levels—micro, meso, and macro—affect coastal farming systems—which are vital to the livelihoods of coastal residents—is crucial given the growing changes in socioecological conditions over the past few decades.

Together with a rising population, coastal systems are facing natural and human-driven change. Understanding how socio ecological drivers at different hierarchical levels: -micro, -meso, and -macro affect coastal farming systems, play a crucial role in the livelihoods of coastal dwellers with increasing shifts in socio ecological conditions during the past several decades. In Southern Bangladesh mixed rice-livestock-aquaculture farming represent the rapid change occurring in many of the world's coastal farming systems in response to these drivers. More homogenous farms with less livestock and more off-farm activities are replaced by heterogeneous, rice-livestock farm types. Changes in farming systems were influenced by micro-level factors including farm plot fragmentation, farmers' experience in cropping, machinery, salinity and soil fertility. The trajectory of farming systems change were also affected by meso-level factors including markets, road infrastructure, labour availability, access to extension and land tenure also affect. Cropping intensity among farms outside polder systems were posistively and significantly influenced by population density, one of macro-level driver. Within polders, a positive but non-significant trend was observed for the influence of population density on cropping intensity. When developing appropriate policy options for sustainable development in South Asia's coastal farming systems, importance of accounting for multiple levels of socio-ecological drivers of change was underscored by the study.(Aravindakshan,2020)

To examine the argument proposed by Robert M.Cc.Netting that small-scale, mixed crop-livestock farming leads to environmentally sustainable agricultural practices, a study was conducted and it is found that there exists strong association between mixed crop livestock operations & sustainable practices. It is the strongest effect in the global, developed & developing country analyses According to a study, there is a substantial correlation between sustainable practices and mixed crop livestock enterprises. In evaluations of both wealthy and developing nations, it has the greatest impact. Animals on farms where people also grow crops urge farmers to recycle animal manure into croplands, and these activities appear to encourage farmers to adopt additional practices that improve agricultural sustainability, such as rotating cover crops and minimizing tillage. (Rudelet, 2016)

2.6 Mixed farming and Social Sustainability

The majority of the world's milk and ruminant meat are produced by mixed crop-livestock systems, which are especially crucial for the livelihoods and food security of the impoverished in emerging nations. The burden of helping to meet the growing demand for food from growing populations will fall mostly on these systems, especially in South Asia and sub-Saharan Africa, where hunger and rural poverty are already prevalent. (Thornton,2014)

The production system influences the embodiment of resources in agricultural products. In a mixed farming system where there is mix of lamb meat; permanent crops: rainfed olive and almond; arable crops: rainfed barley, irrigated barley, alfalfa and sunflower, emergy flows, transformity values and emergy indices at the system level is studied. The fully-integrated mixed system obtained a balanced position in intensity, efficiency and sustainability while specialized pasture-based sheep system had the lowest intensity and efficiency and the highest sustainability, as opposite to the partially-integrated mixed system. Due to their higher capacity to use local and renewable natural resources, all sheep sub-systems had comparatively lower intensity and higher sustainability than crops. The findings suggest that further support of agricultural development based on local and renewable natural resources and best practices is necessary to ensure long term farming sustainability and social welfare. (Ortega,2017)

Women play an important role in sheep rearing in Mexico. Such women are invisible to researchers in policy making. So a gender based approach is needed to raise the profile of the women. This would include clarifying how and why sheep production duties are allocated between women and men in households and understanding how and why policies differentially affect women and men in terms of their access to productive resources entitlement programs. Chiapas sheep are considered sacred creatures with a soul and they are members of the family. Women in Chiapas is responsible for sheep management, and they are known as “shepherdesses” which highlights their role, describing that sheep production is part of a women's ethnic identity. Production interventions could be facilitated by targeting women clients and making better use of their knowledge and practical experience.(Vazquez,2013)

Women performed roles like Kitchen gardening, post harvest operations like storing, cleaning & drying the produce, preparation & preservation of fruits, feeding animals, preparation of milk and milk products. Women agricultural labourers often performed roles in the field of crop production like weeding, assisting in cleaning farm, residues, carry inputs to the field, collecting fodder etc. Participation of farmwomen in decision making was found to have positive & significant relationship with mixed farming productivity at 1% level of significance & negatively related with role performance. (Shilaje, 1994)

The small sized holding and meagre income obtained from the crop enterprise alone may not be sufficient to support a family. Hence, majority of the farmers take up dairying as an additional enterprise which provides extra income and gainful employment to the family members throughout the year. In majority of the holding, men folk are being employed in more remunerative vocation. Under this circumstance the women folk is rather compelled to shoulder the entire responsibility of managing the farm. Most of the studies highlights the role and contribution of women in increasing productivity of mixed farming systems. To understand the role of farm women in mixed farming, a study was conducted in Kollam and Kannur districts of Kerala. Kitchen gardening, post harvest operation and management and care of animals are the roles performed by farm women. Women agricultural labourers often performed field oriented task. Women always participated in taking decisions in areas like seed selection, choice of crops, care and management of animals and number of animals to be maintained. (Shilaja,1994)

A study focused in Thrissur and Palakkad districts of Kerala with the objective of examining the dimensions of gender in farming activities in terms of type and volume of work undertaken, role in decision making and pattern of time use by men and women in farm and family. Men dominated in all production, marketing and household activities in the independent decision making. Men dominated in crop activities and women in dairying and household in the work participation. Men and women in general allotted 8 hours for productive work but work of women continued at home. The most welcome change was that in the decision making, regarding production, marketing and household affairs joint decision of men and women was getting increasing importance.(Subhadra,2009)

A very important dimension of mixed-farming systems is that women are clearly recognized for their vital roles in small- scale livestock production. This does not imply, however, that women formally own the animals or benefit from animal sales. Compared to men, women have less access and control over grazing land, water, fodder, credit, markets, and veterinary services. Women's labour and responsibilities remain under-recognized and underappreciated in policy design and implementation (García, 2013)

Similarly Iranian women also play an important role in agriculture. Rural Iranian women in a number of traditional societies raise small animals such as goats and poultry to provide them with a traditionally acceptable source of income over which they may have some control. A study was conducted in Tafresh area of Iran to examine factors influencing participation of rural women in mixed farming activities. Regarding their overall participation in mixed farming, sixteen characteristics of rural women had significant relationships. Nine variables were positively & significantly correlated with overall participation of rural women in mixed farming and some variables were negatively correlated with the participation of rural women in mixed farming. (Fami, 2006).

Viability of family farming is strongly linked to labour productivity and opportunity costs of labour in the wider economy. Increasing labour productivity is as important as increasing land productivity in order to ensure the quality of life of family farmers (De Schutter, 2011). Labour productivity of most Uruguayan family farm systems is lower than lower than the opportunity cost of labour, estimated as the cost of temporary hired labour in the region. Within similar resource endowment, wide variability in labour productivity can be observed between farms. For the development of more sustainable family farm systems, quantifying and understanding the main causes of the gap between current and attainable labour productivity, and its variability among family farms is crucial. A study was conducted to develop a method to examine labour productivity in the framework of a co-innovation project and to analyze the main causes of low labour productivity in family farms, in order to propose strategies to increase it. In south Uruguay, low labour productivity and high workload are common problems among family farmers. It was found that nine of the fourteen farms studied had in 2013-14 a labour productivity equal or lower than the opportunity cost of labour (4 U$S hour-1), and the maximum estimated was 8 U$S hour-1 (Colnago, 2015)

2.7 Determinants of Sustainability of Mixed Farming

In Shushtar township, a study was conducted to identify factors affecting the sustainability of production systems in 2011 among 160 people. Identifying factors that threaten the sustainable and continuous production is of great importance because agricultural production cooperatives have special importance in the region economy. Descriptive results showed that most of farmers are illiterate and old. 66.78 % of production cooperatives lie in the relatively stable group and also reveals that there is a positive and significant relationship between age, farming experience, type of agriculture, agricultural land area, and area of cultivated land, ecological characteristics, social status, knowledge and attitudes for sustainable agricultural production cooperatives with stability. Six variables of total production, attitude to sustainable agriculture, the amount of intake facilities, social association, and relational properties indicate about 81% of dependent variable of production cooperatives has been showed in multivariable regression analysis for identifying the influencing factors to sustainability. (Joneydi, 2012)

Sustainable intensification practices (SIPs) involve a process to produce high yields for existing land without affecting the environment. A study in Pakistan takes the initiative to investigate the determinants regarding the adoption of five SIP practices such as improved seeds, organic manure, crop rotation, intercropping, and low tillage. Furthermore, this study analyzes the adoption of SIPs with randomly collected data from 612 farmers through multistage sampling. To identify the factors associated and to analyze the mutually dependent adoption decisions, a multivariate probit model (MVP) is employed. The factors that predict the adoption of SIPs are education, the area under cultivation, access to information, extension access, social participation, rainfall variability, and temperature increase. The highest SIP practice adopted was organic manure and crop rotation was between all the ecological zones, whereas low tillage was the least adopted practice. Compared to other ecological zones, adoption intensity in mixed cropping zones was slightly higher. The important synergies amid natural resource management and input-based SIPs were also revealed by the study. Hence, the study highlights the perseverance and importance of social groups and recommends the government to formulate comprehensive policies to facilitate institutional access and elevate the adoption level amongst the farming community. (Jabbar, 2020)

The best potential livelihood strategy for farm households is crop–livestock diversification. The most dominant crops that have immense contribution for human nutrition are barley, wheat and faba bean and crop residue mainly used to feed livestock. Therefore, crop–livestock producers, agricultural practitioners, the Ethiopian government and partner organizations needed to be given due attention for agricultural extension service, investment for supplementary irrigation and integrated mixed crop–livestock systems. (Mekuria, 2018)

The mixed crop and livestock (MCL) farming could enhance farmers to improve their farming practice. In Magelang Regency, the study aimed to analyse factors that influence the adoption of MCL farming and data was collected through personal interview based on structured questionnaire from 161 smallholder farmers. To analyse the binary choices of practicing MCL farming, logit models was applied. Age, consulting toward extension agent, and number of livestock kept by farmer, experience on raising livestock and type of ruminants are the major determinants of adoption of mixed crop and livestock. The younger farmers and farmers who raised large ruminants were have more possibility to adopt the MCL farming practice. **(Widarni, 2020)**

2.8 Constraints in Mixed Farming

Agriculture is the backbone of Indian economy. The Indian farmers mainly depend on animals for their farming activities which is also major source of income to the small and marginal farmers. Thus keeping milch animals has become the part of the agriculture. India ranks first in the world milk production. Mixed farming system is a combination of crop production and livestock. While, adopting mixed farming farmers faces different constraints viz., personal, social, technical, economical etc. A study conducted in Anand Taluk of Anand district of Central Gujarat analysed constraints in the adoption of mixed farming. The study revealed that insufficient supply of high quality inputs based on farmers demand in mixed farming, shortage of laborers that can do both crop production and animal husbandry related activities are the major input-supply related constraints faced by the farmers in the adoption of mixed farming. Lack of knowledge on disease prevention practices in animals, lack of knowledge about livestock/crop insurance was the major technological constraints. Lack of timely technical advice on livestock and crop management practices, delay in approval of loan and subsidy were the administrative constraints. Absence of support price in case of glut in the market, fluctuations in market price of products was the market related constraints. The personal and socio psychological constraints were lack of knowledge about optimization of crop rotation practices in mixed farming and the suggestions offered by farmers were to promote supply of quality concentrate feeds for livestock for mixed farming, timely availability of loan/subsidy, to develop model for location, farm size and herd size specific mixed farming for small, medium and big farmers.(Onima ,2016)

The study conducted in Palakkad and Thrissur districts of Kerala is to assess the constraints associated with production and marketing of mixed farming. In the production of crop and milk together, fifteen problems were reported by farmers of which four were common to both activities. The second important problem faced in both crop production and milk production is the low productivity. The study revealed that non availability of land is the most crucial problem to crop production and feed cost to milk production. In both cases low price for the product was the most crucial. Equally important were transportation problem (cost or distance) and lack of marketing facilities. (Subhadra, 2009)

A study of constraints perceived by farmers in crop - dairy mixed farming system on small farms in Parbhani district of Marathwada region of Maharashtra state highlighted that the non-availability of inputs at village level, high cost of inputs and lack of technical guidance in time were the major constraints reported by 100 per cent, 86.67 per cent and 71.67 per cent farmers, respectively. Low productivity is the major constraint in dairy animal rearing in the study area in case of local cow owner majority of respondent i.e. 100 per cent were facing the constraints. Low price of milk, high cost of feed and fodder and lack of organized market are the major constraints in case of crossbreed cow. Beside these major constraints respondents dairy owners were also faced some other constraints in milk production and marketing of local cow, crossbred cow and of buffaloes.(Shrey,2015)

While all these studies reported the perception of farmers, a study conducted in Hisar district of Haryana highlighted the perception of scientists about the factors affection mixed farming. The important constraints pointed by the the scientists are young generation does not like animal husbandry related work', 'non-availability of pasture and fellow land', 'non-availability of green fodder', 'farmers lack of knowledge about improved animal husbandry practices', 'high cost of animal feeds', etc. On the other hand, items like 'there is perception that animals cause diseases', 'changing milk consumption patterns', 'more time is required for agriculture leaving less for animal husbandry', 'lack of market for dairy products' etc. were perceived as least serious.(Rachna,2017)

2.9 Research Gap

After having reviewed the available literature on the similar direction, it is evident that majority of studies highlighted the need and implications of mixed farming in supplementing income, integrating crop production and livestock and promoting sustainability. Mixed farming plays an important role in reducing poverty among the rural masses compared to other farming systems. The present study aims to explore economic, environmental, and social sustainability, along with the complementarity of mixed farming practices. By exploring the multidimensional aspects of sustainability, the research provides insights into the potential for mixed farming systems to contribute to sustainable development. By investigating these elements, the study contributes to the existing body of knowledge on sustainable agricultural practices of mixed farming. However, there is a lack of comprehensive research that examines the interplay between these three pillars of sustainability in the context of mixed farming system. Additionally, the impact of mixed farming practices on long-term resilience and rural livelihoods remains underexplored, highlighting a significant research gap in understanding the holistic sustainability of mixed farming systems. The present study addresses these gaps and provides valuable insights into sustainable agricultural development.

CHAPTER 3
MIXED FARMING SYSTEMS: MECHANISMS, TECHNOLOGIES, AND PRACTICES IN INDIA AND KERALA

3.1 Introduction

This chapter explores the foundational concepts and definitions related to mixed farming, providing an in-depth understanding of the mechanisms, modes, and technologies that shape mixed farming practices. It provides an insight into the characteristics of a successful mixed farming system, emphasizing the critical components that contribute to its effectiveness and sustainability of mixed farming. Additionally, the chapter examines the state of mixed farming in India, highlighting its diverse practices, challenges, and innovations. Special focus is given to farming in Kerala, exploring the unique agricultural landscape of the region and the specific factors that influence its mixed farming systems. Through this comprehensive exploration, the chapter aims to lay the groundwork for understanding the broader context of mixed farming system and its implications for agricultural development and sustainability.

3.2 Definitions of Mixed Farming

There are many definitions for mixed farming. The common definitions of mixed farming that are found in literature are summarized below.

Mixed farming is a type of farming system in which crop production and livestock rearing are combined to sustain and satisfy as many needs of the farmer. Some of the definitions have specified limits to the contribution of livestock production to the total income of the farm. The livestock enterprises may contribute at least 10% and should not exceed 49% of entire yield. In mixed farming as livestock manure is utilized as fertilizer for crop production, this facilitates organic manuring and maintenance of soil health. Throughout the year mixed farming provides employment to the farmer and his family. In mixed farming waste products of each enterprise is properly used. Agricultural by-products are properly used in mixed farming. It further provides a sort of stability to the farm business. (Subha et al,)

According to the FAO (Livestock, Environment and Development Initiative – LEAD website), Mixed Farming System (MFS) are defined as farming systems conducted by households or by enterprises where crop cultivation and livestock rearing together form integrated components of a single farming system. The primary drivers of mixed farming are (i) the distribution of risks between crop and animal productions, (ii) the complementary nature of crops and livestock, and (iii) the flexibility to modify crop/livestock ratios in response to opportunities, risks, and requirements.

Others define MFS as systems in which more than 10% of the waste products from crop production are used to feed livestock, and more than 10% of the value of production comes from non-livestock farming enterprises. Such context-relevant integration of crops and animals in the same system appears to support a biological, ecological, economic and social sustainability in the global food production chain. (Sere´ and Steinfeld, 1996)

European research studies use the terms "mixed systems" or "mixed farming systems" to consider all farming systems involving both crops and livestock (Havet et al., 2014; Schiere and Kater, 2001; Wilkins 2008). This definition includes all farming systems having at least one livestock component and some crop production, allocated either for cash crops or for animal feeding only. Thus it can be concluded that mixed farming is a combination of crops and livestock.

According to FAO, "The best known form of mixed farming is when crop residues are used to feed the animals and the excreta from the animals are used as nutrients for the crops." Mixed farming is considered by the FAO as probably the most benign agricultural production system from an environmental perspective because it is, at least partially, a closed system (Schiere and Kater, 2001). The waste products of one agricultural activity (crop residues), which would otherwise be heaped on to the natural resource base, are used by the other agricultural activity (livestock rearing) within the farming system, which returns its own waste products (manure) back to the first agricultural activity. Hence mixed farming provides many opportunities for recycling and organic farming and has become the most preferred farming system of many agriculturalists and environmentalists. (FAO)

More precisely, Seré et al. (1996) defined mixed farming systems as "having more than 10 percent of the dry matter fed to animals coming from crop by-products or stubble; or where more than 10 percent of the total value of production comes from non-livestock farming activities." (EIP-AGRI Focus Group on Mixed Farming Systems, 2017)

American research studies use the term "integrated crop-livestock systems" with the specific acronym ICLS (Franzluebbers et al., 2014; Hendrickson et al, 2008). For Hendrickson et al. (2008): "Integrated agricultural systems have multiple enterprises that interact in space and time, resulting in a synergistic resource transfer among enterprises. Dynamic-integrated agricultural systems have multiple enterprises managed in a dynamic manner". (EIP -AGRI Focus Group on Mixed Farming Systems, 2017)

Franzluebbers et al. (2014) underlined that ruminants associated with arable cropping when associated spatially and temporally with arable cropping is an essential foundation for integrated crop-livestock systems (ICLS), either within single farms or among specialised farms within a region. The farm and landscape level were both considered at least theoretically since Russelle et al. (2007) introduced the local level. (EIP -AGRI Focus Group on Mixed Farming Systems, 2017)

According to Sadhu and Singh(1993) mixed farming may be treated as a special case of diversified farming. In many of the cases, mixed farming means the combination of crops and livestock and that is why this combination is almost treated as interchangeable with mixed farming. This particular combination is important in the sense that these support each other and add to the farmers' profitability. (Amutha, 2016)

According to Raju and Rao(1990), mixed farm is that type of diversified agriculture, in which a farmer invariably devotes to livestock production as a complementary enterprise. At least 10 percent of the gross income must be contributed by the livestock and the upper limit being 49 percent under Indian conditions. (Amutha, 2016)

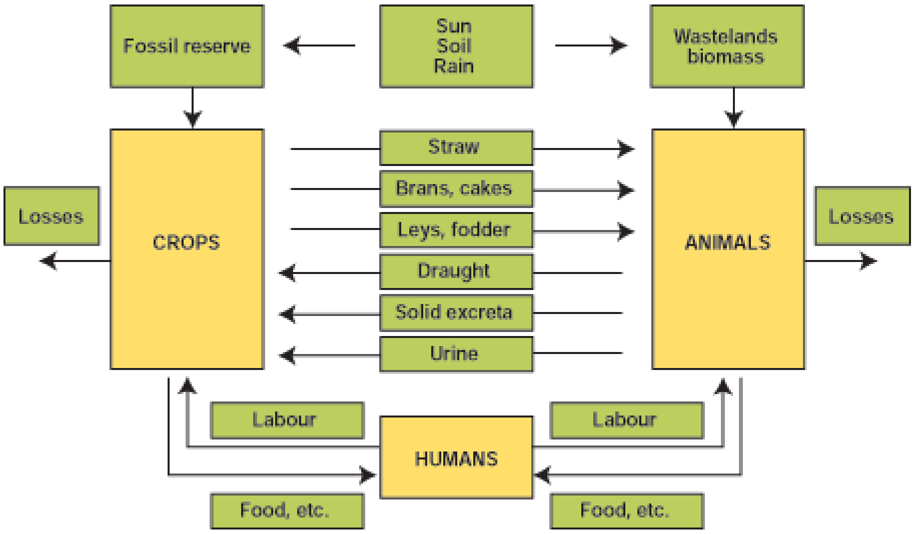
According to the report of National Commission on Agriculture (1976) mixed farming has been defined as a farming system where both crop and livestock production are combined for efficient and effective use of land, labour and capital. They stated that crop raising alone cannot provide sufficient income for the economic well-being of the farmers due to frequent calamities like drought, floods, etc.(Subhadra, 2007)

3.3 Mechanism of Mixed Farming

Mixed farms are systems that consist of different components, which work togetheras entirety. Thus mixed farming system cannot be studied as each component but in their entirety for understanding the factors that drive the decisions of mixed farmers. That principle is here referred to as the "command ideotype"(Donald, 1981; Schiere *et al.*, 1999). The principle of "communal ideotype" is the most important principle that increase the production of mixed farming system along with the realization of several functions between crops and livestock. (FAO)

The livestock in mixed farming are reared using local resources such as pasture, crop residues, fodder etc and the oil extraction, grain milling waste etc in return they provide livestock products for mixed farmers. Through recycling of waste products and exchange of resources within the farming system itself helps the farmers to save money. While livestock rearing is a source of income for farmers, mixed farming provide full time employment to farmer and can contribute to soil fertility and texture. (FAO)

Figure 3.1 Mechanism of Mixed Farming



Source: FAO

3.4 Different Modes of Mixed Crop-Livestock Systems

Even in integrated systems the exchange of resources such as dung, draught and crop residues takes place in degrees that differ among the so-called modes of farming (Schiere and De Wit, 1995), based on the availability of land, labour and capital respectively. The different modes of farming are Expansion agriculture (EXPAGR), Low External Input Agriculture (LEIA), High External Input Agriculture (HEIA) and New Conservation Agriculture (NCA). (FAO)

The Expansion Agriculture mode is applicable when land is plentiful and if scarcity of land occurs, agriculture can be expanded to other areas where fallow land still occurs. This type of mixed farming is found in West Africa, Old Asia and Europe. Livestock in mixed farming system are sent out to graze and they occasionally come home and used for various agricultural needs. In this type of farming, crop fields could be shifted to other places in search of soil fertility as it is assumed that land is abundant. But this method is rare because land resources are scarce. (FAO)

In real world, land is scarce and there is no possibility for shift in farming from one place to another. So there arises another mode of mixed farming that is LEIA. Low external input agriculture suggests that demand has to be adjusted according to availability of resource. Farmers are forced to make adjustments or modify the existing practices or use the existing resources due to lack of external inputs like fuel, fertilizers, pesticides etc. As crop cultivation cannot be shifted to another region when there is decline in soil fertility, farmers use manure of livestock ie dung is carried to fields in order to enhance the fertility of soil. Similarly more livestock cannot be reared to produce more dung. (FAO)

In high external input agriculture, gives little importance to exchange and recycling of resources. HEIA depend more on external inputs such as seeds, fertilizers, pesticides etc. Exchange of resources takes place if there is excessive use of fertilizers. In this farming demand for input is determined by demand for output. The environment is affected by this type of farming and forces a shift from HEIA to NCA. (FAO)

With NCA farming, output targets are closely aligned with the resource base as possible. This strategy is a hybrid of HEIA and LEIA; it seeks to restore the depleted nutrients while simultaneously achieving keen farming and modifying cropping and consumption patterns to fit regional circumstances. To avoid herbicides and improve fallows for grazing, pasture cultivation is important and it also promotes soil regeneration and suppress weeds. (FAO)

3.5 Types of Technology

There are a number of technologies related to mixed farming. Generally speaking, technology is a way to solve an issue. If a worker or a machine can milk the cow in place of a farmer who is sick of doing it, the farmer will be pleased. Farmers who become weary of pulling weeds by hand will be pleased to utilize herbicides or a hoe to make the task simpler. Any intervention which solves a problem can be treated as technology, regardless of whether it is technological, managerial, or policy-related. But cost of technology must cover extra return and saved effort. (FAO)

- **Input- and management-based technologies**

The output of a certain animal or farm can be increased by employing more inputs (feed, fertilizer, and pesticides), utilizing a machine to save labour, or digging wells if there is insufficient water. These technologies are input- and mechanization-oriented. Understanding the farm as a mixture of soil, plants, or animals, or the region as a combination of farms, people, mountains, subterranean water reservoirs, etc., is the main goal of management-based technology. Losses can be prevented with proper management. For example: When constructing the sheds for livestock, the sheds can be built in such a way that either sunlight enters at times that are convenient for the management or to let the sunlight enters unnecessarily or wrong time. Although collecting and preserving animal manure can take a lot of work, proper management is necessary to apply it when it's needed to fulfill its intended purpose.Through careful management of livestock (hygiene, timely feeding) and a sharp eye (recognizing the onset of an illness) might assist prevent the need for a cure, even though veterinarians can be called in to cure disease. (FAO)

- **Accelerating and defusing technologies**

Although it is challenging to distinguish between defusing and accelerating technologies, they are related to the exploitative-regenerative technologies and the previously mentioned distinction between input and management-oriented technologies. A medication given to a cattle forces it to conceive even when its body is too weak and this is an example of accelerating technology. The cow will collapse if it is forced to conceive again, and additional inputs will be needed to get it back in shape. Soil liming is another example of an accelerating technology. But they further deplete already weak soil. When cattle or goats are allowed to graze already-eroded hillsides, the same process occurs. For many centuries, liming, also known as marling, was a popular method of fertilization in Europe. Adding calcium, the primary ingredient in lime, to liberate phosphorus from the soil-nutrient may result in soil depletion.

Instead of accelerating technology, defusing it tends to take a more comprehensive approach, examining the problem's underlying causes and determining how to halt or reverse the fundamental processes. Defusing technologies are important in NCA and are typically methods that fallow land, rotate crops instead of utilizing chemicals (as in HEIA) to improve fertility or fight weeds or disease, or lessen erosion instead of enduring its effects. To help a cow replenish the reserves needed for the upcoming lactation, a good management technique would be to cease milking her a few weeks earlier while she is weak. In the end, the diffusing management strategy suggests paying attention to environmental stress signals. Instead of striving to exceed (local) carrying capacity, it seeks to decrease or adapt consumption and restore the resource base.

- **Indigenous and exogenous technologies**

Although the line separating indigenous and exogenous technology is not always clear-cut, it helps distinguish between solutions that are developed and accumulated over many generations by farmers and those that are imported. Emphasizing the existence of indigenous technology opens up a wealth of local creativity and knowledge that can be used to adapt foreign technologies for local usage. Farmers are frequently able to develop low-cost solutions that would not have been thought of by others. Technical solutions that are imported, such as a disease vaccine or a new feed conservation method, can undoubtedly be beneficial. However, some might not suit local conditions, and it can be more cost-effective to employ a local solution. Ethnoveterinary medicine, in which women use local plants to treat or prevent illness in their goats, chickens, or other animals, and the optimal time to plant or plough are typical instances of traditional knowledge. Utilizing indigenous technologies can also be helpful in managing local company owners, herding rights, and soil differences. There is no "cure for all" in indigenous knowledge; for example, it offers little to no strategies for dealing with infectious diseases and the emergence of new disorders that accompany development. However, it has been demonstrated that applying local knowledge to local issues significantly increases the acceptance of development programs.

Technologies for national and/or local problems

The national level is more affected by certain issues in animal production than are small farmers. While diseases like classical swine fever, foot-and-mouth disease (FMD), and rinderpest harm farmers, they mostly threaten a nation's export licence. Put another way, a lot of farmers won't be inspired to do actions that don't directly benefit them. Large-scale initiatives will need to consider that. The desire of governments to ensure that food is affordable and available to urban populations is a more extreme example. It might be necessary to produce cereal food even though farmers may be against this.

- **Technologies for individual farmers and for society**

In order to offer inputs, effort on credits and savings, or on a watershed program, for example, cooperatives are helpful types of farmers' organizations for development. Not all technologies, meanwhile, are beneficial for group efforts. For instance, whereas treating a broken leg or an animal that has had a difficult birth is dependent on individual interests, a vaccination campaign almost likely requires the establishment of groups. While farmers' study groups constitute collective activity, farmers and/or their extended families make the decisions about their investments and agricultural and animal management techniques.

- **Exploitative and regenerative technologies**

Though it addresses the farmers' and farming's time horizon, this distinction is similar to that under the section of accelerating and defusing technology. Planting the fodder grass Brachiaria results in higher yields but also more depleted soils. Although investing in soil regeneration or planting legumes yields less in the immediate term, they guarantee a living for future generations. Specifically, the NCA mode of mixed farming places a strong focus on regeneration through the use of technologies like leys, nutrient recycling, cropping/livestock component, and erosion management with fodder crops.

3.6 Mixed Farming and the Communal Ideotype

The concept of the "communal" ideotype, which Donald (1981) coined for wheat breeding, highlights that the yield of entire plot is more important than yield of an individual plant; in other words, no farmer is interested in high yielding individual plant (i.e. component of a system) yields if they do not result in an increase in total farm yields (entire system). The communal ideotype and the design and selection of technologies in mixed crop-livestock farms can be shown in a number of ways:

According to a study conducted in India under LEIA settings using various crop-animal combinations, using cows that produced 10 liters per animal per day resulted in better farm outputs overall than using cows that produced 16 liters per animal per day. High-yielding dairy cows cannot be fed fibrous crop wastes like straw; therefore, aiming for a high milk output per cow would lower farm profitability overall and prevent the utilization of these resources.An additional problem, namely the ideal mix of crops and animals, is revealed by a study of crop-livestock combinations in Kenya. High-yielding grade cows are more advantageous to large farmers, while small farmers are better suited with cattle that match their resources.

Field observations pinpoint the idea that farmers should modify certain aspects of their farms to increase overall productivity. Crossbred cows or medium-producing animals are used instead of purebreds in various tropical and temperate regions. Even at the sacrifice of some grain output, farmers in drought-prone areas select grain crops that also provide high-quality straw or fodder. (FAO)

The utilization and implementation of a specific technology and/or management technique are reactions to a stressful circumstance. Furthermore, what is effective in one location might not be in another. In recognizing local issues and adapting exogenous problem-solving technologies to local circumstances, participation is frequently underappreciated. The word "participation" here should be interpreted broadly to mean that farmers should be heard by policymakers and vice versa; that animal needs are viewed in relation to crop and soil needs; and that the cost of food in the city is correlated with what would be needed to establish and sustain robust rural communities for long-term food security.

The use of a technology or management strategy are solutions to problems or a particular situation.. In addition, the solutions or strategy or technology that works in one place may not work in another situation. In order to modify the existing technology or strategy suitable to local condition or to identify problems of local farmers, participation of farmers must be ensured. That means while designing the policy farmers must be listened by policy makers so that needs of animals can be related to needs of crops, price of food in urban areas can be related with rural farming community for food security. It indicates that each individual component's optimal production level is determined in proportion to the entire yield. This idea, known as the communal ideotype, calls on governments, academic institutions, and educational institutions to shift their focus from individual farm components to the entire farm, region, or community. Farmers have long been aware of this and have frequently chosen a mixture that produces medium yields in mixed systems, such as crossbreds rather than purebreds or crops and/or animals with multiple or dual purposes rather than single-purpose species.

3.7 Successful Mixed Farming Systems

Systems that exist for a long period are considered sustainable. It must be acknowledged, meanwhile, that no system can last indefinitely; that is, all systems eventually become unsustainable. Every system must constantly adapt, especially when there is a significant imbalance in the interaction between the practice and its reserves. The infield/outfield ratio in EXPAGR or HEIA, or the relation between management capacity and management demand when a farming system transitions from HEIA to NCA, are examples of systems and their resource bases.

The Infield/Outfield System

An outfield/infield system is a mixed system that uses animals to graze "outfields" that are far from the village. This allows all or some of the plant nutrients that are excreted to be concentrated on the "infields" that are close to the farmhouse. In the EXPAGR mode, where land is plentiful, it is a type of mixing. The system has existed in a variety of versions. In order to preserve the nutrients in the animal dung and urine, it can be enhanced by building special stables where straw from the cropland, forest litter, or even topsoil from the outfield is used. It can also use animals that are grazed during the day and only fed on crop fields at night while being

An outfield/infield system is a mixed system that grazes animals "outfields" far away from the village in order to focus all or part of the excreted plant nutrients on the "infields" near the farmyard. It is a type of mixing in the EXPAGR mode where land is plentiful. The system exists in many forms. It can be strengthened by building farmhouses in which straw from the crop land, waste from the forest or even topsoil from the outfield are used to maintain the nutrients of the dung and urine from the animals. As the amount of recycling on the farm increases, the system progressively switches to the LEIA or NCA mode. Having existed throughout pre-medieval Europe and Russia until the early 1900s, the system has been in place for centuries. Many tropical countries still use it today. Examples of improvements include the introduction of legumes for nitrogen delivery, better nutrient conservation in the stable, and more timed and localized dung treatment on the field.

The Kano Close-Settled Zone

For the past 30 years, an example for the intensive mixed farming system of the NCA mode, where all available land are utilized for cultivation is Kano close-settled zone in the Soedano-Sahelian region of Nigeria. Small ruminants consume waste products of crop production, especially those of groundnuts and cowpeas, which is the good fodder, and the nitrogen in the leguminous crops is preserved in the manure, which is brought back to farmers' fields to be used as fertilizer. The money obtained from the sale of legume grains allows farmers to buy other goods or, if they so choose, inorganic fertilizer. When farmers' fields receive harmattan dust—a breeze that carries sand from North-Sahel and the Sahara—during the dry season, nutrients are supplied to the system. With a focus on small ruminants and a high labour input need, the system enables farmers to oversee an effective nutrient recycling system. During the wet season, they have to tie the animals inside the compound, gather weeds and crop wastes for animal feed, and return the dung to the fields.

The Cipav System

Colombia has created a particular crop-livestock system that relies on the contributions of methane, sugar cane, and pigs. After the name of the institute where it was created, it is known as the CIPAV system. Its primary ingredient is sugar cane, which yields fuel (bagasse) and feed (juice and tops), and it is being used and tested in various places of the world. The protein comes from multipurpose trees and water plants like duckweed, but the trees also provide other vital functions including reducing erosion, acting as carbon dioxide and methane sinks, and fostering biodiversity. Trees and sugar cane both have highly effective biological pest management systems that don't require a lot of artificial chemicals. Additionally, they may be readily divided into high- and low-fiber fractions as needed for the various final applications of fuel and feed for sheep, cattle, and pigs. Pigs and ducks are the recommended animals because they have a high meat: methane production ratio and can easily adapt to the high-moisture content dietary supplies. They are complemented by sheep, which can eat mostly the cane tops and tree foliage. In addition to providing meat and milk, buffaloes and/or triple-purpose cattle can also provide draught power. To reduce environmental harm and increase nutrient recycling to the crops, all cattle are kept in partial or complete confinement. The growing adoption of many of the CIPAV model's components by resource-poor and enterprising farmers is evidence of its adaptability. (FAO n.d)

Sukhomajri Project in India

Sukhomajri is a hill town in northwest India, close to Chandigarh. Once extensively forested, the hills have suffered from overgrazing and significant erosion as a result of growing human and livestock populations. In the 1970s, vegetation covered only 5 percent of the uplands, and erosion rates of 150–200 tonnes/ha were not unusual. To service the city of Chandigarh, a dam was built in 1958, creating a lake. However, by 1974, more than 60% of the lake was filled with sediment. The authorities initially attempted, but failed, to convince the village's Gujjar ranchers to quit using the slopes for their goats and cattle in order to save the lake. The turning point was the decision to construct a small dam in the hills to supply water to the community and strengthen the dam's catchment. Farmers received subsidized seed and fertilizer, and the stored water was utilized to irrigate neighboring farms. Farmers who did not profit continued to graze on the hills despite the significant rise in yields. In order to expand the irrigation system, the villagers then unanimously suggested building additional tiny dams. In order to manage the water, they also recommended establishing a society of water users founded on the equity principle. A "coupon" system was established, allowing families with limited or no land to either water rights was sold or used the water to sharecrop on other people's land that was water-scarce. The society was tasked with maintaining the dams and their catchments, distributing the water, and keeping records. Any member whose livestock was discovered grazing in the hills lost their water rights.

From that point on, the village started to grow quickly. To supply milk for the expanding settlements nearby, the locals traded their goats for high-yielding buffaloes. The fast-growing fodder grasses in the hills were used to stall-feed the buffaloes. These initial actions had positive effects right away and encouraged the villagers to participate in more improvement experiments. For example, the farmers created new technologies based on lablab and velvet beans and started experimenting with green manures, which had never been tried before. The farmers started planting vegetables as maize yields rose and their subsistence was guaranteed. There are no subsidies offered; the project is self-help. The farmers had built about 300 km of erosion works by 1990 using just their own labor. The landless in the region are benefiting from a rise in the daily pay, and out-migration has essentially stopped. Many landless people have started to claim rights to land that they formerly thought was worthless but is now productive due to new technologies.

3.8 Mixed Farming System in Different Countries

This section elaborates mixed farming system practiced in different countries; India and Kerala to get an idea about practices and conditions under various contexts. Mixed farming is common in one form or the other all over the world. During the pre-world war-II period, there were extensive areas devoted to subsistence crop and livestock farming located in East Europe, the Soviet Union, the Middle East and Mexico. After world war-II there has been an increasing pressure on peasants to collectivise their petty holdings. This has happened especially in socialist countries of Eastern Europe.(Mnadape,1988). Due to drastic changes in agricultural sector, the subsistence mixed farming covers a very limited part of global arable land.

In Asia, mixed farming systems are the backbone of Asian agriculture (Devendra, 1983). Crops and animals are main components of integrated farming in Asia and it is well developed especially in small scale agriculture. Synergistic interactions have a greater total effect than the sum of the individual effects (Edwards *et al,* 1988). In this farming system, there will be exchange of resources which results into complementarity and resource use efficiency in these systems. Similarly in North America and throughout Europe, mixed farming especially combination of commercial crops and livestock is found in common.

In Indonesia, the Three-Strata Forage Systems (TSFS) is environment friendly way of producing and maintaining the required feed of cattle and goats. In dry land farming areas such as eastern Indonesia and South Asia the system combines production of food crops, including maize, groundnuts, cassava and pigeon pea, with shrubs and trees to supply year round feed for stock (Nitis *et al,* 1990).Rice-fish-duck system is also seen in Indonesia. A best example for mixed farming is rice-fish-ducks system and this system is successful in achieving efficiency of integrated natural resource use and its economic benefits.

In United States mixed farming is the second most extensive type of agriculture, and covers a large part of eastern half of the country. It extends through Ohio, Indiana, Illinois, Iowa and Nebraska on the north, and Virginia, Tennessee, Georgia, Oklahoma and much of Texas on the south. A small area in Pacific North-West also has mixed farming.

In Central Sri Lanka, crop production involves trees especially coconuts and fruits, root crops and herbs integrated about 20 per cent of these farms with livestock production such as dairy cattle, goats and poultry.

Mixed farming systems including both crop and livestock are widespread at all altitudes in Latin America (Voccaro, 1997). In the South American Savannas, despite conventional separation of crops and livestock, as, integration is becoming common on large farms

In Zimbabwe, mixed farming systems are based on small holder mixed farming using livestock draught power and minimum external inputs. Livestock are indispensable for cropping because they offer labour and manure, as well as milk and meat which contribute to household consumption and income.

Mixed farming systems, involving complementary interactions between crops and livestock such as using animal traction and manure for cropping and feeding crop residues to livestock, are increasing in sub-Saharan Africa (Powel et al., 1995). Mixed farming - crop livestock integration replaced conventional specialized production systems of shifting cultivation and nomadism and promoted permanent cultivation and reduced grazing. Through mixed farming in the sub humid and wetter parts of the semiarid zone, agricultural productivity has increased.

In Spain (Encisco et al., 1995), during the last decade, many farmers have moved from the traditional cereals or horticultural production towards diversification, combining traditional crops with livestock production. As a result, farmers are utilizing labour more efficiently and have been able to raise their income so that they can stay in rural areas and sustain farming.

In Thailand (Chantalakhana, 1990) most of the people depend directly on agriculture for their subsistence and survival, with small farm systems forming the backbone of traditional agriculture.

By diversifying crops and livestock, in Philippines the integration of aquaculture with livestock production has enhanced resource use efficiency, minimized risk, and this contributed towards additional food and income.

It is reported that in Argentina's Pampean region (Pizzarro and Cocciamani, 1994), the main activity of the owner contractor farmers is crop production, with small amounts of land devoted to pigs. These form small farmers' groups also follow a crop pasture rotation system.

In South East Asian countries, crop/livestock farming systems are dominant. Animal production involves both ruminants and non-ruminants contribute a significant proportion of farmers' income. The ruminants and non- ruminants are integrated with crops. Systems vary according to agro ecological zone and various degrees of farming operations.

Denmark became one of the leading exporters of foods of animal origin like butter, cheese, bacon and poultry meat due to well balanced and comprehensive mixed farming system. The success story of Denmark (Prabhakaran and Raut, 1980) is clearly illustrative of the fact that the small holdings are likely to be economically more viable than large holdings. Due to this, primary importance is given to integrate rural development in the current Five year plan and special programmes are implemented suitable for small and marginal farmers.

Cornwall, UK, is home to an well managed mixed farm. A simpler crop rotation was once practiced at the MFS farm, where some crops were sown in the spring, some in the winter, and others undersown with a new pasture. Grassland and cattle production are essential for utilizing the geographic advantages in a sustainable manner for future success, especially in the Cornish environment, which is wet and maritime. To generate an extra source of income, male dairy calves raised for rose veal utilize secondary products from the main dairy output. The complementarity between crops and livestock reduce labour and improve the quality of life of farmers.

Approximately 1900 hectares of land make up the biodynamic/organic mixed farm Juchowo, which is situated in northwest Poland and is utilized for nature preservation, vegetables, grasslands, and arable crops. Along with offspring, the farm also contains 370 dairy cows of the Holstein-Frisian and Brown-Swiss breeds. The breeds were chosen because they lived a long time. The foundation of the crop rotation is made up of legume crops, which also contribute significantly to increased soil fertility. Social therapy, research, and education are some of the several social activities that take place on the farm.

An illustration of the implementation of mixed farming among 48 local farmers at the regional level and turning nutrient spillovers into a useful fertilizer in South Tyrol, Italy, established a firm to collaborate with the local biogas sector, an advisor, and a researcher in order to support this regional integration. One of the main agricultural pursuits in the region is dairy farming, although nutrient spillovers have resulted from the valley's enormous concentration of cattle. However, there is a considerable requirement for fertilizers for vineyards in particular parts of South Tyrol. By conditioning manure digestate through a biogas plant, this collaboration project enables nutrient exchanges between the two sectors.

In South-Western France, mixed farming methods are also observed at the regional level. In order to create optimal mixed farming systems by linking specialized crop and animal areas, a study was carried out in the Aveyron River Basin. In order to diversify short cereal rotations and maize monocultures, hypothetical scenarios were developed. One key lever that was taken into consideration was the temporary addition of alfalfa grasslands to cropping systems. According to the scenarios, a new supply chain for harvesting, processing, transporting, and distributing alfalfa to livestock systems—where farmers currently buy large quantities of expensive protein-rich concentrates—was anticipated to be developed as a result of the coordination of cooperatives from the crop and livestock sectors.

Around the world, mixed farming systems generate the majority of milk (90%) and meat (54%). The majority of these items are produced regionally by the mixed farming systems of the OECD countries and Asia, but smallholder farmers in sub-Saharan Africa, West Asia, North Africa, Central America, and South America also mostly depend on mixed farming. Because nutrients and energy move from crops to cattle and back again, mixed farming frequently uses resources in a very self-sufficient manner. Such a closed system, by definition, provides positive incentives to offset environmental impacts ("internalize the environmental costs"), hence reducing or improving the base of natural resources.

3.9 Mixed Farming System in India

In India, the importance of mixed farming was realised even in early independence period and ICAR during 1941-46, initiated scheme for simultaneous investigation and demonstration of mixed farming in 4 provinces of undivided India (U.P, M.P, North West frontier, Pakistan).At all the places, mixed farming unit remarkably gave better results. North Indian region was considered as the best region for mixed farming.(Mandape.1988)

In independent India, the emphasis on mixed farming was given for the first time in the third five year plan and some resources were earmarked for the development of mixed farming. River valley project for mixed farming was included in the plan proposal of animal husbandry. (Mandape,1988)

The small scale mixed farming is the most dominant and common type of farming found in India. Livestock production based on family labour and waste products of crop production is the supplementary source of income and employment to farmers. In India there is variation in mixed farming in the matter of both time and space due to agroclimatic, technological and socio economic factors. Diversity and complexity is the major feature of this system and these farming systems are enhancing over time. The demand for animal products is rising quickly as a result of urbanization, changes in tastes and preferences, and increases in population and income. Compared to cereals, fruits and vegetables, livestock products have higher income elasticity of demand.

Integrated farming have been practiced in Indian farmers since long times, primarily involving small and large animals like, cow, buffalo, goat, sheep etc. This type of farming system provide additional source of income and value added products. The sustainability of farm is strongly influenced by crop- livestock integration. The cultivation of food crops is the primary occupation of people in rural areas and they spend their free time in livestock rearing. So livestock rearing act as complementary in integrated farming.

The cultivation of a variety of grains, legumes, tubers, fodder, fodder trees, and livestock are all part of the highland mixed farming system. The transfer of nutrients to farmed land typically comes from grazing or the cutting of fodder trees from higher altitude woodland regions in the more isolated areas, where mineral fertilizers are extremely expensive or unavailable and the distance to markets is prohibitive. Successful vegetable cultivation, especially of potatoes, can lead to a highly intensive system of commercial production in more accessible places. Similarly, horticulture, especially apple orchards, has grown significantly in the Himachal Pradesh hills. In general, ruminant cattle are crucial components of the system because they generate financial income, milk, manure, and draught power.

Although there is no extensive irrigation system to sustain the rainfed mixed agricultural method, dry season agriculture is sometimes made possible by relatively small areas that are irrigated from tanks, which lessens their susceptibility to drought. The usage of tube wells has expanded this conventional tank-based supplemental system in recent decades. While maize, sorghum, finger millet, vegetables, green and black grams, and groundnuts are more prevalent in the more warm regions of Southern part of India, the system's cooler northern regions grow wheat, barley, vegetables, and fodder crops. As cash crops, soy, rapeseed, chilli, onions, and sesame are primarily farmed in smaller areas. Only in areas with irrigation is double cropping feasible. The upper parts of the landscape are used for the cultivation of oilseeds, pulses, and coarse grains. Mango is among the fruit trees that are grown in home gardens. Since most areas are too remote for commercial milk production, livestock are crucial components of the farming system that sustains the majority of cattle, sheep, and goats in the area. They also typically account for the majority of the cash income earned by farm families, especially through the sale of adult animals or young stock.

It is reported that mixed farming of cross-bred cows is more efficient for the utilization of land, capital, labour and other inputs of the farmer who has small holding of one hectare in a semi-arid tract of land in Haryana. In dry farming area of Haryana there is scope for increasing farm employment and income by integrating the livestock enterprise with crop farming and by adoption of the new dryland agricultural production technologies. (Harishkumar et al., 1994)

The state West Bengal is dominated by small and marginal subsistence farmers. Farm holding size is very small. Mixed farming can provide round the year employment opportunity and household food and nutritional security to resource poor farm families.(Roy,2009)

A large number of farmers are available in middle Gujarat with considerable herd size and land under crops. The Anand Agricultural University, AMUL, NDDB and other organisations are functioning in the development of mixed farming among the farmers. (Onima,2014)

In Maharashtra the relationship between the crop production and livestock is expressed as complementary. In Maharashtra, where famines are common occurrence and majority of area is dry, mixed farming offers special advantages such as balanced farming providing more employment, income and covering risk of complete failure of mono-cropped farming.(Waghmare,2004)

For the Andaman and Nikobar Islands, mixed farming system modelsdeveloped are coconut-cum-fodder-cum-fish or prawn culture, coconut-cum-fish culture in salt-affected areas, and fruit-fodder-milch cattle. Mixed farming, which combines crop production with one or more animal activities, such as cattle, sheep, goats, pigs, and poultry, fish etc., is what defines Indian agriculture. Although in India farming is not commercialized to a big level, it remains that farmer take decisions regarding his farming, with a view of maximizing income. Although the farmer may not be maximizing net profit in the usual sense, it is reasonable to infer that he wants to maximize farm revenue so that he and his family may be supported. The general well-being of the family will influence the choice of enterprise mix on a farm.

3.10 Mixed Farming Systems in Kerala

Kerala’s agriculture is unique, characterised by small landholdings and the diverse agroclimatic conditions that favour the cultivation of a variety of plantation crops, cash crops, spices, and food crops. (Economic Review, 2024). Agriculture is the main occupation of Kerala and the major crops are coconut, paddy etc. The agricultural development programmes of the State have been oriented to a farm plan-based development approach giving priority to integrated farming systems. (Economic Review, 2024). The major cropping systems in Kerala are based on coconut, paddy, plantation, arecanut, spices etc and widespread practice of mixing these crops with livestock production.

In Kerala, mixed farming systems are widespread pattern of land use that sustain a range of crops and plants in addition to various related businesses, such as cattle and poultry, dispersed around homes and run at varying intensities. The production of various crops, livestock, poultry, and/or fish is done primarily to meet the diverse demands of farmers. Soil, plants, animals, other inputs, and environmental elements interact in a complicated way. In Kerala, where cows are the most popular animal, it is unusual to combine livestock and agriculture. For a very long time, Kerala's indigenous farmers have used mixed farming as one of their survival tactics. In Kerala, where the typical farm household size is average, mixed farms are prevalent and offer a viable land use strategy. A diverse range of crops are typically planted in the area surrounding the home or farmyard, providing the farm family with both privacy and shelter as well as a varied and high-quality meal. In Kerala, households along the shore, coconut is a staple crop. Kerala and other regions of northeastern India are homesteads, a unique kind of farming method.(Subadra,2007)

According to John and Mercy (2003), Kerala follows three basic farming systems: (a) a coconut-based system that includes a variety of intercrops, such as pepper, arecanut, cocoa, clove, banana, ginger, turmeric, tubers, fodder crops, pineapples, pulses, oilseeds, vegetables, green manure crops, and cover crops; (b) rice-based system that includes one or two crops of paddy, summer vegetables, pulses, or oilseeds, with or without aquaculture components; and (c) a homestead farming system that includes a variety of components, including perennials, food and fodder crops, livestock, fishery, poultry, apiaries, and poultry.

The raising of livestock is steadily gaining popularity and making a substantial contribution to the improvement of the lives of the poorest of the poor. Additionally, the milk provides the farmer's family with a significant additional source of cash and nourishment. With addition to assisting in dairy production by purchasing compound feed and other inputs, the steady flow of liquid cash from the daily sale of milk also aids with crop development by enabling the purchase of other agricultural inputs such as high-quality seeds, fertilizers, pesticides, weed killers, and so on. Additionally, the selling of milk enables rural households to purchase necessities for everyday living.

Kerala has a long history ofpracticing coconut based farming system. Many crops are cultivated as intercrops in coconut gardens since there is enough space between them. Raising high-quality fodder crops became essential when cattle was incorporated into homesteads. In order to maintain a sustainable dairy unit, farmers tried growing fodder in coconut gardens due to the decreasing amount of available land. In a coconut-based agricultural method, byproduct use is maximized and adequate to supply a farm family's fuel needs. Integrated farming involving rice, fish, livestock, and poultry has been established in both the Pokkali and Kuttanadu rice ecosystems. Studies about farming system have helped to evolve a homestead model for coastal uplands of southern Kerala under irrigated conditions. One cow and its calves or two or three goats or poultry birds raised on kitchen waste are examples of mixed farming in Kerala that impart sustainability. Pepper was trailed on coconut, arecanut and jack and no separate standards were provided. (Salam et al. 1992)

It has been discovered that mixed farming, which involves growing leguminous fodder crops like Stylosanthes alongside fodder grasses like hybrid Napier or Guinea grass, can be profitable. Three to four dairy animals can be raised on a one-hectare coconut garden using the aforementioned crops. The animals provide a lot of cattle manure, which when added to the soil will increase its fertility. The palm production will increase with this type of mixed cultivation.

In coconut, various subsidiary enterprises could also be integrated to generate more employment and income for the family. One such viable and compatible system has been developed at Central Plantation Crops Research Institute, Kasargod in an 1.2 hectare area with the following enterprises such as (a) Cultivation of grasses in the interspaces, (b) Dairying with 5-6 milch animals, (c) Poultry birds (100 number broiler birds each per batch), (d) Japanese quails (100 number), (e) Rabbits (10 female and 4 male), (f) Aquaculture (625 m2 surface area), (g) Agriculture with Indian bees and (h) Biogas unit (3 m3 area)

Pokkali is a unique saline tolerant rice variety that is cultivated using extensive aquaculture in an organic way in the water-logged coastal regions, Pokkali fields is spread in about 27000 ha in the coastal area of Ernakulam, Alappuzha, Trichur and Kannur districts.(sasidharan,2012) Rice & Prawn are rotationally grown in these fields. Income from prawn yields compensates the losses from rice cultivation. It is considered as sustainable system. The merits of this mixed farming practice are not affected by seasonal fluctuations, complementarity nature, maintenance of soil fertility, environment friendly, ecologically sound, economically viable and socially acceptable. Similarly mixed farming is possible by mingling crops like coconut, banana and yams with the livestock like buffaloes, ducks and fish. One of the ideal mixed farming which involves more than two components that can be seen in Kerala is the integration of paddy, coconut, banana and yams with buffaloes, ducks and fish. The complementary effects on land preparation are manuring, weeding, plant protection etc. In the case of multilevel integration as mentioned above increases the economic benefits such as reduction in production costs, increase in income etc. three to four times fold. Ecological benefits are reduction in use of agricultural chemicals, Improvements in soil conditions, recycling of agricultural wastes, perceptible improvement in soil biological properties etc.

3.11 Conclusion

In India, a significant portion of the population lives in rural areas and majority of population still depends on agriculture for their livelihood. The development of mixed farming has the potential for poverty eradication. Mixed farming is a balanced and productive farming system because of the complementary nature between crop production and livestock production. Mixed farming meet the requirements of sustainability standards by being ecologically sound, economically viable, and socially acceptable.

CHAPTER 4
COMPLEMENTARITY IN MIXED FARMING

4.1 Introduction

The chapter deals with complementary synergy that is benefitted from mixed farming which produces two or more outputs together rather than separately due to intrinsic production activities such as the crop residuals as livestock feed, especially during the summer season and likewise manure from cattle is used as fertiliser for paddy cultivation. In Corning's classification the different forms of synergy that relate to presence of complementarity between farm enterprises are functional Complementarity, augmentation, combining farm resources, information sharing, joint decision making and cost and risk sharing.(Vilano et al. 2010)

Complementary relationships between crop and livestock farming activities have been documented in many studies (Tilman et al., 1996; Loreau, 1998; Yachi and Loreau, 2007). In fact, the synergy degrees may vary spatially and temporally, even within the same agroecological system.(Vilano et al., 2010) A study has suggested that the diversification of farming systems secures synergies between crop and livestock production, improves productivity, and ensures the resilience of integrated agricultural production systems. (Dhehibi B, 2023)

The study aims to explore the complementary relationship between two components such as paddy cultivation and cattle rearing within mixed farming system and so presents a framework of "complementarity" analysis as the theoretical basis for analyzing the synergistic relationship between two components of mixed farming system. The original concept "complementarities" was first introduced by Edgeworth in which he defined activities as complements, if doing (more of) any one of them increases the returns to doing (more of) the others. (Choi et al., 2008) By combining the methodology followed by Choi et al., 2008 and Lee, 2011 it has been tried to assess whether activities and practices in mixed farming system are mutually complementary and so tend to be adopted together, with each enhancing the contribution of the other. Therefore, the impact of a system of complementary practices will be greater than the sum of its parts because of the synergistic effects of bundling practices together. (Choi et al., 2008)

Before entering into the complementarity of mixed farming, the socio economic characteristics of mixed farmers are discussed. Mixed Farming is the practice of producing crops and rearing livestock for food, fiber, and other products essential for human life. Thus features of mixed farming are also presented.

4.2 Socio –Economic Characteristics of Mixed Farmers

The major socio-economic characteristics considered are age of farmers, gender, religion, social category, education level, farming experience, occupation, family size, family types etc. have been discussed in details as below.

4.2.1 Age wise Classification of Mixed Farmers

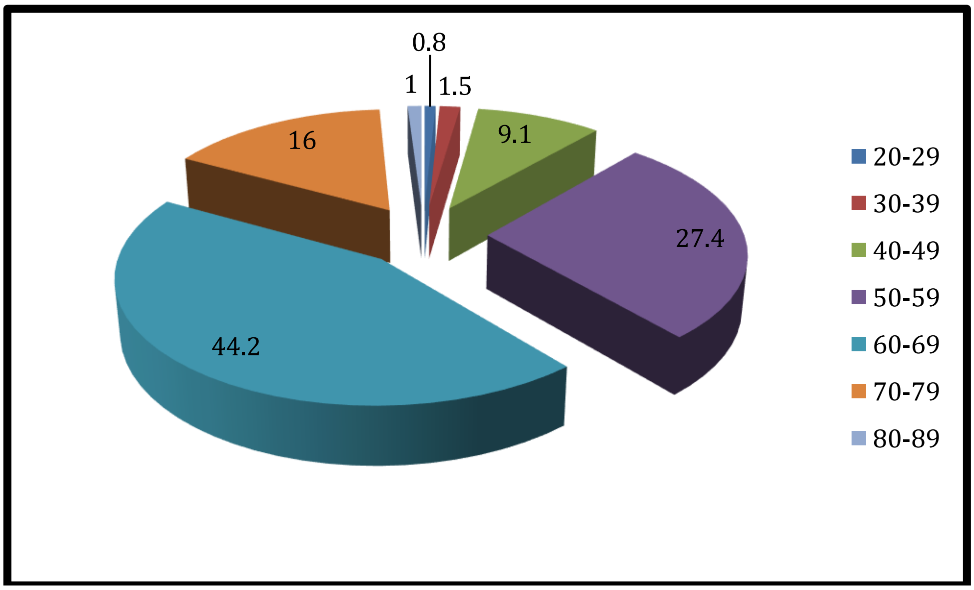
The table 4.1 illustrates the age distribution of mixed farmers. In mixed farming, age has a big impact on decision-making, knowledge and labour capacity.

Table 4.1 Age wise Classification of Mixed Farmers

Age	Frequency	Percent
20-29	3	.8
30-39	6	1.5
40-49	36	9.1
50-59	108	27.4
60-69	174	44.2
70-79	63	16.0
80-89	4	1.0
Total	**394**	**100.0**

Source: Primary Data

Figure 4.1 Age wise Classification of Mixed Farmers



Source: Primary Data

From the above table 4.1 and figure 4.1, it is clear that 44.2% of respondents belong to the age category 60-69. 27.4 % of respondents belong to the age category of 50-59. 16% of respondents belong to the age category of 70-79 and 9.1 % of respondents belong to the age category of 40-49. Only 1% and .8% of respondents belong to the age category of 80-89 and 20-29 respectively. The younger people are less attractive to mixed farming. Majority of the mixed farming population is in the age group above 50. Farmers usually gain important expertise and knowledge in mixed farming as they get older than 50, which helps them in their decision-making about paddy cultivation and cattle rearing.

4.2.2 Gender wise Classification of Mixed Farmers

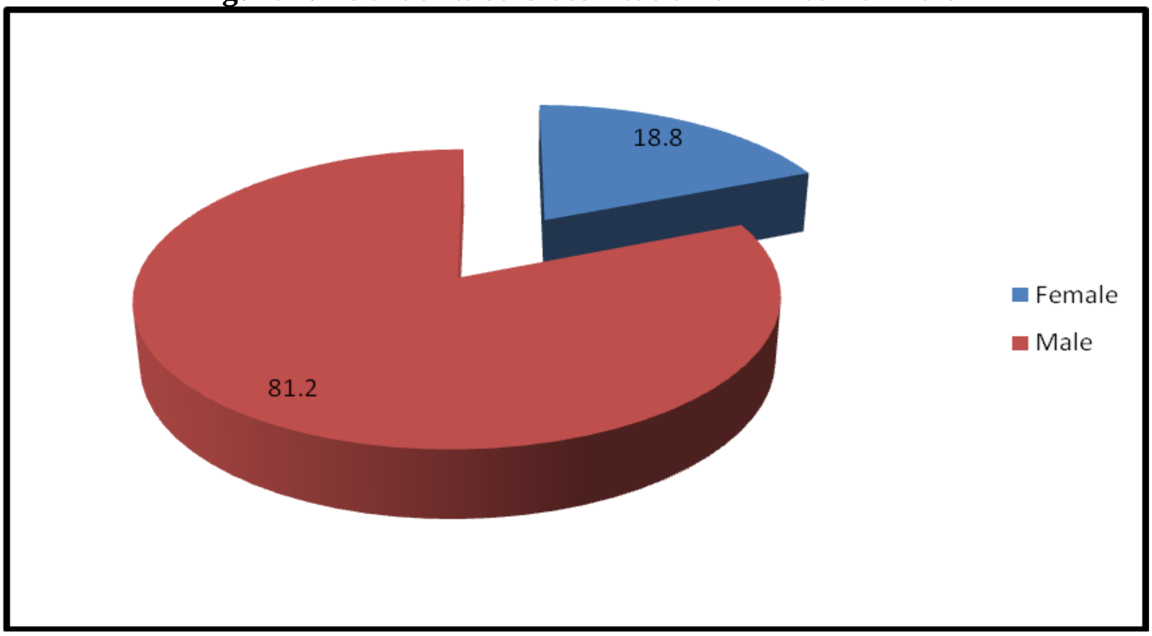
The table 4.2 shows gender wise distribution of mixed farmers. Gender plays an important role in mixed farming.

Table 4.2 Gender wise Classification of Mixed Farmers

Gender	Frequency	Percent
Female	74	18.8
Male	320	81.2
Total	**394**	**100.0**

Source: Primary Data

Figure 4.2 Gender wise Classification of Mixed Farmers



Source: Primary Data

The table 4.2 and figure 4.2 shows that 18.8% of respondents are females and rest 81.2% of respondents are males. Since men make up the majority of mixed farmers, they usually have more influence over farming choices, land ownership, and access to resources like technology and loans.

4.2.3 Religion wise distribution of mixed farmers

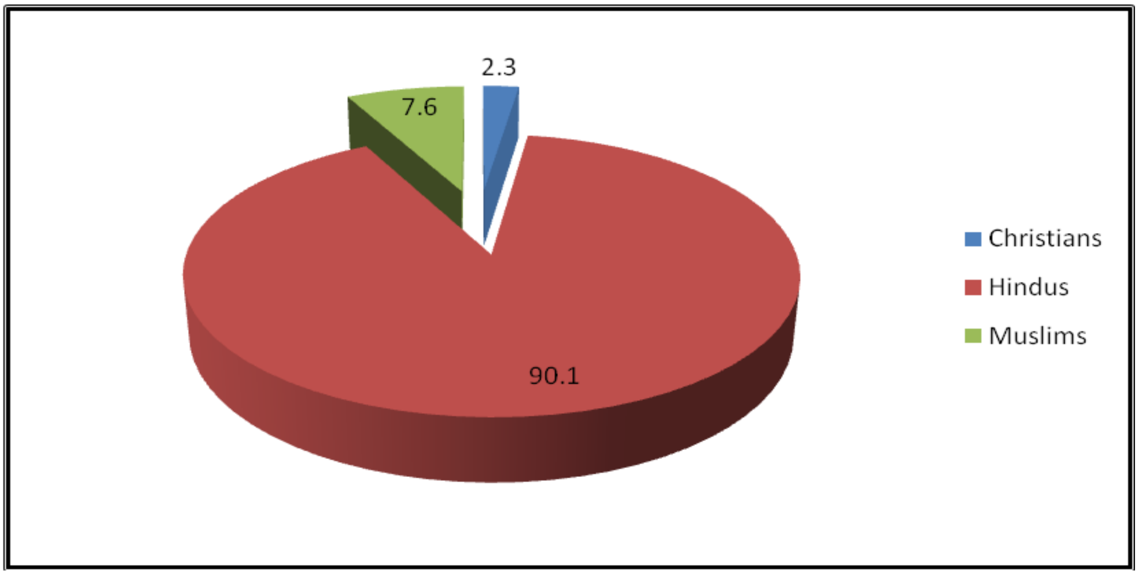
The table 4.3 depicts religion wise distribution of mixed farmers. It illustrates representation of each religious group within the mixed farming community.

Table 4.3 Religion wise Classification of Mixed Farmers

Religion	Frequency	Percent
Christians	9	2.3
Hindus	355	90.1
Muslims	30	7.6
Total	**394**	**100.0**

Source: Primary Data

Figure 4.3 Religion wise Classification of Mixed Farmers



Source: Primary Data

It is evident from the table 4.3 and figure 4.3 that 90.1 % of farmers are Hindus. While Muslims constitute 7.6% of population and Christians constitute 2.3% of population. Majority of the mixed farmers are Hindus.

4.2.4 Social Category of Mixed Farmers

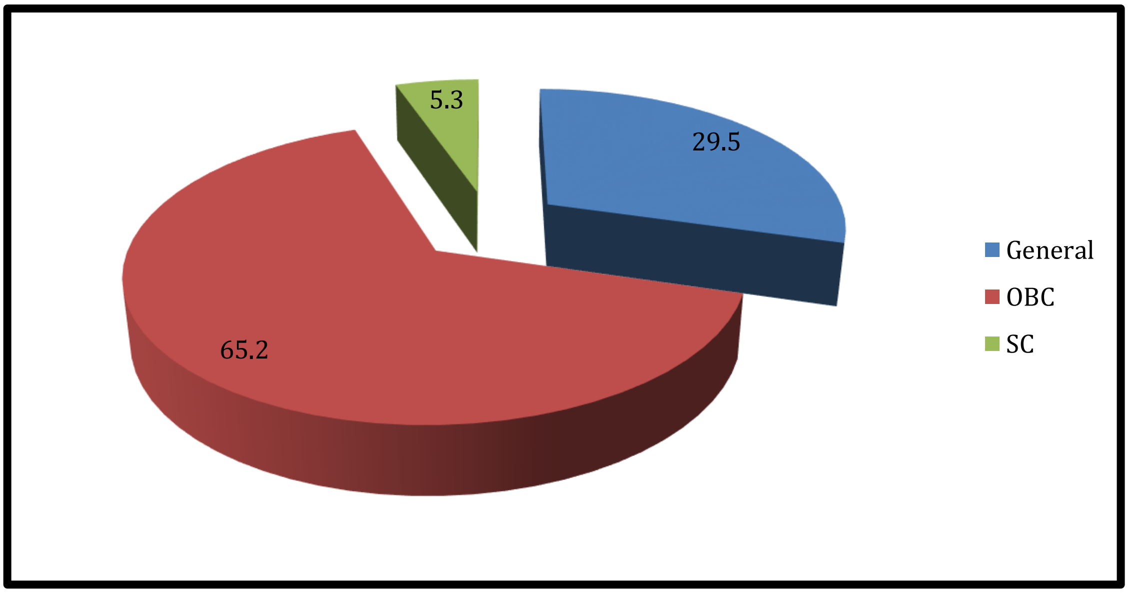
The table 4.4 shows the social category of mixed farmers. The distribution of mixed farmers by social category demonstrates how farming participation varies among various social groupings.

Table 4.4 Social Category of Mixed Farmers

Social Group	**Frequency**	**Percent**
General	116	29.5
OBC	257	65.2
SC	21	5.3
Total	**394**	**100.0**

Source: Primary Data

Figure 4.4 Social Category of Mixed Farmers



Source: Primary Data

From the table 4.4 and figure 4.4 it is clear that 65.2% of farmers belong to OBC category, while 29.5% of farmers belong to General category. Only 5.3 farmers belong to SC category. The higher proportions of mixed farmers belong to OBC category.

4.2.5 Education wise Classification of Mixed Farmers

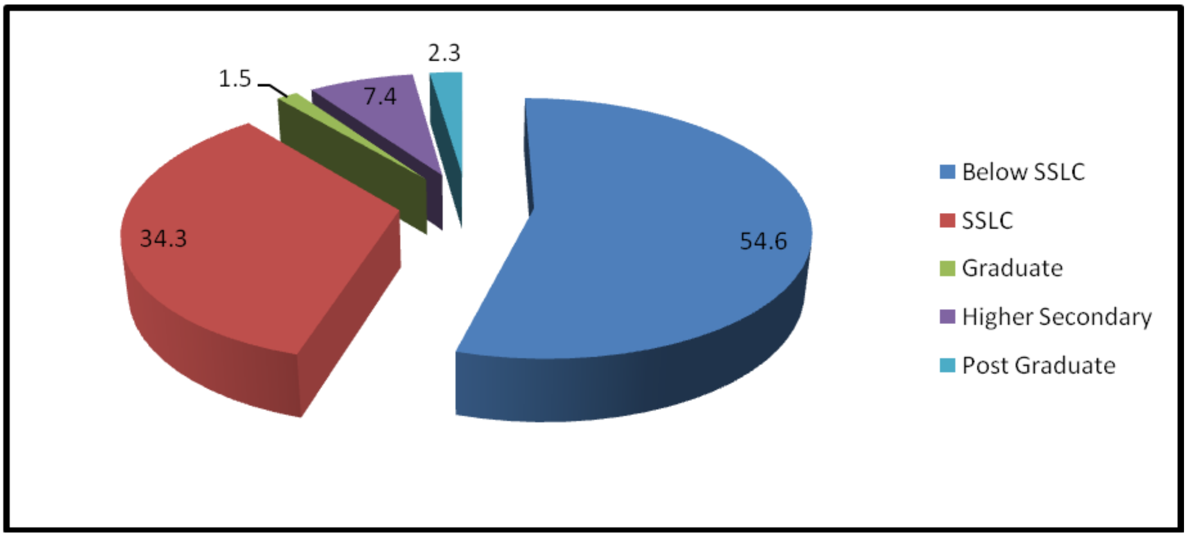
The table 4.5 depicts education wise classification of mixed farmers. The education-wise classification of respondents provides information of the diverse educational levels of mixed farmers involved in the study.

Table 4.5 Education wise Classification of Mixed Farmers

Education	Frequency	Percent
Below SSLC	215	54.6
SSLC	135	34.3
Graduate	6	1.5
Higher Secondary	29	7.4
Post Graduate	9	2.2
Total	**394**	**100.0**

Source: Primary Data

Figure 4.5 Education wise Classification of Mixed Farmers



Source: Primary Data

From the table 4.5 and Figure 4.5, it is clear that, majority i.e. 54.6% of farmers are below SSLC, only smaller percentage has higher educational qualifications. Only 7.4% of farmers have completed higher secondary school education, while 1.5% and 2.2% of farmers have completed graduation and post graduation respectively. 34.3% of farmers have obtained SSLC.

4.2.6 Farming Experience of Mixed Farmers

Farming experience refers to the knowledge and skills acquired by mixed farmers through practical involvement in mixed farming that is paddy cultivation and cattle rearing over time. This experience influences farmers' decision-making, productivity, and ability to adapt to changes in mixed farming methods and market situations. The table 4.6 illustrates the farming experience in paddy cultivation, farming experience in cattle rearing and farming experience in mixed farming which is the combination of both activities.

Table 4.6 Farming Experience of Mixed Farmers

Farming Experience (in years)	N	Mean	Std. Deviation
Farming experience in paddy production	394	34.05	14.900
Farming experience in cattle rearing	394	30.16	13.851
Experience in mixed farming	394	29.50	14.451

Source: Primary Data

From the table it is clear that average farming experience of farmers in paddy production is 34.05 years and in cattle rearing is 30.16 years. In mixed farming, average experience of farmers is 29.50 years.

4.2.7 Occupation wise Classification of the Mixed Farmers

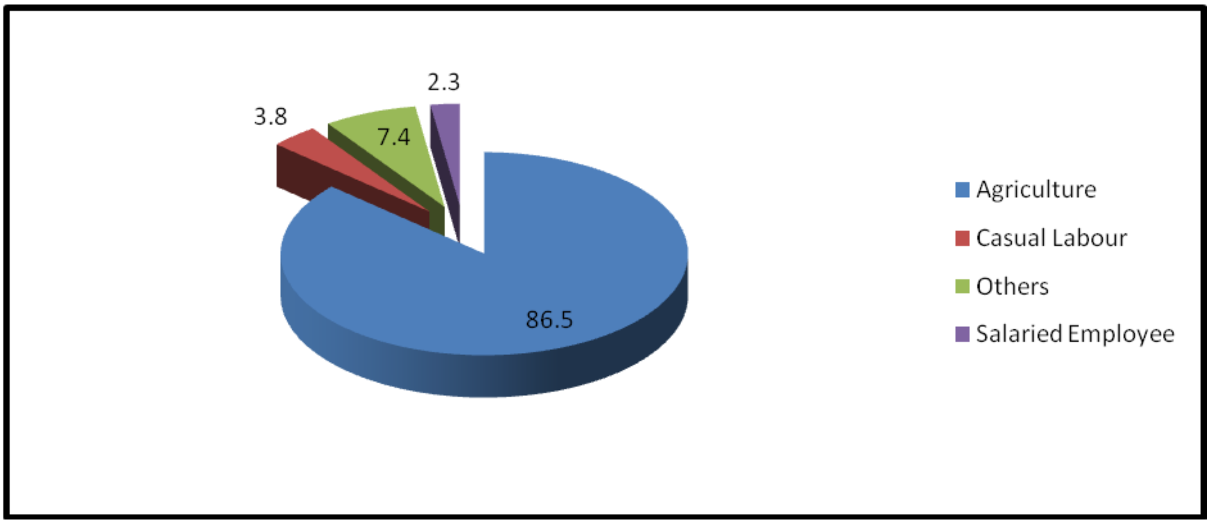
The table 4.7 indicates the occupation wise classification of mixed farmers. The study can understand occupational pattern of respondents, the reliance on agriculture, the presence of alternative income sources, and the overall employment trends within the community by identifying the distribution of occupations among mixed farmers.

Table 4.7 Occupation wise Classification of the Mixed Farmers

Occupation	Frequency	Percent
Agriculture	341	86.5
Casual Labour	15	3.8
Others	29	7.4
Salaried Employee	9	2.3
Total	**394**	**100.0**

Source: Primary Data

Figure 4.6 Occupation wise Classification of Mixed Farmers



Source: Primary Data

From the table 4.7 and figure 4.6 it is clear that 86.5% of mixed farmers' main occupation is agriculture. 7.4% of mixed farmers' main occupation is in other areas, such as small businesses, small shops, etc. 3.8% farmers are casual labourers and 2.3% of farmers are salaried employee. Even if the majority of respondents are farmers, the inclusion of salaried workers and casual laborers in the responses shows income source diversification, or the role of non-farming employment among mixed farming communities.

4.2.8 Ration card Status of Mixed farmers

The table 4.8 depicts the type of ration card the mixed farmer holds which pinpoints dependence on state government for food security. The study evaluate farmers' economic standing, which indicates mixed farmers who are marginalized or at risk, and determine how much they rely on government assistance.

Table 4.8 Ration card Status of Mixed farmers

Type of ration card	Frequency	Percent
AAY	71	18.0
APL	78	19.8
BPL	245	62.2
Total	**394**	**100.0**

Source: Primary Data

From the table 4.8 it is clear that 62.2% of farmers are BPL card holders, while 18% and 19.8% of farmers hold AAY cards and APL cards respectively.

4.2.9 Family Type of Mixed Farmers

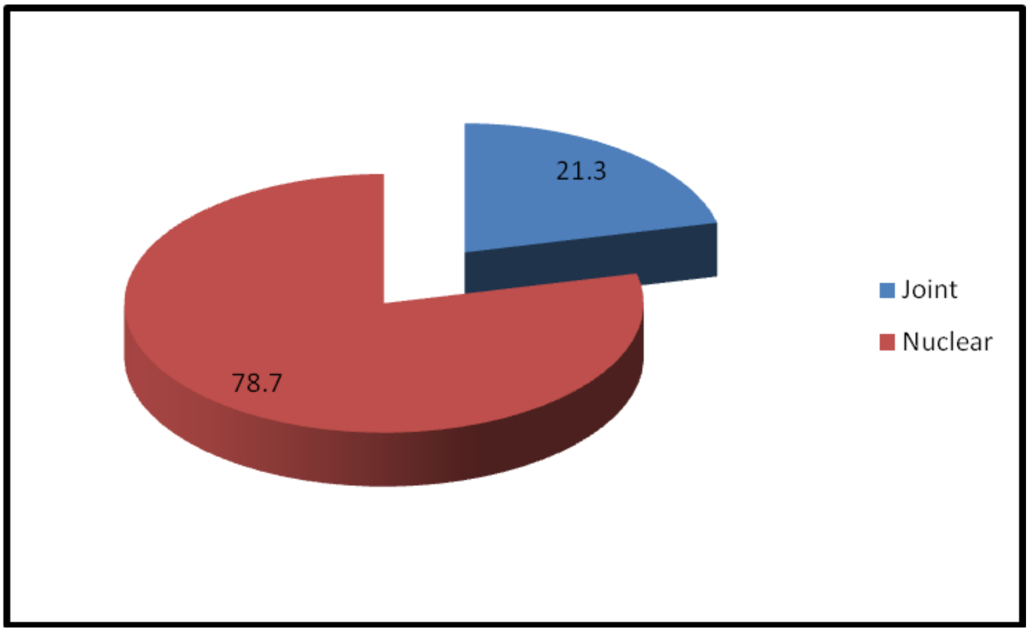
The family type directly influences the agricultural practices of mixed farming. The family type- joint or nuclear exert influence on labour availability, management of mixed farming activities, resource management etc.

Table 4.9 Family Type of Mixed Farmers

Family type	Frequency	Percent
Joint	84	21.3
Nuclear	310	78.7
Total	**394**	**100.0**

Source: Primary Data

Figure 4.7 Family Type of Mixed Farmers



Source: Primary Data

From the table 4.9 and figure 4.7, it is clear that 78.7% of farmers have nuclear family while 21.3% of farmers have joint family.

4.2.10 Household Size Distribution of Mixed Farmers.

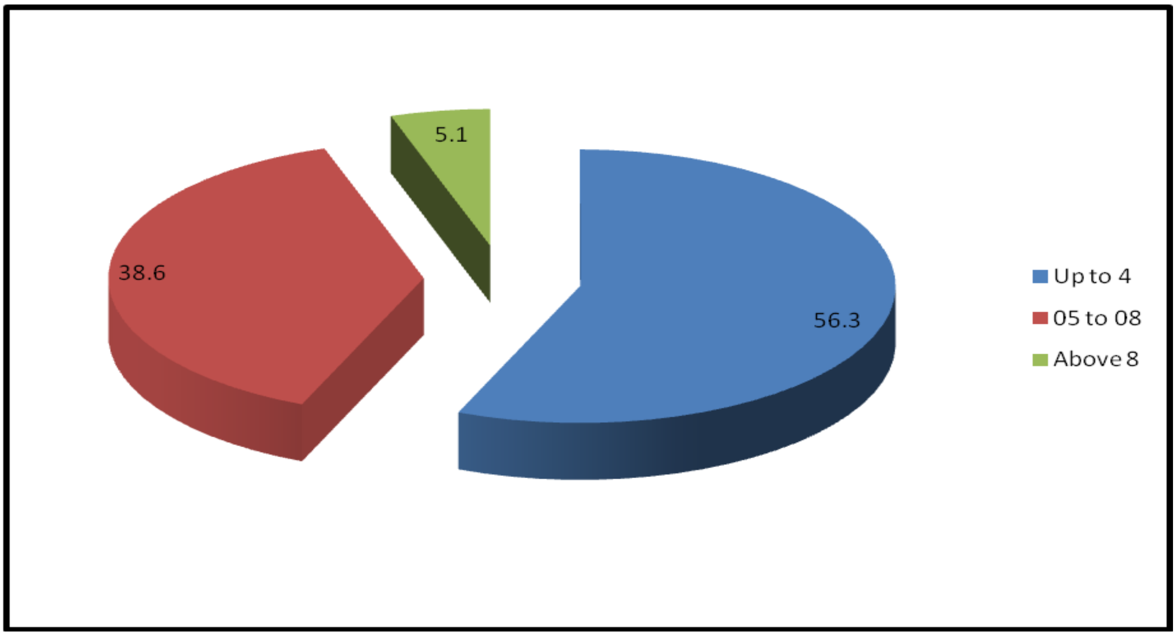
The table 4.10 depicts the household size distribution of mixed farmers. The household size of mixed farmers is studied because it influences the availability of family labour in mixed farming activities.

Table 4.10 Household Size Distribution of Mixed Farmers

Number of members	Frequency	Percent
Up to 4	222	56.3
5-8	152	38.6
Above 8	20	5.1
Total	**394**	**100.0**

Source: Primary Data

Figure 4.8 Household Size Distribution of Mixed Farmers



Source: Primary Data

From the table 4.10 and figure 4.8 it is clear that 56.3% of farmers have household size up to 4 and 38.6% of farmers have 5-8 members in the household. Only 5.1% of farmers have above 8 members in the household.

4.2.11 State of Health of Mixed Farmers

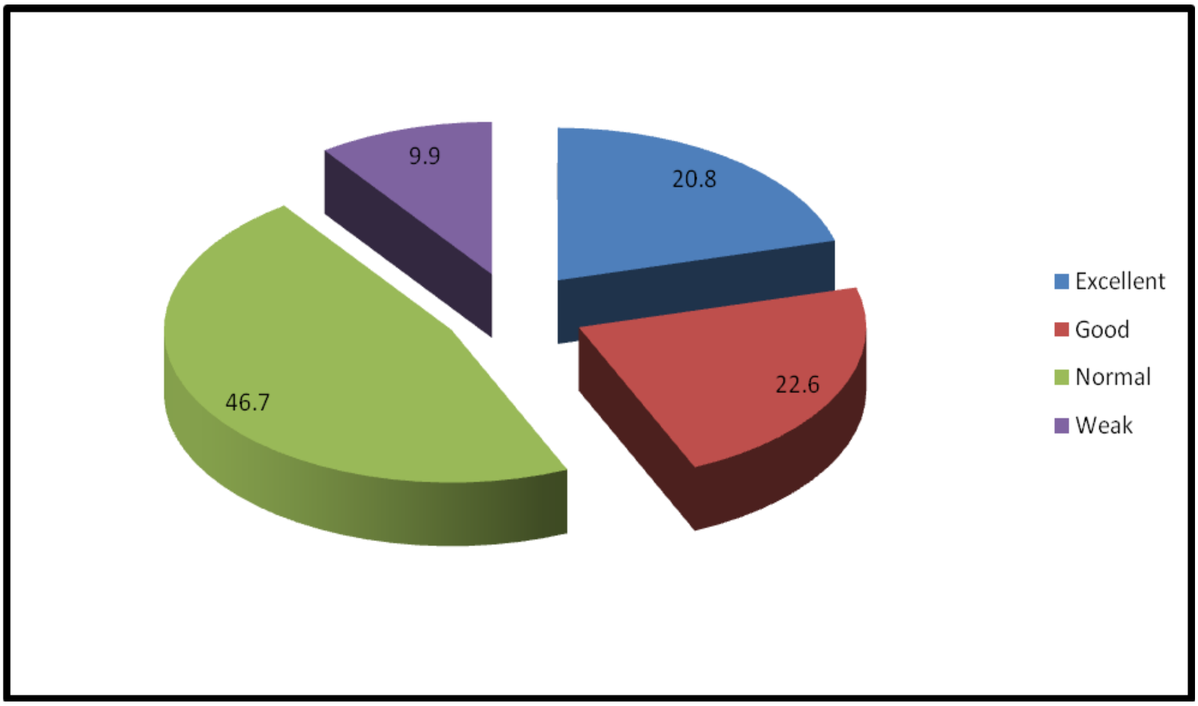
The table 4.11 illustrates the state of health of mixed farmers and is of significant importance as mixed farming is an agricultural activity which is highly demanding family labour requiring long hours of work every day thus affecting their ability to work, productivity and overall well being.

Table 4.11 State of Health of Farmers

State of Health	Frequency	Percent
Excellent	82	20.8
Good	89	22.6
Normal	184	46.7
Weak	39	9.9
Total	**394**	**100.0**

Source: Primary Data

Figure 4.9 State of Health of Farmers



Source: Primary Data

From the table 4.11 and figure 4.9 it is clear that 46.7% of mixed farmers report having normal health, while 22.6% of mixed farmers consider health as good. 20.8% of mixed farmers report excellent health and 9.9% of mixed farmers describe their health as weak.

4.2.12 Management of Mixed Farming

The table 4.12 depicts how mixed farming is managed by family members. Mixed farming is managed by family members, with each member of the family contributing to various aspects of mixed farming activity, from planting of paddy and harvesting to cattle rearing. In mixed farming, the family unit serves as the backbone of all farming operations, where roles are shared based on skills and availability. This family-driven management structure in mixed farming not only ensures that the farm runs efficiently but also helps to maintain strong connections to tradition and community. By working together, family members can address challenges, adapt to changing circumstances, and sustain the farm for future generations. The management team of mixed farming is classified into 4. Single member management, management team of two members, management team of three members and management team of four members.

Table 4.12 Management of Mixed Farming

Management team	Management Classification	Management	Frequency	Percent
Single member management	Male only	Husband	72	18.3
	Female only	Mother	3	.8
		Wife	12	3.0
Management team of two members	One male and one female	Husband- Wife	257	65.2
		Mother-Son	16	4.1
	Two females	Mother - Daughter	11	2.8
	Two males	Father-Son	9	2.3
Management team of three members	Two male and One female	Husband- Wife-Son	8	2.0
		Father-Son-Wife	3	.8
Management team of four members	Two male and two female	Husband-Wife-Son-Wife	3	.8
		Total	**394**	**100.0**

Source: Primary Data

The table 4.12 illustrates the involvement of different family members in mixed farming, with varying frequencies indicating the extent of their participation. In some cases, individual family members like the husband, wife, or mother work alone on the farm, handling tasks involved in mixed farming. In other scenarios, families work together, such as the husband and wife i.e. 65.2% who likely share responsibilities for all aspects of mixed farming, or multigenerational groups like the husband-wife-son or husband-wife-son-wife where both parents and children assist with the work. Smaller family units, like father-son or mother-daughter, also contribute, but their involvement is less frequent. Overall, the table shows that family members contribute to mixed farming, with larger family groups often sharing tasks more broadly while smaller ones tend to focus on specific responsibilities. From the table it is apparent that majority of mixed farms are managed by the management team with two members.

4.2.12 Technologies used in Mixed Farming

The table 4.13 depicts the technologies adopted by farmers in mixed farming. Generally speaking, technology is a way to solve an issue. If a worker or a machine can milk the cow in place of a farmer who is sick of doing it, the farmer will be pleased. Farmers who become weary of pulling weeds by hand will be pleased to utilize herbicides or a hoe to make the task simpler. There is only one requirement for any intervention to qualify as a technology, regardless of whether it is technological, managerial, or policy-related. One "calculation" that is frequently performed differently by farmers, scientists, and/or policymakers is that the cost of the technology should be covered by the sum of the additional return it generates and the work or effort that is saved. (FAO, n.d)

Table 4.13 Technologies used in mixed farming

Technology		Frequency	Percent
Tractor	Yes	394	100.0
	No	0	0
	Total	394	100.0
Tiller	Yes	80	20.3
	No	314	79.7
	Total	394	100.0
Sowing Machine	Yes	86	21.8
	No	308	78.2
	Total	394	100.0
Harvesting Machine	Yes	331	84.0
	No	63	16.0
	Total	394	100.0
Winnowing Machine	Yes	80	20.3
	No	314	79.7
	Total	394	100.0
Milking Machine	Yes	3	.8
	No	391	99.2
	Total	394	100.0

Source: Primary Data

The table 4.13 shows technologies used by the mixed farmers. All farmers use tractors for land preparation and only 20.3% of farmers use tiller for land preparation. Sowing machine is used by 21.8% farmers and winnowing machine by 20.3% farmers. 84% of farmers use harvesting machine for harvesting paddy and only .8% of farmers use milking machine for milking cattle.

4.2.13 Training Programmes Attended by Mixed Farmers

The table 4.14 depicts the training programmes attended by mixed farmers. The training programmes provide farmers essential skills and knowledge that enhance their productivity and make informed decisions.

Table 4.14 Training Programmes Attended by Farmers

Training Programmes		Frequency	Percent
Training Programmes attended by farmers for paddy cultivation	Yes	151	38.3
	No	243	61.7
	Total	394	100.0
Training Programmes attended by farmers for cattle rearing	Yes	136	65.5
	No	258	34.5
	Total	394	100.0
Training Programmes attended by farmers for mixed farming	Yes	56	14.2
	No	338	85.8
	Total	394	100.0

Source: Primary Data

The above table 4.14 shows the training programmes attended by farmers. The training programmes attended by farmers for paddy cultivation are 38.3% and for cattle rearing is 34.5% while only 14.2% farmers have attended training programmes for mixed farming. The training programs for mixed farming are relatively less and this will affect the productivity and sustainability of mixed farming.

4.2.14 Reasons for raising cattle along with paddy cultivation

The table 4.15 highlights the reasons for raising cattle along with paddy cultivation. The cattle rearing along with paddy cultivation provides farmers extra income, manure, milk etc. In addition to this it is a gainful employment for farmers. Farmers can use grass of paddy fields, which is a further reason for raising cattle.

Table 4.15 Reasons for raising cattle along with paddy cultivation

Reasons		**Frequency**	**Percent**
Extra income	Yes	332	84.3
	No	62	15.7
	Total	394	100.0
Gainful Employment	Yes	313	79.4
	No	81	20.6
	Total	394	100.0
For Manure	Yes	361	91.6
	No	33	8.4
	Total	394	100.0
To Utilize Grass	Yes	307	77.9
	No	87	22.1
	Total	394	100.0
For Milk	Yes	340	86.3
	No	54	13.7
	Total	394	100.0

Source: Primary Data

From the above table 4.15 it is clear that 91.6% of farmers raise cattle for manure which can be utilized for paddy cultivation. 86.3% of farmers rear cattle for milk availability. 84.3% of farmers consider cattle rearing as extra income source.79.4% of farmers consider it as a gainful employment and 77.9% of farmers rear cattle to utilize grass.

4.2.15 Classification of farms on the basis of size of Mixed Farming Area

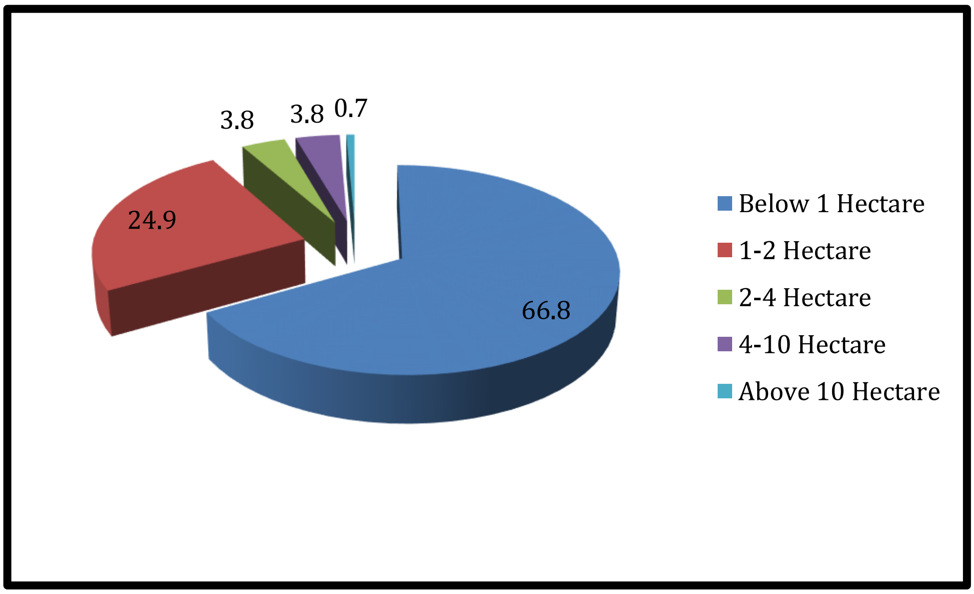
The table 4.16 depicts categorization of farms on the basis of mixed farming area size. "A mixed farm is a combination of areas for paddy cultivation, farmyard, and farm buildings."The land used for cultivating paddy, area used for cattle rearing or other farmyard operations, and areas for farm buildings like storage, equipment sheds, and housing are all parts of a farm.

Table 4.16 Classification of farms on the basis of size of Mixed Farming Area

Sl No	Size of land	Frequency	Percent
1	Below 1 Hectare	263	66.8
2	1-2 Hectare	98	24.9
3	2-4 Hectare	15	3.8
4	4-10 Hectare	15	3.8
5	Above 10 Hectare	3	.7
	Total	394	100.0

Source: Primary Survey

Figure 4.10 Classification of farms on the basis of size of Mixed Farming Area



Source: Primary Survey

The table 4.16 and figure 4.10 indicates the categorization of farms on the basis of mixed farm area size. From the table it is clear that 66.8% of mixed farmers hold below 1 Hectare. That is majority of farmers are marginal farmers. 24.9% of farms hold 1-2 hectares of mixed farm area. That is 24.9 % of farmers are small farmers. 3.8% of farms hold 2-4 hectares of mixed farm area. 3.8 % of farms hold 4-10 hectares of mixed farm area. Only .7% of farms hold above 10 hectares of mixed farm area. That is .7% of farmers are large farmers.

4.2.16 Descriptive Statistics of Mixed Farm Area

The table 4.17 illustrates the descriptive statistics of mixed farm area. The area of farmyard and farm buildings is represented in cents for better understanding.

Table 4.17 Descriptive Statistics of Mixed Farm area

Area	N	Mean	Std. Deviation
Area of farmyard (in cents)	394	2.56	5.3394
Area of farm buildings (in cents)	394	.84	5.50405
Agricultural area in hectares	394	1.02	1.58555

Source: Primary Data

From the table 4.17 it is clear that average area cultivated by the farmers for paddy is 1.02 Hectares and average area of farmyard for a mixed farmer is 2.56 cents, while average area of farm building is only .85 cent.

4.2.17 Breed of Cattle

The table 4.18 exhibits the breed of cattle that are reared by farmers. The study has considered mainly two types of breed such as international breed and local breed.

Table 4.18 Breed of Cattle

Breed of cattle	Frequency	Percent
International breed	355	90.1
Local breed	39	9.9
Total	394	100.0

Source: Primary Data

From the table 4.18 it is clear that 90.1% of mixed farmers adopt international breed of cattle and only 9.9% of farmers adopt local breeds.

4.2.18 Ownership of cattle by mixed farmers

The table 4.18 highlights the ownership of cattle by mixed farmers. Ownership of cattle by farmers refers to the number of heads that the mixed farmers possess and manage at the end of the year.

Table 4.19 Ownership of cattle by mixed farmers

	Number of heads at the end of the year	Frequency	Percent
In milk	Upto 2	305	77.4
	3-5	83	21.1
	6-8	6	1.5
	Total	394	100.0
Young stock	Upto 2	354	89.8
	3-5	37	9.4
	6-8	3	.8
	Total	394	100.0
Others	0	383	97.2
	1	7	1.8
	2	4	1.0
	Total	394	100.0

Source: Primary Data

The table 4.19 shows ownership of cattle by mixed farmers. Cattle are classified as in milk, young stock and others. 77.4% of farmers hold up to 2 in milk cattle, 21.1% of farmers hold 3-5 in milk cattle and only 1.5% of farmers hold 6-8 in milk cattle. In the case of young stock, 89.8% of farmers hold upto 2 heads, 9.4% of farmers hold upto 3-5 heads and only .8%

of farmers hold 6-8 heads. Only 1.8% of farmers hold other head of 1 and 1% hold other heads of 2.

4.3 Computing Complementarity Index

The study intends to investigate the complementary interaction between two elements, such as paddy agriculture and cattle rearing. As the theoretical foundation for examining the synergistic interaction between two elements of a mixed farming system, the study presents a paradigm for "complementarity" analysis. It has been attempted to determine whether the activities in mixed farming systems are mutually complementary and, thus, tend to be adopted jointly, with each one improving the contribution of the other, by integrating the methods used by Choi (2008) and Lee (2011). Because of the synergistic effects of combining practices, a system of complementary practices will have a greater impact than the sum of its parts. (Choi et al., 2008)

Based on the concept of complementarity and its supermodularity functional representation, the study considered net farm income in the context of a supermodular function. To analyze data in the context of a supermodular function, the study first need to clarify a few concepts. There are two agricultural activity within mixed farming system.(M_1 and M_2). Each agricultural activity can be adopted by the farmer $(M_1 = 1)$ or not adopted $(M_1 = 0)$ and $(M_2 = 1)$ or not adopted $(M_2 = 0)$. (Choi et al., 2008) The performance function $Y = f(M_1,M_2)$ is supermodular and $M1$ and $M2$ are complements if and only if:

$f(1, 1) + f(0, 0) \geq f(1, 0) + f(0, 1)$. (Choi et al., 2008)

i.e. adding a agricultural activity while already executing the previous activity has a higher net farm income than when using the first strategy in isolation. Even though the concept of complementarities offers a set of important implications for analyzing organizational performance, there is no well-established theory to conceptualize the association between M1 and M2. (Choi et al., 2008) Complementarity based on net farm income refers to the synergistic relationship between paddy cultivation and cattle rearing where their combined activity leads to higher net farm income than if they were managed independently.

Table 4.20 Complementarity Function

Performance Function	***Description***
$f(M_1,M_2)$	*Net farm income of agricultural activity ie mixed farming given that both paddy production and cattle rearing practiced simultaneously*
$f(0,0)$	*Net farm income of mixed farming without either paddy production or cattle rearing being practiced*
$f(M_1,0)$	*Net farm income of agricultural activity that only paddy production is practiced*
$f(0,M_2)$	*Net farm income of agricultural activity that only cattle rearing is practiced*

Source : (Choi et al., 2008)

$$\text{Complementarity Index (CI)} = \frac{f(M_1, M_2) + f(0,0)}{f(M_1, 0) + f(0, M_2)} \quad \text{----------- 1 (Choi et al., 2008)}$$

$$= \frac{(NFI_P + NFI_C) - \Delta C + NFI_0}{(NFI_P + NFI_C)} \quad \text{-----------2}$$

NFI_P = Net farm income of paddy cultivation
NFI_C= Net farm income of cattle rearing
NFI_0= Net farm income of on farm activities other than paddy cultivation and cattle rearing
ΔC = Change in costs due to mixing or Complementarity of these activities
NFI_P= $CR+Y_K$ - OE -------3 (FAO, 2020)
NFI_C= $CR+Y_K$ -OE------4 (FAO, 2020)
NFI_0= Farmer’s declaration of net farm income from on farm activities
CR = Total farm cash receipts including direct program payments (FAO, 2020)
Yk = Income in kind (FAO, 2020)
OE = Total operating expenses after rebates (including costs of labour) (FAO, 2020)

4.3.1 Cash receipts and income in kind of paddy cultivation

The table 4.22 shows the cash receipts of paddy cultivation. It includes the annual value of paddy and paddy bye product. Even if there are three seasons of paddy cultivation, no farmer cultivates III crop that is crop in Puncha season. If paddy is cultivated in two seasons, the annual value of paddy and its by-products for both seasons is considered for the year. The income in kind is included in the annual value of paddy and its by-products.

4.3.2 Number of Seasons in which Paddy is Cultivated

The number of seasons in which paddy is cultivated is important for calculating the annual value of paddy and its by-product. Understanding the number of cultivation seasons helps in determining the overall production, which in turn influences the calculation of the annual value of paddy and its by-products.

Table 4.21 Number of Seasons in which Paddy is Cultivated

No of Seasons	Frequency	Percent
1	160	40.6
2	234	59.4
Total	**394**	**100.0**

Source: Primary Data

From the table 4.21 it is clear that 59.4% of farmers cultivate paddy for two seasons and 40.6% of farmers cultivate paddy for only one season.

4.3.3 Descriptive Statistics of cash receipts of paddy cultivation in a year

The table 4.22 shows the average annual production of paddy and its by-product. This data provides valuable insights into production of paddy and helps in assessing the crop's economic value over the year

Table 4.22 Descriptive Statistics of Cash Receipts of Paddy Production in a year

Cash Receipts from paddy	N	Mean	Std. Deviation
Average Annual Production Quantity of paddy(in kgs)	394	4107.20	5641.029
Average Annual value of paddy by- product.	394	14317.61	18159.265
Average Quantity of own consumption of paddy(in kg)	394	1012.88	3542.704
Average of own consumption of paddy by- product in Rs.	394	10851.14	12776.897
Average Quantity of sale of paddy (in kg)	394	3559.91	5472.614
Average price of paddy per kg sold	394	27.36	3.727
Average sale of paddy by- product in Rs.	394	3346.17	9959.855
Average Annual value of paddy product in ₹	394	117897.68	174554.017
Total product value from paddy production in ₹	394	132215.29	184602.119

Source: Primary Data

The table 4.22 summarizes the average annual production of paddy in kg is 4107.20 in a year and average annual production of by- product in a year is ₹14317.61. The annual average quantity of own consumption of paddy is 1012.88 kg. The annual average sale of paddy is 3559.91 kg. The average price of paddy per kg sold is ₹27.36. The average sale of paddy by-product is ₹3346.17 and average consumption of paddy by-product is ₹10851.14. From the table it is clear that the average annual value of paddy product produced in a year is

₹117897.68 and average annual value of paddy by-product (straw) produced in a year is ₹ 14317.61.

4.3.4 Operating Expenses of paddy cultivation

Operating expenses represent business costs incurred by farm businesses for goods and services used in the production process. (FAO, 2020) Expenses include both purchase and self-produced items that are: Property taxes, custom work, seeds, rent, fertilizer and lime, chemicals, machinery and building repairs, irrigation, fuel for heating and machines, wages, interest and business share of insurance premiums.(FAO, 2020) In this context, the study examines the role of imputed expenses and paid out expenses of paddy cultivation. The paid out expenses are expenses that require an outflow of money that is paid out of pocket by the mixed farmer. The imputed expenses are expenses that are not measured in money terms and it is not paid out of pocket by the mixed farmer. The imputed expenses occur in the items like seeds, bio fertilisers, labour, manure, etc.

Table 4.23 Operating Expenses of paddy cultivation

Item	N	Mean	Std. Deviation
Paid out expenses of seeds	394	2003.95	4588.115
Imputed expenses of seeds	394	1675.66	3686.056
Total Expenses of seeds	394	3679.60	5453.157
Paid out expenses of chemical fertilizers in a year	394	11948.06	18102.310
Paid out expenses of bio fertilizers	394	1087.61	4042.627
Imputed expenses of bio fertilizers	394	625.38	1694.270
Total expenses of bio fertilizers	394	1712.99	4516.546
Paid out expenses of manure	394	809.90	4256.751
Imputed expenses of manure	394	4995.05	6311.306
Total expenses of manure	394	5804.94	7932.282
Paid out expenses of Pesticides	394	2469.82	5565.296
Imputed expenses of Pesticides	394	64.21	409.199
Total expenses of Pesticides	394	2534.03	5553.663
Paid out expenses of bio pesticides	394	355.74	2011.817
Imputed expenses of bio pesticides	394	132.87	722.295
Total expenses of bio pesticides	394	488.60	2380.485
Expenses of transportation charges	394	1730.24	4670.663
Expenses of diesel	394	590.10	2531.507
Expenses of electricity	394	57.11	530.171
Expenses of irrigation	394	496.91	1469.831

Paid out expenses of human labour	394	32090.74	38507.213
Imputed expenses of labour	394	133108.14	158482.299
Expenses for minor repair and maintenance of machinery and equipment used in crop production	394	778.63	4885.939
Interest charges	394	1825.76	3683.318
Expenses for machine hiring	394	16641.88	22311.924
Cost of Crop Insurance	394	579.65	1186.500
lease rent for land used for crop production	394	3228.43	8881.427
Marketing cost	394	349.89	1844.990
Subsidy	394	3429.77	6597.902
Other expenses	394	478.48	1862.761

Source: Primary Data

The table 4.23 summarizes the expenses of mixed farms for paddy cultivation in a year. Average expenses of seeds are ₹ 3679.60. Among these imputed expenses of seeds are ₹1675.66 and paid out expenses of seeds are 2003.95. The average paid out expenses of chemical fertilizers are ₹11948.06. The average expenses of bio fertilizers are 1712.9. Among these average paid out expenses are ₹1087.61 and average imputed expenses are 625.38.The average expenses of manure are ₹5804.94. Among these average paid out expenses are ₹809.90 but average imputed expenses are ₹4995.05. The average expenses of pesticides are ₹2534.03. Among these average paid out expenses are ₹2469.82 and average imputed expenses are only ₹64.21. The average expenses of bio pesticides are ₹488.60. Among these the average paid out expenses are ₹355.74 and imputed expenses are ₹132.87. The transportation expenses are ₹ 1730.24 and average expenses of diesel and electricity are ₹590.10 and ₹57.11 respectively. The average expenses of irrigation are ₹496.91. The average paid out expenses of human labour are ₹32090.74 and average expenses of minor repair and maintenance of machinery and equipment used for paddy cultivation are ₹778.63. The interest charges of loans availed for paddy cultivation is ₹ 1825.76 and average expenses of machine hiring are ₹16641.88. The average expenses for crop insurance are ₹579.65 and average rent for land used for paddy cultivation are ₹3228.43. The average marketing cost is ₹349.89 and other expenses are ₹478.48. The average subsidy availed by farmers are ₹3429.77. From the table, it is clear that in paddy cultivation the highest expenses are for the imputed value of labour that is family labour. This indicates that labour costs play a significant role in the overall operating expenses of paddy cultivation.

4.3.5 Cash receipts and income in kind of Cattle Rearing

The cash receipts of cattle rearing come from the sale of livestock, dairy products and other animal by-products. These receipts are important for maintaining the financial stability of livestock farming operations and covering operating expenses. The net sale and purchase of cattle are referred to as livestock transactions. It is calculated by assessing the difference between annual receive/live births/sale and annual death/purchase of cattle in a year.

Table 4.24 Cash receipts and income in kind of Cattle Rearing

Cash Receipts of cattle rearing	**N**	**Mean**	**Std. Deviation**
Average No of days of milking in a year	394	254.66	105.980
Average litre of milk per day	394	10.54	7.238
Average Number of days milk used for self consumption	394	254.92	106.864
Average litre of milk used for self consumption in a day	394	1.63	1.765
Average Number of days milk sold to other households	163	114.92	148.174
Average Litres of milk sold to other households in a day	163	1.94	4.324
Average Value of milk per litre sold to other households	163	50.11	25.715
Average Number of days milk sold to dairy coopertaive society	394	210.27	132.210
Average Litres of milk sold to cooperative society in a day	394	8.322	16.038
Average Value of milk per litre sold into cooperative society	394	40.18	4.807
Average Number of days milk sold to others	18	215.8	51.285
Average Quantity of milk sold per day to others	18	7.75	2.926
Average Value of milk per litre sold it to others	18	50.5	10.968
Average milk produced in a year	394	2974.1307	2361.829
Annual average value of milk from cattle in ₹	394	121101.26	98984.380
Annual average value of manure from cattle in ₹	394	13082.87	12631.314
Annual average Net sale and Purchase of Livestock in ₹	394	31326.90	51517.919
Total product value from cattle rearing in ₹	394	165511.03	115482.014

Source: Primary Survey

From the table 4.24 it is clear that the average annual value of milk produced from cattle rearing is ₹ 121101.26 and average annual value of by-product from cattle that is manure produced is ₹ 13082.87. The annual net sale and purchase of livestock is ₹ 31326.903. Accordingly, the average yearly product value of raising cattle ₹165511.03.

4.3.6 Operating expenses of Cattle Rearing in a year.

The table 4.25 shows the descriptive statistics of operating expenses of cattle rearing in a year. The expenditure items included under cattle rearing are cattle feed, green fodder, dry fodder, straw, concentrates, breeding, insurance, labour cost, marketing cost and other expenses.

Table 4.25 Descriptive Statistics of Operating Expenses of Cattle Rearing in a year

Item	N	Mean	Std. Deviation
Paid out expenses of cattle feed per year	394	71696.10	53307.201
Imputed expenses of cattle feed in a year	394	6889.34	37946.347
Total expenses of cattle in a year	394	78585.44	73459.094
Paid out expenses of green fodder in a year	394	8106.02	45099.039
Imputed expenses of green fodder in a year	394	18597.26	22028.069
Total expenses of green fodder in a year	394	26703.27	51062.546
Paid out expenses of dry fodder in a year	394	6033.38	16943.523
Imputed expenses of straw in a year	394	20866.42	37266.099
Total expenses of dry fodder in a year	394	26899.79	41577.739
Paid out expenses of concentrates in a year	394	6100.51	43031.658
Imputed expenses of concentrates in a year	394	7742.13	36630.188
Total expenses of concentrates in a year	394	13842.64	66731.189
Expenses for breeding in a year	394	1378.55	2702.532
Expenses for health services in a year	394	2313.96	4145.384
Interest on loans utilized for farming of animals in a year	394	1499.52	4982.464
Labour charges in a year	394	5157.36	28714.783
Imputed expenses of labour	394	264220.76	126193.070
Cost of livestock insurance	394	2935.43	10705.175
Marketing cost in a year	394	1621.07	6305.596
Other expenses in a year	394	193.40	1752.311

Source: Primary Data

The total expenses of cattle feed in a year is ₹78585.44. Among these the average paid out expenses of cattle feed is ₹71696.10 and average imputed expenses of cattle feed is ₹6889.3401. The total expenses of green fodder in a year are ₹26703.27. Among these the average paid out expenses of green fodder is ₹8106.02 and average imputed expenses of green fodder are ₹18597.26. The total expenses of dry fodder in a year are ₹26899.7970. Among these the average paid out expenses of dry fodder is ₹6033.38 and average imputed expenses of dry fodder are ₹20866.42. The total expenses of concentrates in a year are ₹13842.64. Among these the average paid out expenses of concentrates is ₹6100.5076 and average imputed expenses of concentrates are ₹7742.13. The average expenses of breeding and health services to cattle are ₹1378.55 and ₹2313.96. The average interest on loans utilized for farming of animals in a year is ₹1499.52. The average cost of livestock insurance is ₹ 2935.43. The average marketing cost and other expenses are ₹1621.07 and ₹193.40 respectively.

4.3.7 Net Farm Income

The table 4.26 shows the net farm income in a year. The table illustrates the net farm income from paddy cultivation, net farm income from cattle rearing and net farm income from on farm activities. Besides that, the table also shows change in cost due to mixing of paddy cultivation and cattle rearing. This change in cost can be seen in expenditure items like expenses of green fodder, expenses of straw and expenses of manure. If the paddy farming and cattle keeping are mixed then the above described expenses which were paid out expenses before mixing, it becomes imputed expenses after mixing these activities.

Table 4.26 Descriptive Statistics of Net farm income

Variables	**N**	**Mean**	**Std. Deviation**
Net Farm Income of paddy cultivation	394	-85908.91	214852.308
Net Farm Income of cattle	394	-259840.17	197328.455
Net farm income of on farm activities in a year	394	4343.91	18670.754
Average Imputed expenses of green fodder in a year	394	18597.26	22028.069
Average Imputed expenses of straw in a year	394	20866.42	37266.099
Average Imputed expenses of manure in a year	394	4995.05	6311.306
Change in cost due to mixing up of paddy cultivation and cattle rearing	394	44458.73	44878.764

Source: Primary Survey

From the table 4.26 it is clear that net farm income of paddy cultivation is ₹-85908.91 and net farm income of cattle rearing is ₹-259840.17. The net farm income of on farm activities in a year is ₹ 4343.91. The change in cost due to mixing up of these activities is ₹44458.73.The reason for a change is due to mixing up of these activities rather than practicing in isolation. Due to this farmers can use manure of cattle for paddy cultivation and at the same time the waste product of paddy cultivation that is dry fodder is used as feed for the animals and green fodder grown at the embankment area of paddy cultivation is also utilized for the cattle rearing. The mixing up of these activities has converted paid out expenses for green fodder, manure and straw into imputed expenses of the farmer. The average imputed expenses of green fodder in a year is ₹ 18597.26 and imputed expenses of straw is ₹ 20866.42. The average imputed expenses of manure in a year is ₹4995.05.

4.3.8 Complementarity Index

The term complementarity index (CI) is developed to show level of joint impact on net farm income by *M1* and *M*2 simultaneously in addition to the performance impact by *M*1 or *M*2 independently. (Choi et al., 2008) The complementarity index is calculated based on above equations (Eq-2)which represent the effectiveness of agricultural activities bundled. This index measures to what extent the two activities are complementary if the two activities are bundled. (Lee et al., 2011) In order to obtain the numerator of the index the study adds up the net farm income due to mixing up of these activities, that is add up the net farm income of when two activities are provided, and when on farm activity is practiced. In the denominator of the index, the study adds up the net farm income of when two individual agricultural activities are provided. If the results of the index are greater than 1.0, two activities i.e. paddy production and cattle rearing are decided as complementary to each other; otherwise, they are not. (Lee et al., 2011)

Table 4.27 Complementarity Index

Complementarity Index	Frequency	Percent
Complementarity Index<1	47	11.9
Complementarity Index>1	347	88.1
Total	394	100.0

Source: Primary Survey

From the data provided, it can be concluded that there is a significant degree of complementarity between paddy cultivation and cattle rearing in mixed farming systems. Specifically, 88.1% of mixed farms exhibit complementary interactions between these two agricultural practices, indicating that farmers find benefits in integrating both activities. Conversely, 11.9% of mixed farms do not demonstrate this complementarity, suggesting that these farms may operate more independently or face challenges in integrating both practices effectively. This strong majority indicates that the combined approach of paddy cultivation and cattle rearing is beneficial for most farmers.

4.4 Distribution of Complementarity Index across agricultural characteristics of Mixed Farming System

Agricultural characterization refers to the process of analyzing and describing the various attributes and features of mixed farming system. This section include evaluating agricultural characteristics of mixed farming such as mixed farming area, livestock ownership in terms of number of in milk cattle, category of mixed farms based on dominance of agricultural activity such as livestock dominant or crop dominant, size of mixed farming, status of farm diversification across complementarity Index. The study has tried to analyse the distribution of complementarity index across the agricultural characteristics of mixed farming system.

4.4.1 Agricultural Characteristics-Descriptive Statistics: The below tables shows the descriptive statistics of agricultural characteristics.

Categorization of Farms on the basis of mixed farming area:

The table 4.28 represents the categorization of farms on the basis of mixed farming area

Table 4.28 Categorization of Farms on the basis of Mixed Farming Area

Sl No	Size of land	Frequency	Percent
1	Below 1 Hectare	263	66.8
2	1-2 Hectare	98	24.9
3	2-4 Hectare	15	3.8
4	4-10 Hectare	15	3.8
5	Above 10 Hectare	3	.7
	Total	**394**	**100.0**

Source: Primary Survey

The table 4.28 indicates the categorization of farms on the basis of mixed farming area. From the table it is clear that 66.8% of farmers hold below 1 Hectare. That is majority of farmers are marginal farmers. 24.9% of farms hold 1-2 hectares of land. That is 24.9 % of farmers are small farmers. 3.8% of farms hold 2-4 hectares of land. 3.8 % of farms hold 4-10 hectares of land. Only .7% of farms hold above 10 hectares of land. That is .7% of farmers are large farmers.

Category of Mixed Farms on the basis of dominance of agricultural activity

The dominance of a single activity, such as paddy production or cattle rearing, in mixed farming can significantly impact the overall complementarity and dynamics of the farming system. In paddy dominated mixed farming systems, the focus is primarily on paddy cultivation, with cattle rearing serving a secondary role for purposes such as manure production or income diversification. This can lead to higher productivity in paddy yields but may limit the potential benefits that come from integrating cattle, such as nutrient recycling and greater resilience to environmental shocks. On the other hand, in cattle rearing-dominant mixed farming systems, cattle are the main source of income and farm sustainability, while paddy production serves to supplement or support animal feed. This can enhance the farm's resilience, as cattle provide a stable source of income even when paddy yields are poor. However, an overemphasis on either activity can lead to imbalances, where the sustainability of the farm may be compromised by over-reliance on one resource, reducing the potential benefits of a more integrated approach.

Mixed farms can be divided into livestock dominant mixed farms and crop dominant mixed farms. If the single activity in mixed farming system that is either crop production or cattle rearing contributes more than 50 % towards the total value of production of the holding decides whether a mixed farm is crop dominant or livestock dominant. If the paddy production contributes more than 50% towards total value of mixed farming, then that mixed farm is crop dominant mixed farm. If the cattle rearing contribute more than 50% of total value of production of the holding,   that mixed farm is livestock dominant mixed farm.

Table 4.29 Category of Mixed Farms on the basis of dominance of agricultural activity

Category	**Frequency**	**Percent**
Livestock dominant	319	81.0
Crop dominant	75	19.0
Total	**394**	**100.0**

Source: Primary Survey

From the table 4.29 it is clear that 319 are livestock dominant mixed farms and only 75 are crop dominant mixed farms.

Ownership of in- milk cattle by mixed farmers

Cattle contributes to the sustainability of mixed farming by enhancing soil fertility, improving resource use efficiency, offering diversification, and building resilience to external risks. These benefits collectively support the long-term environmental, economic, and social sustainability of farming systems

Table 4.30 Ownership of in-milk cattle by mixed farmers

Number of in- milk cattle heads at the end of the year	Frequency	Percent
Upto 2	305	77.4
3-5	83	21.1
6-8	6	1.5
Total	**394**	**100.0**

Source: Primary Survey

The table 4.30 shows ownership of cattle by mixed farmers. Cattle are classified as in milk, young stock and others. 77.4% of farmers hold upto 2 in milk cattle, 21.1% of farmers hold 3-5 in milk cattle and only 1.5% of farmers hold 6-8 in milk cattle.

- **Status of Farm Diversification**

According to National Industrial Classification,(NIC) 2008, Mixed farming system includes combined production of crops and animals without specialized production of crops or animals.(NIC,2008) In this context, the study discusses about farm diversification. Farm diversification means that is share of paddy production or cattle rearing contributes not greater than 66% towards total value of production of the holding.

Table 4.31 Status of Farm Diversification

Farm Diversisfication	Frequency	Percent
No	285	72.3
Yes	109	27.7
Total	**394**	**100.0**

Source: Primary Survey

From the table 4.31, it is clear that only 27.7% of mixed farms have farm diversification while the remaining 72.3% lack diversification.

Size of mixed farming

Based on the total value of production of mixed farming, the mixed farms are classified into 3 such as small size, medium size and large size.

Table 4.32 Size of Mixed Farming

Size of mixed farming	Frequency	Percent
Small size	130	33.0
Medium size	132	33.5
Large size	132	33.5
Total	**394**	**100.0**

Source: Primary Survey

From the table 4.32 it is clear that, 33% size mixed farms are small size and 33.5% of farms are medium size and large size.

The study has formulated one main hypothesis and several sub- hypotheses. For testing the hypotheses Independent-Samples Kruskal-Wallis Test and Independent-Samples Mann-Whitney U Test is performed. The main hypothesis is presented below.

Null Hypothesis-H0: Complementarity Index remains same across agricultural characteristics of mixed farming system.

Null Hypothesis-H0a: Complementarity Index remains same across various categories of mixed farming area.

For testing the hypothesis Independent-Samples Kruskal-Wallis Test is conducted. The results of hypothesis testing is given below in the table 4.33

Table 4.33 Hypothesis Test Summary

<table>
<tr><td rowspan="6">Complementarity Index</td><th>Mixed Farming Area</th><th>Mean rank</th><th>Z</th><th>Sig</th><th>Decision</th></tr>
<tr><td>Below 1 Hectare</td><td>195.44</td><td rowspan="5">7.025</td><td rowspan="5">0.134</td><td rowspan="5">Retain H0a</td></tr>
<tr><td>1-2 Hectare</td><td>205.99</td></tr>
<tr><td>2-4 Hectare</td><td>211.00</td></tr>
<tr><td>4-10 Hectare</td><td>197.33</td></tr>
<tr><td>Above 10 Hectare</td><td>34.00</td></tr>
</table>

Source: Primary Survey

The table 4.33 shows that the p value is .135 and it is greater than than .05 (at 5% level of significance). Therefore the study retain the null hypothesis and conclude that complementarity index remain same across categories of mixed farming area.

Null Hypothesis-H0b: Complementarity Index remains same across various category of mixed farms on the basis of dominance of agricultural activity.

For testing the hypothesis Independent-Samples Mann-Whitney U Test is conducted. The results of hypothesis testing is given below in the table 4.34

Table 4.34 Hypothesis Test Summary

	Category of Mixed farming on the basis of dominance of agricultural activity	Mean rank	Z	Sig	Decision
Complementarity Index	Livestock dominant Mixed farming	204.29	-2.441	.015	Reject H0b
	Crop dominant Mixed farming	168.61			

Source: Primary Survey

The p value is .015 and it is less than .05 (at 5% level of significance). Therefore the study rejects the null hypothesis and concludes that complementarity level varies across crop dominant and livestock dominant mixed farms. The test statistic is 9796.000. The livestock dominant mixed farms have has highest mean rank 204.29 suggesting that it leads to higher level of complementarity. The crop dominant mixed farms has lowest mean rank 168.61 suggesting that it leads to lowest level of complementarity.

Null Hypothesis-H0c: Complementarity Index remains same across various categories of in milk cattle

For testing the hypothesis Independent-Samples Kruskal-Wallis Test is conducted. The results of hypothesis testing is given below in the table 4.35

Table 4.35 Hypothesis Test Summary

	Land	Mean rank	Z	Sig	Decision
Complementarity Index	Upto 2	193.32	14.867	.001	Reject H0c
	3-5	200.10			
	6-8	374.00			

Source: Primary Survey

The p value is .001 and it is less than .01 (at 1 % level of significance). Therefore the study reject the null hypothesis and conclude that complementarity level varies across categories of in milk cattle at the end of the year. The test statistic is 14.867. The mixed farms having 6-8 in milk cattle have highest mean rank 374.00 suggesting that it leads to higher level of complementarity. The mixed farms having up to 2 in milk cattle have lowest mean rank 193.32 suggesting that it leads to lowest level of complementarity.

Null Hypothesis-H0d: Complementarity Index remains same across various groups of mixed farmers on the basis of status of farm diversification.

For testing the hypothesis Independent-Samples Mann-Whitney U Test is conducted. The results of hypothesis testing is given below in the table 4.36

Table 4.36 Hypothesis Test Summary

Complementarity Index	**Category of Mixed farming based on status of farm diversification**	**Mean rank**	**Z**	**Sig**	**Decision**
	No	182.74	-4.161	.000	Reject H0d
	Yes	236.10			

Source: Primary Data

The p value is .000 and it is less than .01 (at 1 % level of significance). Therefore we reject the null hypothesis and conclude that complementarity level varies across categories of on farm diversification. The test statistic is 11325. The mixed farms having farm diversification have highest mean rank 236.10 suggesting that it leads to higher level of complementarity. The mixed farms having no farm diversification have lowest mean rank 182.74 suggesting that it leads to lowest level of complementarity.

Null Hypothesis-H0e: Complementarity Index remains same across various scales of mixed farming

For testing the hypothesis Independent-Samples Kruskal-Wallis Test is conducted. The results of hypothesis testing is given below in the table 4.37

Table 4.37 Hypothesis Test Summary

Complementarity Index	**Land**	**Mean rank**	**Z**	**Sig**	**Decision**
	Small size	176.84	7.001	.030	Reject H0e
	Medium Size	213.17			
	Large size	202.18			

Source: Primary Data

The p value is .030 and it is less than .05 (at 5 % level of significance). Therefore we reject the null hypothesis and conclude that complementarity level varies across various size of mixed farming. The test statistic is 7.001. The medium size mixed farming have highest mean rank 213.17 suggesting that it leads to higher level of complementarity. The small size mixed farming have lowest mean rank 176.84 suggesting that it leads to lowest level of complementarity.

4.5 Conclusion

Complementarity in mixed farming refers to how paddy cultivation and cattle rearing can work together to achieve better outcomes compared to when they are considered in isolation. From the analysis it is clear that the mixed farming demonstrate significant complementarity. For example, livestock manure can be used to fertilize paddy fields, while paddy cultivation provide dry and green fodder for the animals, thus reducing input cost and creating a more efficient and sustainable farming system. Complementary practices reduce waste by utilizing byproducts from one part of the system (such as crop residues) in another part (e.g., livestock feed, composting), promoting a circular and more sustainable approach to farming. Therefore measuring complementarity in mixed farming is essential for optimizing resource use, enhancing productivity, and promoting sustainability. In summary, measuring complementarity in mixed farming is crucial for promoting sustainability, boosting productivity, enhancing resilience, and ensuring efficient resource use. By understanding and applying complementarity, farmers can improve yields, mitigate risks, and contribute to long-term food security and environmental sustainability. The study affirms Poor But Efficient Hypothesis of T W Schultz because in mixed farming, there is optimum allocation of available resources that no resources are left openly unemployed. There is no wastage of resources in mixed farming due to exchange of waste products between the enterprises.

The hypothesis testing is conducted to examine the distribution of the Complementarity Index is same across various agricultural characteristics of mixed farming., The agricultural characteristics include mixed farming area, category of mixed farms on the basis of dominance of agricultural activity such as livestock-dominant mixed farming and crop-dominant mixed farming, various categories of in-milk cattle, status of farm diversification in mixed farming, and different size of mixed farming such as small size, medium size and large size. The results indicate that the complementarity index remains consistent across different land categories. However, the complementarity level varies between crop-dominant and livestock-dominant mixed farms. Additionally, variations in complementarity levels are observed across categories of in milk cattle at the end of the year, as well as in category of mixed farms based on farm diversification. Finally, the complementarity level also differs across various sizes of mixed farming, highlighting the dynamic nature of sustainability within agricultural practices."

CHAPTER 5
ECONOMIC, ENVIRONMENTAL AND SOCIAL SUSTAINABILITY OF MIXED FARMING

5.1 Introduction

Mixed farming, an agricultural practice that integrates both crop cultivation and livestock rearing, plays a vital role in promoting sustainability. This approach harnesses the synergies between crops and animals, allowing for efficient resource use and enhanced biodiversity. By recycling nutrients through crop residues and manure, mixed farming reduces the need for synthetic fertilizers and fosters soil health. Additionally, it can improve resilience to climate change, as diverse systems are often better equipped to withstand extreme weather events. Furthermore, mixed farming supports local economies by providing a variety of products and reducing reliance on external inputs. As global challenges such as food security and environmental degradation intensify, the sustainability of mixed farming emerges as a promising pathway to achieve balanced, productive, and resilient agricultural systems.

Measuring sustainability of mixed farming is crucial for ensuring that farming practices do not harm the environment and can continue to meet the needs of future generations. This chapter deals with analysis of primary data for measuring the sustainability of mixed farming in Palakkad district of Kerala. The economic sustainability of mixed farming is covered in the first section. The environmental and social sustainability of mixed farming are covered in the second and third sections, respectively. Lastly, the economic, environmental, and social aspects of sustainability are combined to evaluate the sustainability of mixed farming. The indicators used for assessing economic sustainability are farm output value per hectare, net farm income of mixed farms and risk mitigation mechanisms followed by mixed farms. The indicators used for measuring environmental sustainability are prevalence of soil degradation, variation in water availability, management of fertilizers, management of pesticides and use of agro bio diversity supportive practices. The social sustainability is assessed using the indicators wage rate in agriculture, food insecurity experience index and secure tenure rights to land.(FAO, 2020) Using these 11 indicators, sustainability index is computed for measuring sustainability of mixed farming. With some adjustments, the FAO's approach to evaluating Indicator 2.4.1 Sustainable Agriculture served as the basis for these 11 indicators and techniques for evaluating the sustainability of mixed farming. Additionally, measuring sustainability in agriculture ensures the economic and social viability of mixed farming. Furthermore, sustainability data of mixed farming informs policy development, guides government support for eco-friendly practices, and meets growing consumer demand for responsibly produced food, opening access to premium markets and enhancing consumer confidence.

5.2 Sustainability of Mixed Farming

Sustainability in mixed farming refers to the ability of farming system that combines crop production with livestock rearing to meet present and future demand for food and livelihoods while conserving environment, ensuring economic viability and supporting social well being. Mixed farms are systems made up of several components that should work as a unit. To comprehend the system, they must therefore be examined as a whole rather than as separate components. By effectively merging the production of crops and livestock, MFS may be able to reduce the need for external inputs and alleviate some of the environmental issues facing agriculture today. However, MFS would have to show greater (or at least comparable) economic, environmental, and social benefits than specialized farming in order to be preserved or reintroduced. Therefore, it is necessary to take into account their level of sustainability and whether or not they could be a good substitute for specialization. There is thus a need to understand better if MFS could contribute to the three sustainability dimensions of farming and to what extent. The sustainability dimensions are economic, environmental and social. The hypothesis of the study is presented below.

H0: Mixed farmers maintain an acceptable level of economic, environmental and social sustainability

5.2.1 Economic Sustainability

The Economic element of mixed farming is related to individuals as well as to the local community and the broader National society. In being a producer of food, for each farmer carries out mixed farming in order to be able to provide for the economic needs of his or her own family and important among these is a need for food. If the system does not make economic sense, if mixed farming is not profitable, and if basic needs are not provided for, the system is unsustainable. Economic sustainability then demands that mixed farmers continue to make a good life and that the population as a whole be supplied with an abundance of high-quality food at reasonable cost. Economic sustainability is measured under three heads: (FAO, 2020)

Table 5.1 Sub- indicators of Economic Sustainability

Sl No	Theme	Sub- indicator
1	Land productivity of mixed farm	Farm output value per hectare of mixed farm
2	Profitability of mixed farm	Net farm income of mixed farm
3	Resilience of mixed farm	Risk mitigation mechanisms of mixed farm

Source: FAO, 2020

The study presents a sub hypothesis which is outlined below

H0a: Mixed farmers maintain an acceptable level of economic sustainability

5.2.1.1. Farm output value per hectare:

The sub-indicator gives a description about farm output value per hectare of mixed farm (crop and livestock). Farm output value per hectare is a measure of the average monetary value of agricultural output per hectare of mixed farm

- Farm output value of mixed farm: The volume of agricultural output at mixed farm level generally takes into account production of multiple outputs, such as paddy, paddy bye product- straw, milk, manure, transactions in livestock.(FAO, 2020) The net sale and purchase of cattle are referred to as livestock transactions. It is calculated by assessing the difference between annual receive/live births/sale and annual death/purchase of cattle in a year. All these output of mixed farms is measured in monetary units. (i.e. quantity multiplied by prices). The multiple outputs produced by a single mixed farm are aggregated in terms of values. The mixed farming area: defined as the area of land used for paddy cultivation, area of farmyard and area of farm buildings
- **Sustainability Criteria of Farm Output Value per Hectare in mixed farming**
- Distance from the 90th percentile of the Farm output value per hectare. The 90th percentile of farm output value per hectare of mixed farming in a year is ₹1456948.40. The 2/3 of 90 percentile is ₹971298.93. The 1/3 of 90th percentile is 485649.47.
- Green (Desirable): The farm output value per hectare of mixed farm is greater than or equal to 2/3 of the 1456948.40 that is ₹971298.933
- Yellow (Acceptable): The farm output value per hectare of mixed farm is between ₹485649.467 and ₹ 971298.933
- Red (Unsustainable): The farm output value per hectare is less than1/3 of 1456948.40 that is ₹485649.47

➢ **Classification of Mixed Farms based on mixed farming area**

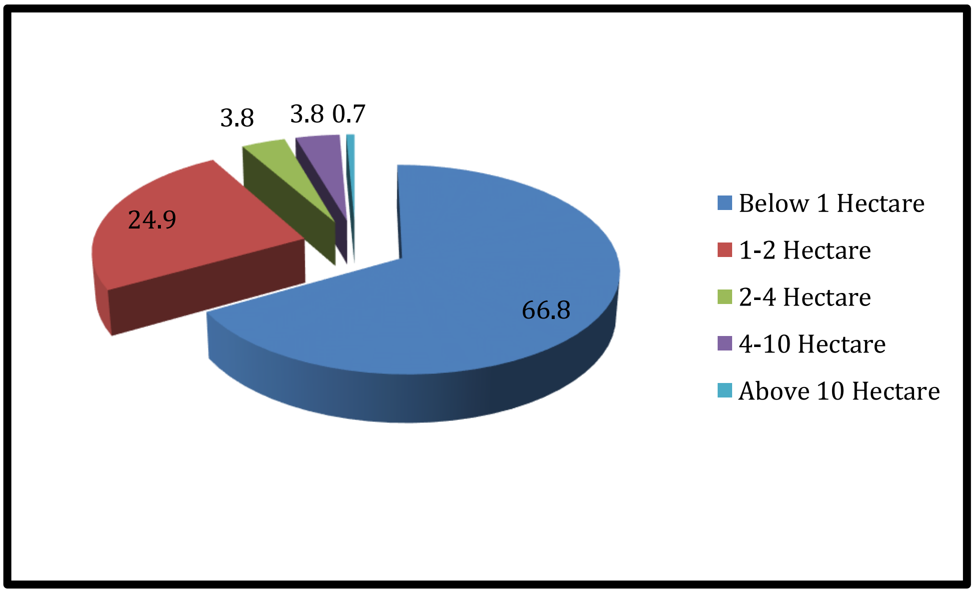
The table 5.2 depicts categorization of farms on the basis of size of mixed farming area. "A mixed farm is a combination of areas for paddy cultivation, farmyard activities, and farm buildings." The land used for cultivating paddy, area used for cattle rearing or other farmyard operations, and areas for farm buildings like storage, equipment sheds, etc. are all parts of a farm.

Table 5.2 Classification of farms on the basis of size of Mixed Farming Area

Sl No	Size of land	Frequency	Percent
1	Below 1 Hectare	263	66.8
2	1-2 Hectare	98	24.9
3	2-4 Hectare	15	3.8
4	4-10 Hectare	15	3.8
5	Above 10 Hectare	3	.7
	Total	394	100.0

Source: Primary Survey

Figure 5.1 Classification of farms on the basis of size of Mixed Farming Area



Source: Primary Data

The table 5.2 and figure 5.1 indicates the categorization of farms on the basis of mixed farm area size. From the table it is clear that 66.8% of mixed farmers hold below 1 Hectare. That is majority of farmers are marginal farmers. 24.8% of farms hold 1-2 hectares of mixed farm area. That is 24.8 % of farmers are small farmers. 3.8% of farms hold 2-4 hectares of mixed farm area. 3.8 % of farms hold 4-10 hectares of mixed farm area. Only .7% of farms hold above 10 hectares of mixed farm area. That is .7% of farmers are large farmers.

➢ **Farm Output Value per Hectare in Mixed Farming –Descriptive Statistics**

The table 5.3 depicts the descriptive statistics of farm output value per hectare in mixed farming. For assessing the farm output value, product and by- product of paddy cultivation and cattle farming are taken into account

Table 5.3 Farm Output Value per Hectare in Mixed Farming –Descriptive Statistics

Item	Frequency	Mean	Standard Deviation
Annual value of paddy product in ₹	394	117897.68	174554.018
Annual value of paddy bye- product	394	14317.61	18159.265
Total product value from paddy production in ₹	394	132215.30	184602.119
Annual value of milk from cattle in ₹	394	121101.26	98984.380
Annual value of manure from cattle in ₹	394	13082.87	12631.314
Annual Net sale and Purchase of Livestock in ₹	394	31326.90	51517.919
Total product value from cattle rearing in ₹	394	165511.03	115482.0144
Total product value from mixed farming in ₹	394	297726.33	213763.972
Average Mixed farming area in hectares	394	1.03	1.586
Farm output value per hectare in ₹	394	586214.56	441850.689

Source: Primary Survey

From the table 5.3 it is clear that the average annual value of paddy product produced by the mixed farms in a year is ₹117897.68 and average annual value of paddy by-product (straw) produced in a year is ₹ 14317.61. At the same time the average annual value of milk produced from cattle rearing is ₹ 121101.26 and average annual value of by-product from cattle that is manure produced is ₹ 13082.87. The annual net sale and purchase of livestock is ₹ 31326.90. Accordingly, the average yearly product value of raising cattle and growing paddy is ₹165511.03 and ₹132215.30, respectively. The average annual product value from mixed farming that combines both paddy production and cattle rearing is ₹297726.33. The average agricultural area operated by farmers is 1.03 Hectares. Therefore farm output value per hectare is ₹586214.56

➢ **Sustainability Level of Mixed Farming in terms of Farm Output Value per Hectare**

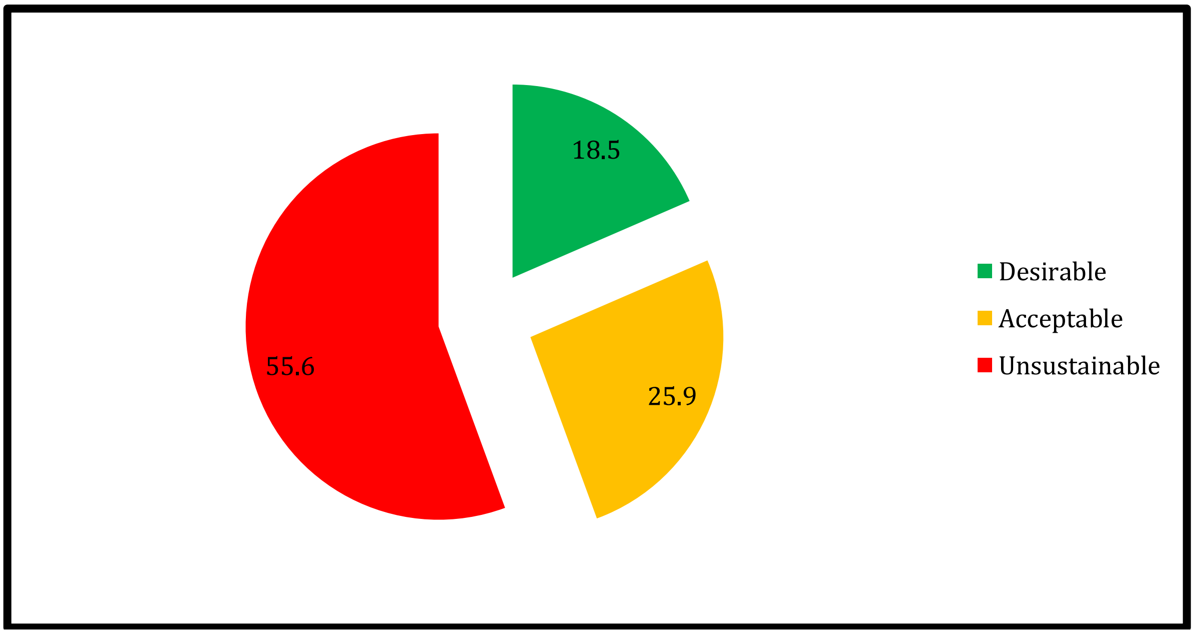
The table 5.4 highlights sustainability level of farm output value per hectare in mixed farming. On the basis of farm output value per hectare, sustainability level of mixed farms is classified as desirable, acceptable and unsustainable.

Table 5.4 Sustainability Level of Mixed Farming in terms of Farm Output Value per Hectare

Sustainability Level	Frequency	Percent	Chi-square Test	p value
Desirable	73	18.5	$\chi2=90.980$	$p < .000^{**}$
Acceptable	102	25.9		
Unsustainable	219	55.6		
Total	**394**	**100.0**		

** At 1% level of significance   Source: Primary Survey

Figure 5.2 Sustainability Level of Mixed Farming in terms of Farm Output Value per Hectare



Source: Primary Survey

The sustainability level of mixed farms in terms of farm output value per hectare is summarized in the table 5.4 and figure 5.2. It is clear from the table 5.4 and figure 5.2 that while 25.9% of mixed farms are categorized as "Acceptable," 55.6% of mixed farms are categorized as "Unsustainable." Of all farms, only 18.5% are deemed "Desirable.**"** Chi-square test for goodness of fit has been performed to examine whether there is any significant difference in the sustainability level of mixed farming in terms of farm output value per hectare. The results indicate that there is statistical significant difference in the sustainability level of management of pesticides among mixed farmers, $\chi 2$ = 90.980, p < .000 (Exact p-value). Hence it is inferred that the level of sustainability regarding farm output value per hectare among mixed farmers are different in Palakkad district.

5.2.1.2 Net Farm Income (NFI) of Mixed Farming

Net farm income (NFI) is the total revenue a mixed farm generates from its operations, minus the total costs of production, including expenses for labor, equipment, and inputs for paddy cultivation and cattle rearing. It is a crucial sign of a mixed farm's financial stability and success since it shows the profit a farmer makes after all operating costs have been paid. The sub-indicator assesses the farm's profitability during the year 2022–2023. The formula for measuring net farm income of mixed farming is

$NFI = CR + Yk - OE$ (FAO, 2020) --------1

where

· NFI = Total Net Farm Income
· CR = Total farm cash receipts from paddy cultivation and cattle rearing
· Yk = Income in kind
· OE = Total operating expenses of paddy cultivation and cattle rearing

Sustainability criteria: The 33rd and 66th percentile is computed from net farm income of mixed farm. Accordingly mixed farm's sustainability is assessed as follows

Green (Desirable): Mixed farms are desirable if the net farm income of the mixed farm is above Percentile 66.

Yellow (Acceptable): Mixed farms are acceptable if the net farm income of the mixed farm is above NFI is between Percentile 33 and Percentile 66

Red (Unsustainable): Mixed farms are desirable if the net farm income of the mixed farm is below Percentile 33.

- **Cash Receipts of Paddy Cultivation and Cattle Rearing –Descriptive Statistics**

The table 5.5 depicts the cash receipts from paddy cultivation and cattle rearing of mixed farms in a year. The study has identified even though there are three seasons of paddy cultivation, in the study area, paddy is cultivated in two seasons. So the annual value of paddy production includes the value of paddy product and it's by- product during the two seasons.

Table 5.5 Descriptive Statistics of Cash Receipts of Paddy Cultivation and Cattle Rearing of Mixed Farms in a Year

Cash Receipts from Paddy Production and Cattle Rearing	Frequency	Mean	Standard Deviation
Annual value of paddy product in ₹	394	117897.68	174554.018
Annual value of paddy by- product in ₹	394	14317.61	18159.265
Total product value from paddy production in ₹	394	132215.30	184602.119
Annual value of milk from cattle in ₹	394	121101.26	98984.380
Annual value of manure from cattle in ₹	394	13082.87	12631.314
Net sale and purchase of cattle in ₹	394	31326.90	51517.919
Total product value from cattle rearing in ₹	394	165511.03	101955.574
Total product value from mixed farming in ₹	394	297726.33	213763.972
Mixed farming area in hectares	394	1.02	1.586

Source: Primary Survey

From the table it is clear that the average annual value of paddy product produced by the mixed farms in a year is ₹117897.68 and average annual value of paddy bye-product (straw) produced in a year is ₹ 14317.61. At the same time the average annual value of milk produced from cattle rearing is ₹ 121101.26 and average annual value of by-product from cattle that is manure produced is ₹ 13082.87. The annual net sale and purchase of livestock is ₹ 31326.90. Accordingly, the average yearly product value of raising cattle and growing paddy is ₹165511.03 and ₹132215.30, respectively. The average annual product value from mixed farming that combines both paddy production and cattle rearing is ₹297726.33.

Operating expenses of Paddy Cultivation in a Year- Descriptive Statistics

The table 5.6 illustrates the operating expenses of paddy cultivation in a year. These expenses help to analyze and understand the key areas where costs are incurred throughout the paddy cultivation process.

Table 5.6 Descriptive Statistics of Operating Expenses of Paddy Cultivation for a year

Types of Operating Expenses	N	Mean	Std. Deviation
Paid out expenses of seeds	394	2003.95	4588.115
Imputed expenses of seeds	394	1675.66	3686.056
Total Expenses of seeds	394	3679.60	5453.158
Paid out expenses of chemical fertilizers in a year	394	11948.06	18102.310
Paid out expenses of bio fertilizers	394	1087.61	4042.627
Imputed expenses of bio fertilizers	394	625.38	1694.270
Total expenses of bio fertilizers	394	1712.99	4516.546
Paid out expenses of manure	394	809.90	4256.751
Imputed expenses of manure	394	4995.05	6311.306
Total expenses of manure	394	5804.95	7932.282
Paid out expenses of Pesticides	394	2469.82	5565.296
Imputed expenses of Pesticides	394	64.21	409.199
Total expenses of Pesticides	394	2534.04	5553.663
Paid out expenses of bio pesticides	394	355.74	2011.817
Imputed expenses of bio pesticides	394	132.87	722.295
Total expenses of bio pesticides	394	488.60	2380.486
Expenses of transportation charges	394	1730.24	4670.663
Expenses of diesel	394	590.10	2531.507
Expenses of electricity	394	57.11	530.171
Expenses of irrigation	394	496.91	1469.831
Paid out expenses of human labour	394	32090.74	38507.213
Imputed expenses of labour	394	133108.15	158482.298
Expenses for minor repair and maintenance of machinery and equipment used in crop production	394	778.63	4885.939
Interest charges	394	1825.76	3683.318
Expenses for machine hiring	394	16641.88	22311.924
Cost of Crop Insurance	394	579.65	1186.500
lease rent for land used for crop production	394	3228.43	8881.427
Marketing cost	394	349.89	1844.990
Subsidy	394	3429.77	6597.902
Other expenses	394	478.48	1862.761

Source: Primary Survey.

The table 5.6 summarizes the expenses of mixed farms for paddy cultivation in a year. Average expenses of seeds are ₹ 3679.60. Among these imputed expenses of seeds are ₹1675.66 and paid out expenses of seeds are 2003.95. The average paid out expenses of chemical fertilizers are ₹11948.06. The average expenses of bio fertilizers are 1712.99. Among these average paid out expenses are ₹1087.61 and average imputed expenses are 625.38.The average expenses of manure are ₹5804.95. Among these average paid out expenses are ₹809.90 but average imputed expenses are ₹4995.05. The average expenses of pesticides are ₹2534.04. Among these average paid out expenses are ₹2469.82 and average imputed expenses are only ₹64.21. The average expenses of bio pesticides are ₹488.60. Among these the average paid out expenses are ₹355.74 and imputed expenses are ₹132.87. The transportation expenses are ₹ 1730.24 and average expenses of diesel and electricity are ₹590.10 and ₹57.11 respectively. The average expenses of irrigation are ₹496.91. The average paid out expenses of human labour are ₹32090.74 and average expenses of minor repair and maintenance of machinery and equipment used for paddy cultivation are ₹778.63. The interest charges of loans availed for paddy cultivation is ₹ 1825.76 and average expenses of machine hiring are ₹16641.88. The average expenses for crop insurance are ₹579.65 and average rent for land used for paddy cultivation are ₹3228.43. The average marketing cost is ₹349.89 and other expenses are ₹478.48. The average subsidy availed by farmers are ₹3429.77.

- **Descriptive Statistics of Operating Expenses of Cattle Rearing in a year**

  The table 5.7 depicts the operating expenses of cattle rearing in a year. The table shows the important costs that are incurred for cattle farming.

Table 5.7 Descriptive Statistics of Operating Expenses of Cattle Rearing in a year

Types of Operating expenses	N	Mean	Std. Deviation
Paid out expenses of cattle feed per year	394	71696.10	53307.201
Imputed expenses of cattle feed in a year	394	6889.34	37946.347
Total expenses of cattle feed in a year	394	78585.44	73459.094
Paid out expenses of green fodder in a year	394	8106.02	45099.039
Imputed expenses of green fodder in a year	394	18597.26	22028.069
Total expenses of green fodder in a year	394	26703.27	51062.546
Paid out expenses of dry fodder in a year	394	6033.38	16943.523
Imputed expenses of straw in a year	394	20866.42	37266.099
Total expenses of dry fodder in a year	394	26899.80	41577.739
Paid out expenses of concentrates in a year	394	6100.51	43031.658
Imputed expenses of concentrates in a year	394	7742.13	36630.188
Total expenses of concentrates in a year	394	13842.64	66731.189
Expenses for breeding in a year	394	1378.55	2702.532
Expenses for health services in a year	394	2313.96	4145.384
Interest on loans utilized for farming of animals in a year	394	1499.52	4982.464
Labour charges in a year	394	5157.36	28714.783
Imputed expenses of labour	394	264220.76	126193.070
Cost of livestock insurance	394	2935.43	10705.175
Marketing cost in a year	394	1621.07	6305.596
Other expenses in a year	394	193.40	1752.311

Source: Primary Survey

The table 5.7 depicts that the total expenses of cattle feed in a year is ₹78585.44. Among these the average paid out expenses of cattle feed are ₹71696.10 and average imputed expenses of cattle feed are ₹6889.34. The total expenses of green fodder in a year are ₹26703.27. Among these the average paid out expenses of green fodder are ₹8106.02 and average imputed expenses of green fodder are ₹18597.26. The total expenses of dry fodder in a year are ₹26899.80. Among these the average paid out expenses of dry fodder are ₹6033.38 and average imputed expenses of dry fodder are ₹20866.42. The total expense of concentrates in a year is ₹13842.64. Among these the average paid out expenses of concentrates are ₹6100.51 and average imputed expenses of concentrates are ₹7742.13. The average expenses of breeding and health services to cattle are ₹1378.55 and ₹2313.96. The average interests on loans utilized for farming of animals in a year are ₹1499.52. The average cost of livestock insurance are ₹ 2935.43. The average marketing cost and other expenses are ₹1621.07 and ₹193.40 respectively.

- **Net Farm Income of Mixed Farming in a Year - Descriptive Statistics**

The table 5.8 depicts the net farm income of mixed farming in a year. The basic formula for measuring net farm income is shown in Equation 1 of this chapter. (Page No. 96) In the study NFI is calculated in three ways: Net Farm Income: Deducting all costs from cash receipts for paddy cultivation and cattle rearing generates net farm income A; subtracting all costs excluding labour expenses from cash receipts results in Net Farm Income B; and subtracting all costs excluding all imputed costs from cash receipts for paddy cultivation and cattle rearing gives Net Farm Income C.

Table 5.8 Descriptive Statistics of Net Farm Income of Mixed Farms in a year

Classification of Net Farm Income	Net Farm Income	N	Mean	Std. Deviation
Net Farm Income A	Net Farm Income of Mixed Farms in a year	394	-349178.85	311228.520
Net Farm Income B	Net Farm Income of Mixed Farms in a year excluding Imputed Expenses of labour	394	48150.06	208896.649
Net Farm Income C	Net Farm Income of Mixed Farms in a year excluding Imputed Expenses	394	113168.15	186862.090

Source: Primary Survey

The table 5.8 summarizes the net farm income of mixed farms in a year. The average annual net farm income of mixed farms is ₹-349178.85, but when net farm income is calculated excluding the imputed expenses of labour, that is, the contribution of family labour it is ₹48150.06, which shows an improvement. When net farm income is calculated excluding all imputed expenses especially expenses on seeds, fertilizers, green fodder, straw, labour etc. again the net farm income shows an improvement of ₹ 113168.15. This type of farming is primarily carried out for the farmers' own consumption or that of their families. The table indicates that family labour is necessary for mixed farming to exist. Thus, family farming is another name for mixed farming. Furthermore, the ongoing existence of mixed farming depends on imputed or own inputs. The farmers could not earn profit from mixed farming if the imputed expenses are not incurred.

- **Sustainability Level of Mixed Farming in terms of Net Farm Income**

The table 5.9 indicates sustainability level of mixed farming regarding net farm income. On the basis of net farm income, sustainability level of mixed farms is classified as desirable, acceptable and unsustainable

Table 5.9 Sustainability Level of Mixed Farming in terms of Net Farm Income

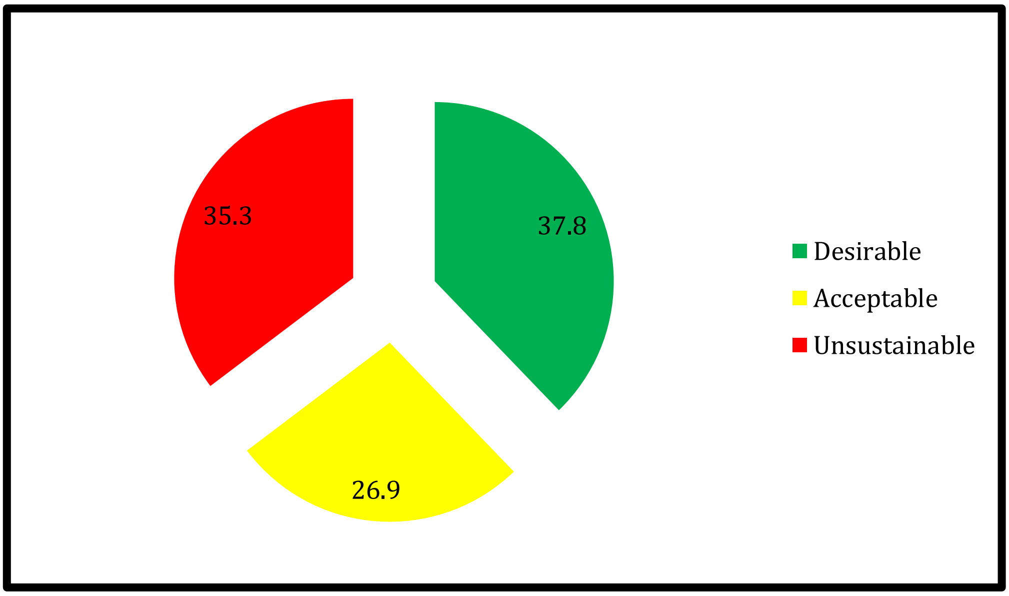
Sustainability Level	Frequency	Percent	Chi- Square Test	p value
Desirable	149	37.8	7.711	.020*
Acceptable	106	26.9		
Unsustainable	139	35.3		
Total	394	100.0		

*At 5% level of significance Source: Primary Survey

Even though three forms of net farm income is measured, Net Farm Income C is used to assess the sustainability. Subtracting all costs excluding all imputed costs from cash receipts for paddy cultivation and cattle rearing give Net Farm Income C.

Since imputed costs are non-cash expenses that do not include actual monetary outflows, such as the value of the farmer's own labour or the usage of own inputs, the net farm income of the farm was computed minus all imputed charges. Since these imputed charges do not reflect actual spending, including them would distort the farm's true financial performance. By removing them, the study can more accurately evaluate the mixed farm's net farm income and focusing on the actual expenses that affect the mixed farm's ability to generate income and cover operating expenses.

Figure 5.3 Sustainability Level of Mixed Farming in terms of Net Farm Income



Source: Primary Survey

The table 5.9 and diagram 5.3 summarizes the sustainability level of mixed farms regarding net farm income excluding all imputed expenses. As can be seen from the table and figure, 26.9% of mixed farms are categorized as "Acceptable," while 37.8% are classified as "Desirable." 35.3 % of mixed farms, however, are classified as "Unsustainable." Chi-square test for goodness of fit has been performed to examine whether there was any significant difference in the sustainability level of mixed farming in terms of net farm income. The results indicate that there is statistical significant difference in the sustainability level of mixed farming regarding net farm inmcome, $\chi2$ = 7.711, p value is .020 (Exact p-value). Hence it is inferred that the level of sustainability regarding net farm income among mixed farmers are different in Palakkad district.

5.2.1.3. Risk mitigation mechanisms of Mixed Farming

This risk mitigation mechanisms followed by mixed farmers are measured by following criteria

- Provision of credit or availed credit.
- Provision of insurance or availed insurance.
- Farm diversification that is share of paddy production not greater than 66% towards total value of production of the holding or Farm diversification that is share of cattle

rearing not greater than 66% towards total value of production of the holding. (FAO,2020)

- On farm diversification that is share of other agricultural activities not greater than 66% towards total value of production of the holding(FAO, 2020)

Availability of credit and/or insurance is defined here as when a given service is available and the holder has enough means to obtain the service (required documents, collateral, positive credit history, etc.).(FAO, 2020) Following the above one or more risk reduction strategies will help the farmer to prevent or adapt to shocks due to price fluctuations, climate change etc.

Sustainability criteria:

A mixed farm holding is considered resilient if it is adopting the risk reduction mechanisms as follows:

Green (Desirable): Adopt at least 3 of the above-listed risk mitigation methods.

Yellow (Acceptable): Adopt at least two of the above-listed risk mitigation methods.

Red (Unsustainable): No opportunity to the listed risk mitigation methods.

Provision of Credit / Availed Credit by mixed farmers

The table 5.10 depicts extent to which the mixed farmers access or avail credit. Access to credit refers to extent to which farmers obtain loans or lines of credit from financial institutions. It plays a crucial role in providing funds for farming purposes

Table 5.10 Provision of credit/Availed Credit

Provision of Credit/ Availed Credit		Frequency	Percent
Provision of credit	No	0	0
	Yes	394	100.0
	Total	394	100.0
Availed credit	No	168	42.6
	Yes	226	57.4
	Total	**394**	**100.0**

Source: Primary Survey

The table 5.10 indicates how far the mixed farms have access to credit or availed credit. From the table it is clear that all mixed farms have access to credit. Only 57.4% of mixed farms have availed credit.

Provision of Insurance/Availed Insurance

The table 5.11 depicts extent to which the mixed farmers access or avail insurance. The study has focused on access to insurance or availed insurance by mixed farmer both in the case of paddy cultivation and cattle rearing

Table 5.11 Access to Insurance/Availed Insurance

Provision of Insurance/ Availed Insurance		Frequency	Percent
Provision of Insurance	No	0	0
	Yes	394	100.0
	Total	394	100.0
Availed Insurance	No	180	44.7
	Yes	214	54.3
	Total	394	100.0
	Total	**394**	**100.0**

Source: Primary Data

The table 5.11 indicates how far the mixed farms are access to insurance or availed insurance. From the table it is clear that all mixed farms have access to insurance. Only 54.3% of mixed farms have availed insurance.

- **Other Risk Mitigation Mechanism Followed by Mixed Farmers**

The table 5.12 summarizes the other risk mitigation mechanisms followed by mixed farmers. Farmers use various risk management strategies to mitigate the challenges they face in mixed farming.

Table 5.12 Other Risk Mitigation Mechanisms followed by Mixed Farmers

Risk Mitigation Mechanisms	Category	Frequency	Percent
Sale of Livestock	No	218	55.3
	Yes	176	44.7
	Total	394	100.0
Income from Livestock products	No	171	43.4
	Yes	223	56.6
	Total	394	100.0

Source: Primary Survey

The table 5.12 shows the sale of animals and revenue from livestock products are two risk mitigation strategies used by mixed farmers in addition to obtaining credit and insurance. If paddy yields are poor due to factors like drought, pest infestations, or floods, income from livestock can help offset these losses and provide financial stability.

➢ **Farm Diversification within the Mixed Farming System**

The table 5.13 shows farm diversification within the mixed farming system itself. Farm diversification means share of a single agricultural commodity that is paddy production or product from cattle rearing not greater than 66% of mixed farms' total value of production.

Table 5.13 Farm Diversification within the Mixed Farming System

Farm Diversification	Share of contribution	Frequency	Percent
Share of Paddy Production in the total production of Mixed Farming System	Less than 66	301	76.4
	Greater than 66	93	23.6
	Total	394	100.0
Share of Cattle Rearing in the total production of Mixed Farming System	Less than 66	201	51.0
	Greater than 66	193	49.0
	Total	394	100.0
Share of Cattle Rearing and paddy production in the total production of Mixed Farming System	Less than 66	109	27.7
	Greater than 66	285	72.3
	Total	394	100.0

Source: Primary Survey

From the table 5.13 it is clear that the share of paddy production in the total production of mixed farming system is greater than 66% for only 23.6 % of farmers. But for 76.4% of farmers the share is less than 66%. It is also evident from the table that the share of cattle rearing in the total production of mixed farming system is less than 66% for 51.0 mixed farmers. But for 49% mixed farmers the share is greater than 66%. The ideal mixed farmers are of 27.7% because the share of both paddy production and cattle rearing in the total value of production of mixed farming is below 66%.

➢ **On Farm Diversification in Mixed Farming System**

The table 5.14 indicates on farm diversification in mixed farming system. On-farm means activities related to the production of crops and livestock that take place on a farm other than paddy production and cattle rearing.

Table 5.14 On -Farm Diversification in Mixed Farming System

Share of on farm diversification in mixed farming system	Frequency	Percent
Nil	240	60.9
Less than 33	151	38.3
33-66	3	.7
Total	394	100.0

Source: Primary Survey

The table 5.14 shows the share of on farm diversification in mixed farming system. 60.9 of mixed farmers do not have on farm diversification. 38.3% of farmers have less than 33% share in mixed farming system. Only .7% of farmers have above 66% of share in mixed farming system.

➢ **Sustainability Level of Mixed Farming in terms of Risk Mitigation Mechanism in Mixed Farming System**

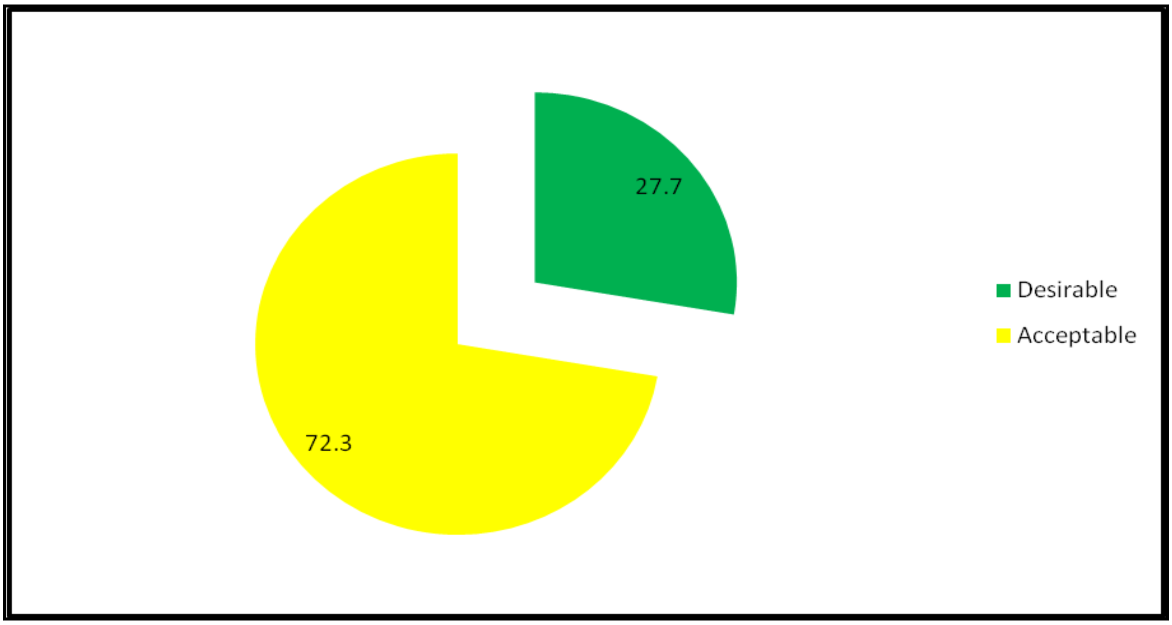
The table 5.15 highlights sustainability level of mixed farming in term of risk mitigation mechanism. On the basis of risk mitigation mechanism adopted by mixed farmers, sustainability level of mixed farms is classified as Desirable, Acceptable and Unsustainable.

Table 5.15 Sustainability Level of Mixed Farming in terms of Risk Mitigation Mechanism in Mixed Farming System

Sustainability Level	Frequency	Percent	Chi- Square Test	p value
Desirable	109	27.7	78.619	.000**
Acceptable	285	72.3		
Total	394	100.0		

** At 1% Level of Significance Source: Primary Survey

Figure 5.4 Sustainability Level of Mixed Farming in terms of Risk Mitigation Mechanism in Mixed Farming System



Source: Primary Survey

The table 5.15 and figure 5.4 summarizes the sustainability level of mixed farms regarding risk mitigation mechanisms. From the table and figure, it is clear that 72.3 % of mixed farms are classified as “Acceptable” while 27.7 % of mixed farms are classified as “Desirable”. Chi-square test for goodness of fit has been performed to examine whether there was any significant difference in the sustainability level of mixed farming in terms of risk mitigation mechanism. The results indicate that there is statistical significant difference in the sustainability level of mixed farming regarding risk mitigation mechanisms among mixed farmers, $\chi2$ = 78.619, p is .000 (Exact p-value). Hence it is inferred that the level of sustainability regarding risk mitigation mechanisms among mixed farmers are different in Palakkad district.

5.2.1.4 Economic Sustainability of Mixed Farming –Summary

The table 5.16 highlights the summary of economic sustainability. By combining the score of three sub indicators, the score of economic sustainability is computed. The three sub indicators of economic sustainability is farm output value per hectare, net farm income and risk mitigation methods of mixed farms. On the basis of economic sustainability, mixed farms is classified as desirable, acceptable and unsustainable

Table 5.16 Economic Sustainability-Summary

Sustainability Level	Frequency	Percent	Chi- Square	p value
Desirable	24	6.1	326.030	.000**
Acceptable	298	75.6		
Unsustainable	72	18.3		
Total	394	100.0		

** At 1% Level of Significance Source: Primary Survey

The table 5.16 summarizes the economic sustainability level of mixed farms. From the table it is clear that 75.6 % of mixed farms are classified as “Acceptable” while only 6.1 % of mixed farms are classified as “Desirable” and 18.3% of mixed farms are “Unsustainable”**.** Chi-square test for goodness of fit has been performed to examine whether there was any significant difference in the economic sustainability level of mixed farming. The results indicate that there is statistical significant difference in the economic sustainability level of mixed farming, $\chi2$ (2) = 326.030, p is .000 (Exact p-value). Hence it is inferred that the level of economic sustainability among mixed farmers are different in Palakkad district.

The null hypothesis (H0a) discussed earlier is acceptable because majority of the mixed farmers maintain an acceptable level of economic sustainability. This gives an insight that mixed farming maintains long term profitability resource use efficiency, reducing wastage and farm diversification.

5.2.2 Environmental Sustainability

The practice of meeting the requirements of the current generation without sacrificing the ability of future generations to provide for themselves is known as environmental sustainability. It involves managing natural resources in a way that ensures the long-term health of the planet's ecosystems, including land, water, air, and biodiversity. Environmental sustainability emphasizes the importance of reducing pollution, conserving resources, and maintaining ecological balance. The environmental sustainability is measured using the following indicators.

Table 5.17 Indicators of Environmental Sustainability

Sl No	Theme	Sub- indicator
1	Soil Health	Prevalence of Soil Degradation
2	Water Use	Variation in Water Availability
3	Fertilizer Pollution Risk	Management of Fertilizers
4	Pesticide Risk	Management of Pesticides
5	Biodiversity	Use of agro-Diversity-Supportive Practices

Source: FAO, 2020

The study presents a sub hypothesis which is outlined below

H0b: Mixed farmers maintain an acceptable level of environmental sustainability

5.2.2.1. Prevalence of Soil Degradation

The sub-indicator assesses how much soil health is impacted by mixed agricultural systems, which makes it a sustainability concern. The four threats are the focus of the study. They are soil erosion, reduction in soil fertility, salinization of irrigated land, excessive water logging and others.

The study has captured mixed farmers' knowledge regarding the condition of their paddy fields related to soil degradation. Mixed farmers are acutely aware of the condition and degree of soil degradation, as experience has shown. Mixed farmers have been given the chance to identify any other threats that affect the health of their soil in addition to being evaluated on their knowledge of common threats including water logging, salinization of irrigated land, soil erosion, and decreased soil fertility. This knowledge will help develop more practical methods for long-term soil health improvement and is important in the larger framework of soil management issues encountered in agricultural activities.

Sustainability criteria:

Proportion of agricultural area of the farm affected by soil degradation. (FAO, 2020)

Green (Desirable): Less than 10% of the farm's total area is affected by any one of the four threats to soil health.

Yellow (Acceptable): 10% to 50% of the farm's total area is affected by any of the four threats to soil health

Red (Unsustainable): Above 50% of the farm's total area is affected by any of the four threats to soil health

- **Prevalence of soil degradation**

The table 5.18 depicts prevalence of soil degradation in paddy fields. The study has identified four threats to soil health such as soil erosion, reduction in soil fertility, salinization of irrigated land, and excessive water logging.

Table 5.18 Prevalence of Soil Degradation

Response	**Soil Erosion**		**Reduction in soil fertility**		**Salinization of irrigated land**		**Excessive Water logging**	
Response	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent
No	379	96.2	377	95.7	374	94.9	337	85.5
Yes	15	3.8	17	5.3	20	5.1	57	14.5
Total	394	100.0	394	100.0	394	100.0	394	100.0

Source: Primary Survey

Soil erosion does not harm 96.2 % mixed farms, but it does affect 3.8% farms. Just 5.3% of mixed farms are impacted by a decline in soil fertility, compared to 95.7% that are not. While 5.1% of mixed farms are impacted by salinization of irrigated land, 94.9% of mixed farms are not. Excessive water logging does not affect 85.5 percent of mixed farms, but it does affect 14.5%. The main risk factor for soil deterioration is severe water logging.

Agricultural Area Affected by Soil Degradation: This variable measures the total area affected by any of the four threats to soil health. (FAO, 2020)

Share of agricultural area affected by any threat: This measures proportion of agricultural area affected by any of the threats to soil health. (FAO, 2020)

$$\textbf{Share of agricultural area affected by any threat: } \frac{\textbf{Agricultural area affected}_i}{\textbf{Agricultural Area of the holding}} * 100$$

Table 5.19 Average agricultural area affected by any threat

Average area affected by soil degradation	**Mean**	**Std. Deviation**
Average area	.821	.321

Source: Primary Survey

Amongst the mixed farmers who responded, there is prevalence of soil degradation, the average area affected by any of the four threats to soil health is .82 Hectares.

- **Sustainability Level of Mixed Farming in terms of Prevalence of Soil Degradation**

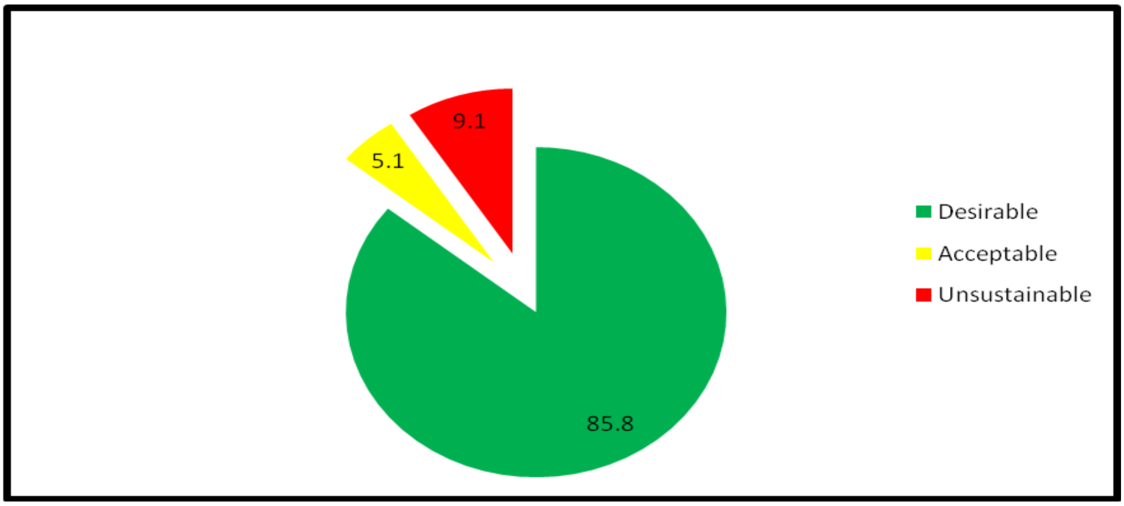
The table 5.20 highlights sustainability level of mixed farming in term of prevalence of soil degradation. On the basis of prevalence of soil degradation affected by mixed farmers, sustainability level of mixed farms is classified as Desirable, Acceptable and Unsustainable.

Table 5.20 Sustainability Level of Mixed Farming in terms of Prevalence of Soil Degradation

Sustainability Level	Frequency	Percent	Chi Square Test	P value
Desirable	338	85.8	488.792	.000**
Acceptable	20	5.1		
Unsustainable	36	9.1		
Total	394	100.0		

** At 1% Level of Significance Source: Primary Survey

Figure 5.5 Sustainability Level of Mixed Farming in terms of Prevalence of Soil Degradation



Source: Primary Survey

The table 5.20 and figure 5.5 illustrates the sustainability status of prevalence of soil degradation in mixed farming system. 85.8 % of mixed farms are classified as “Desirable,” while 5.1% are deemed “Acceptable” regarding prevalence of soil degradation. But 9.1% of mixed farms are operating at “Unsustainable” levels. Chi-square test for goodness of fit has been performed to examine whether there is any significant difference in the sustainability level of mixed farming in terms of prevalence of soil degradation. The results indicate that there is statistical significant difference in the sustainability level of mixed farming regarding prevalence of soil degradation among mixed farmers, $\chi 2 = 78.619$, p is .000 (Exact p-value). Hence it is inferred that the level of sustainability regarding prevalence of soil degradation among mixed farmers are different in Palakkad district.

5.2.2.2. Variation in Water Availability

The sub-indicator measures the extent the mixed farming contributes to water consumption patterns that are not sustainable. The sub-indicator illustrates the extent to which mixed farming practices result in unsustainable patterns of water use. Three layers of sustainability are linked to farmers' water shortage knowledge and activities, which are documented in the study. Whether the farmer uses water to irrigate crops on at least 10% of the farm's agricultural area and why, if the response is negative (does not need, cannot afford); whether the farmer is aware of the problems with water availability in the area and observes a decline in water availability over time; and whether there are organizations (water users organizations, others) are some examples of how these awareness and behaviour are expressed.

Sustainability criteria:

The following criteria are used to evaluate farm sustainability in respect to water use:

- Green (Desirable): At least 10% of the farm's agricultural land is used for crop irrigation and water availability has been consistent over time.
- Yellow (Acceptable): At least 10% of the farm's agricultural land is used for crop irrigation; it is unknown if water availability has remained constant or decreased over time; nonetheless, there is an organization that efficiently distributes water among users.
- Red (Unsustainable): in all other cases.

Irrigation Status of Agricultural Holdings

The table 5.21 indicates summary of mixed farms' dependency of irrigation for paddy cultivation.

Table 5.21 Irrigation Status of Agricultural Holdings.

Need for Irrigation	Frequency	Percent
yes	172	43.7
No, I do not require irrigation	222	56.3
No, I cannot afford to pay for irrigation.	0	0
No, there is no water available	0	0
Total	394	100.0

Source: Primary Survey

From the table 5.21 it is clear that 56.3% of mixed farms do not need irrigation. 43.7% of farms are irrigated.

- **Share of agricultural area irrigated**:

This variable measures the share of total agricultural area irrigated for crops.(FAO,2020)

Share of agricultural area irrigated = $\frac{\textbf{Total Agricultural Area Irrigated}_i}{\textbf{Agricultural area of the holding}}$ *100 (FAO,2020)

Table 5.22 Share of agricultural area irrigated

Agricultural Area Irrigated in Hectares	Mean	Std. Deviation
Average area	.25	.578

Source: Primary Survey

The average agricultural area irrigated for crops is 0.25 hectares, representing 28.95% of the total agricultural area. This statistic underscores the extent of irrigation practices in the region and their importance for crop production.

- **Observation of mixed farmers in relation to reduction in water availability from well or other sources**

The table 5.23 shows observation of mixed farmers in relation to reduction in water availability from well or other sources. Mixed farmers' views are crucial because they offer important insights into the difficulties associated with water availability. Their personal experiences aid in identifying important problems and guiding the development of plans for enhancing water management and guaranteeing sustainable agriculture.

Table 5.23 Observation of mixed farmers in relation to reduction in water availability from well or other sources

Variables	Frequency	Percent
No, there is enough water available when I need it.	245	62.2
Yes, my well's water level is decreasing steadily.	107	27.2
Yes, there is shortage of water in river, lake or canal and I can't have reliable supply when I need it	42	10.6
Total	394	100.0

Source: Primary Survey

Based on the survey data, it is evident that 62.2% of mixed farms reported that water is consistently available in sufficient quantities when needed. However, a significant concern arises as 27.2% of mixed farmers indicated that the water levels in their wells are progressively declining. Additionally, 10.6% of farmers expressed that water from rivers, lakes, or canals is becoming scarce, resulting in an unreliable supply when required. This data highlights critical challenges regarding water availability for mixed farming operations.

- **Farmers' awareness of the Water Users Organizations**

The table 5.24 highlights about farmers awareness regarding water management organizations. A Water Users Association (WUA) is a cooperative organization formed by individual water users who come together to manage water-related activities for their shared benefit. These associations operate on a user-driven and participatory approach to efficiently oversee water resources.

Table 5.24 Farmers' awareness about Water Users Organizations

Farmers' Awareness	Frequency	Percent
No there are none	272	69.0
Yes, they are working well	71	18.0
I don't know	3	.8
Yes, they are not working well	48	12.2
Total	394	100.0

Source: Primary Survey

Based on the survey data 69% of farmers have reported that there are no such organizations dealing with water allocation. 18% of mixed farmers have indicated that there are water user organizations in their area and they are working well. 12.2% of farmers have indicated that there is water user organization, but they are not working well. .8% has reported about their lack of awareness regarding water user organization.

➢ **Sustainability Level of Mixed Farming in terms of Variation in Water availability**

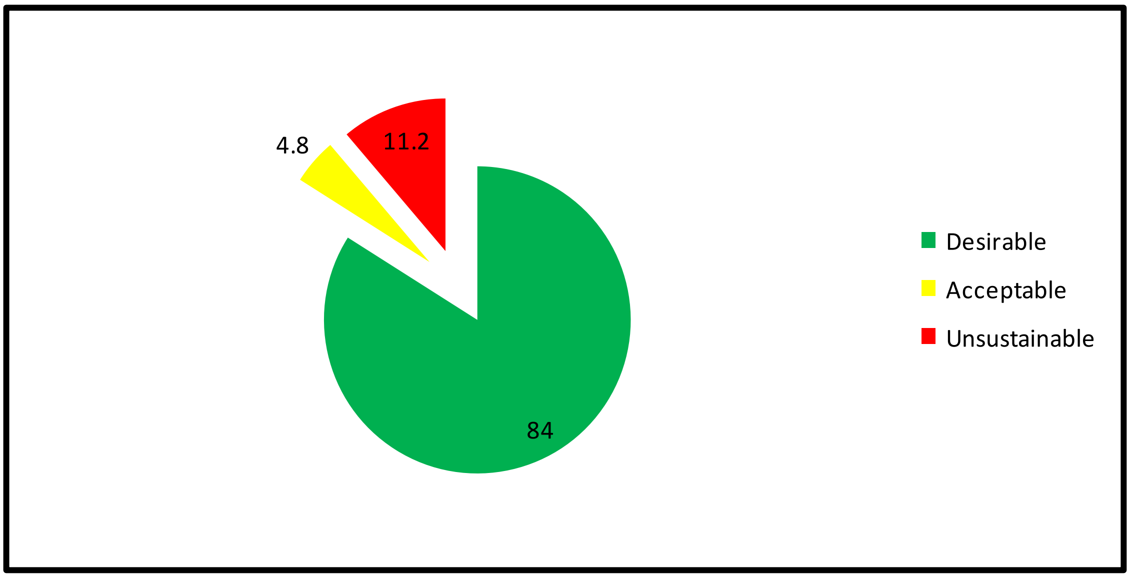
The table 5.25 highlights sustainability level of mixed farming in term of variation in water availability. On the basis of variation in water availability affected by mixed farmers, sustainability level of mixed farms is classified as Desirable, Acceptable and Unsustainable.

Table 5.25 Sustainability Level of Mixed Framing in terms of Variation in Water availability

Sustainability Level	Frequency	Percent	Chi Square	P value
Desirable	331	84.0	457.711	.000**
Acceptable	19	4.8		
Unsustainable	44	11.2		
Total	**394**	**100.0**		

**At 1% level of significance Source: Primary Survey

Figure 5.6 Sustainability Level of Mixed Framing in terms of Variation in Water availability



Source: Primary Survey

The table 5.25 and figure 5.6 shows the sustainability status of variation in water availability in mixed farming system. 84% of mixed farms are classified as "Desirable" while 4.8% are deemed "Acceptable" regarding variation in water availability. But 11.2 farms are operating at "Unsustainable" level. Chi-square test for goodness of fit has been performed to examine whether there is any significant difference in the sustainability level of mixed farming in terms of variation in water availability. The results indicate that there is statistical significant difference in the sustainability level of mixed farming regarding variation in water availability among mixed farmers, $\chi2 = 457.711$, p is .000 (Exact p-value). Hence it is inferred that the level of sustainability regarding variation in water availability among mixed farmers are different in Palakkad district.

5.2.2.3 Management of Fertilizers

The study involves surveying farmers about their fertilizer usage, with a particular emphasis on mineral or synthetic fertilizers. Their knowledge of the environmental hazards connected to the use of these fertilizers and manures, as well as mixed farmers' methods for managing plant nutrients, is evaluated by the study.

➢ **Sustainability Criteria**

Green (Desirable): The mixed farm uses fertilizers and takes at least six specific measures to mitigate environmental risks associated with their use.

Yellow (Acceptable): The mixed farm uses fertilizers and takes at least four measures to mitigate environmental risk associated with their use.

Red (Unsustainable): The mixed farm uses fertilizer and does not take any of the specific measures to mitigate environmental risks associated with their use.

Table 5.26 Usage of Fertilizers and Awareness of the environmental risks associated with excessive /misuse of fertilizer

Variables		Frequency	Percent
Usage of Fertilizers	Yes	394	100.0
	No	0	0
	Total	394	100.0
Awareness of mixed farmers about the environmental risks associated with excessive /misuse of fertilizer	Yes	394	100.0
	No	0	0
	Total	394	100.0

Source: Primary Survey

The table 5.26 clearly indicates that all mixed farmers surveyed utilize fertilizers in their agricultural practices. This finding highlights the widespread reliance on fertilizers within the farming community.

- **Farmers Usage of Fertilisers**

The table 5.27 illustrates farmers' usage of fertilizers. The major fertilisers used by the farmers are Phosphorous Fertilizer, Nitrogen Fertilizer and Potassium Fertilizer.

Table 5.27 Farmers' usage of fertilizers

Name of Fertilizer		Frequency	Percent
Phosphorous Fertilizer	No	24	6.1
	Yes	370	93.9
	Total	394	100.0
Nitrogen Fertilizer	No	15	3.8
	Yes	379	96.2
	Total	394	100.0
Potassium Fertilizer	No	39	9.9
	Yes	355	90.1
	Total	394	100.0
Nitrogen and Sulfur containing Fertilizer	No	385	97.7
	Yes	9	2.3
	Total	394	100.0
Others	No	385	97.7
	Yes	9	2.3
	Total	394	100.0

Source: Primary Survey

From the table 5.27 it is clear that three fertilizers such as Phosphorous Fertilizer, Nitrogen Fertilizer and Potassium Fertilizer are widely used by farmers. Farmers often use a combination of these fertilizers to meet the specific nutrient needs of paddy crops, taking into account soil conditions and local agricultural practices. Proper nutrient management is essential for optimizing crop productivity and ensuring sustainable agricultural practices.

- **Measures to mitigate environmental risks due to excessive use of fertilizers**

The table 5.28 indicates the measures adopted by farmers to mitigate environmental risks due to excessive use of fertilizers.

Table 5.28 Measures to mitigate environmental risks due to excessive use of fertilizers

Measures		Frequency	Percent
Follow retail outlet directions while applying fertilizers in paddy fields not exceeding suggested doses	No	29	7.4
	Yes	365	92.6
	Total	394	100.0
Use organic manure alone or in combination with chemical fertilizers in paddy cultivation	No	29	7.4
	Yes	365	92.6
	Total	394	100.0
Growing Cover crops	No	275	69.8
	Yes	119	30.2
	Total	394	100.0
Application of mineral fertilizer over the growing period in paddy cultivation	No	43	10.9
	Yes	351	89.1
	Total	394	100.0
Consider soil type and climate in deciding fertilizer application and doses in paddy cultivation	No	44	11.2
	Yes	350	88.8
	Total	394	100.0
Soil testing of paddy fields during 5 years	No	137	34.8
	Yes	257	65.2
	Total	394	100.0
Planting of perennial plants to reduce water runoff from fields including loss of pesticides and fertilizers	No	128	32.5
	Yes	266	67.5
	Total	394	100.0
Liming of soil	No	40	10.2
	Yes	354	89.8
	Total	394	100.0

Source: Primary Survey

It is evident from the table 5.28 that 92.6 % of respondents adopt the measures like usage of mineral fertilizer along with manure and recommended doses of mineral fertilizers are applied by the farmers. Next important measure adopted by farmers to mitigate environmental risks is liming of soil. 88.8 % of farmers consider soil type and climate in deciding fertilizer application and doses. Planting of cover crops and soil testing are the two measures least adopted by the farmers for the management of fertilizers.

➢ **Sustainability level of Mixed Farming in terms of Management of Fertilizers**

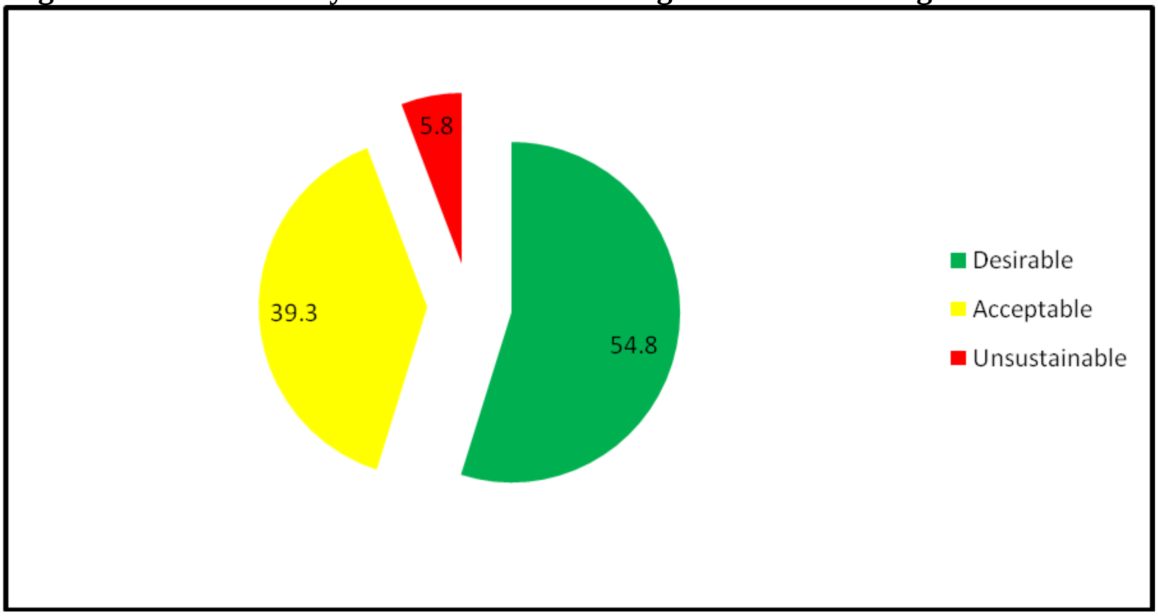
The table 5.29 highlights sustainability level of mixed farming in term of management of fertilizers. On the basis of management of fertilizers by mixed farmers, sustainability level of mixed farms is classified as Desirable, Acceptable and Unsustainable.

Table 5.29 Sustainability level of Mixed Farming in terms of Management of Fertilizers

Sustainability level	Frequency	Percent	Chi Square	P value
Desirable	216	54.8	148.208	.000**
Acceptable	155	39.3		
Unsustainable	23	5.8		
Total	**394**	**100.0**		

** At 1% level of significance Source: Primary Survey

Figure 5.7 Sustainability level of Mixed Farming in terms of Management of Fertilizers



Source: Primary Survey

The table 5.29 and figure 5.7 shows the sustainability status of management of fertilizers in mixed farming system. 54.8% of mixed farms are classified as **"Desirable"** while 39.3% are deemed "Acceptable" regarding management of fertilizers. But 5.8% farms are operating at "Unsustainable" level. Chi-square test for goodness of fit has been performed to examine whether there was any significant difference in the sustainability level of mixed farming in terms of management of fertilizers. The results indicate that there is statistical significant difference in the sustainability level of mixed farming regarding management of fertilizers among mixed farmers, $\chi2 = 148.208$, p is .000 (Exact p-value). Hence it is inferred that the level of sustainability regarding management of fertilizers among mixed farmers are different in Palakkad district.

5.2.2.4 Management of Pesticides

The use of pesticides on farms, the kind of pesticide used, and the type of measure or measures taken by mixed farmers to reduce the risks involved are the basis of the sub-indicator.The study examines the various pesticides used by mixed farmer and measure adopted by farmers to mitigate the environmental and health risks involved in the use of pesticides.

Sustainability criteria:

The following criteria will be used to evaluate mixed farm sustainability in respect to pesticides:

Green (Desirable): Farmers use only moderately hazardous or slightly hazardous pesticides but not restricted pesticides and takes at least four environmental-related measures and three health-related measures associated with the use of pesticides.

Yellow (Acceptable): Farmers employs slightly hazardous pesticides but at the same time they are restricted pesticides and follow at least four environmental-related measures and all three health-related measures.

Red (Unsustainable): Farmers employs moderately hazardous pesticides but at the same time they are restricted pesticides even though farmers follow at least four environmental-related measures and all three health-related measures.

- **Usage of Pesticides**

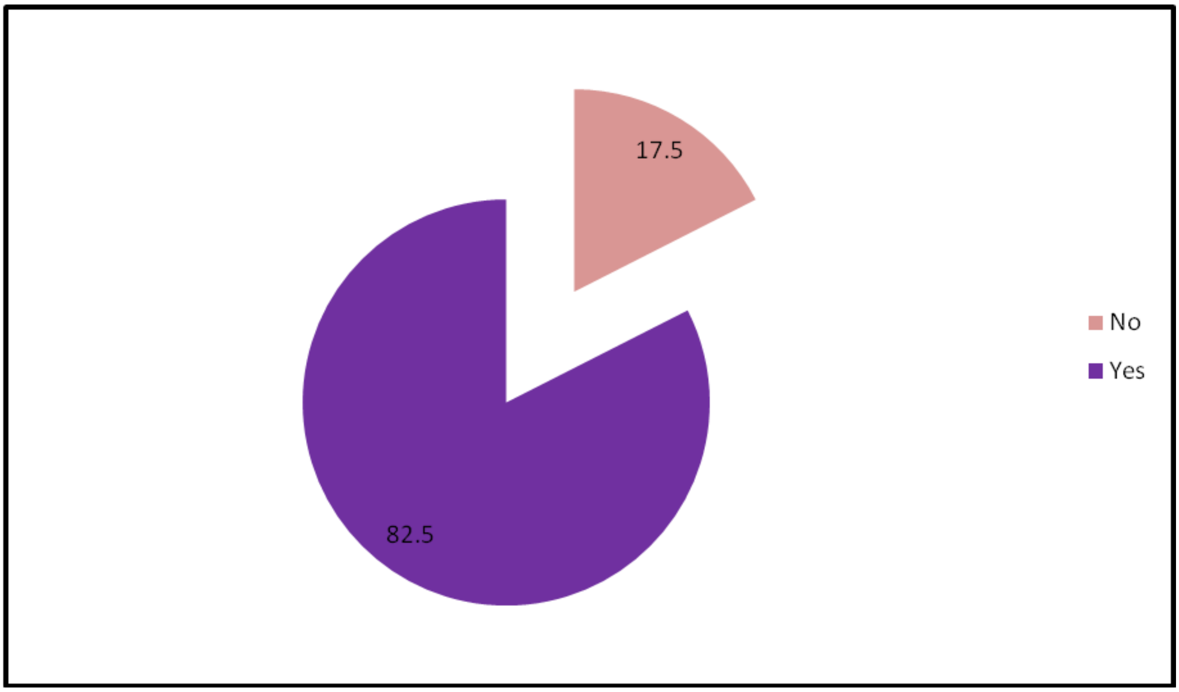
The table 5.29 illustrates the use of pesticides by farmers for crop production. The use of pesticides in agriculture is necessary for protecting crops from pests, diseases, and weeds, which can otherwise severely reduce yield and quality. Insecticides, herbicides, and fungicides are the pesticides used to ensure more productive and healthy crops. However, their widespread use raises concerns about environmental impacts and health risks. Additionally, improper or excessive use of pesticides can threaten long-term agricultural sustainability. Therefore, the use of pesticides must be carefully managed to balance effective pest control with environmental and public health protection.

Table 5.30 Usage of Pesticides for crop production by the agricultural holding

Category	Frequency	Percent
No	69	17.5
Yes	325	82.5
Total	**394**	**100.0**

Source: Primary Survey

Figure 5.8 Usage of Pesticides for crop production by the agricultural holding



Source: Primary Survey

The table 5.30 and figure indicates that 82.5 % of farmers use pesticides in paddy production while 17.5% of farmers do not use pesticides for paddy production

- **Types of Pesticides for crop production by the agricultural holding**

The pesticides used by farmers are classified on the basis of WHO classification. According to WHO, pesticides are classified into extremely hazardous(Class Ia), Highly hazardous(Class Ib), Moderately hazardous(Class II), Slightly hazardous (ClassI) and Unlikely to present acute hazard (Class U). The study has made another classification such as restricted and not restricted based on list of pesticides which are banned, refused registration and restricted in use in India.

Table 5.31 Types of Pesticides for crop production by the agricultural holding

Types of Pesticides	**Frequency**	**Percent**
Moderately Hazardous and Restricted	211	53.6
Slightly Hazardous and Restricted	11	2.8
Moderately Hazardous	48	12.2
Slightly Hazardous	55	14.0
No pesticide	69	17.5
Total	394	100.0

Source: Primary Survey

The data on table 5.31 exhibits the classification of pesticide usage based on its hazard level and restriction status. The majority of the pesticides fall under the category of "Moderately Hazardous and Restricted," accounting for 53.6% of the total. This suggests that a significant portion of pesticide use is moderately hazardous and restricted pesticides. Other categories, such as "Moderately Hazardous" (12.2%) and "Slightly Hazardous" (14%), represent a smaller but still significant proportion of pesticide use, indicating various levels of risk. The "Slightly Hazardous and Restricted" category forms only 2.8%, showing that fewer pesticides in use are both slightly hazardous and restricted in application. Interestingly, 17.5% of the mixed farmers report no pesticide usage, implying a proportion of environments or cases where pesticide application is either not required or avoided. This is a positive indicator for environments focused on sustainability or minimizing chemical intervention. Chloropyrifos, cypermethrin, and karate are examples of moderately hazardous class II and restricted pesticides. Malathion is recognized as a restricted and slightly hazardous insecticide. Gambhir and Ekalux are moderately hazardous. Aatrex is one pesticide that is slightly hazardous.

- **Health measures adopted by farmers while applying pesticides.**

The table 5.32 illustrates health measures adopted by farmers to mitigate the health risks associated with use of pesticides. Farmers adopt various measures to protect the health and thereby reduce the adverse effect on human health and ecosystems

Table 5.32 Health measures adopted by farmers while applying pesticides.

Measures		Frequency	Percent
Follow label Directions	No	37	11.4
	Yes	288	88.6
	Total	325	100.0
Cleaning of equipment after use	No	51	14.1
	Yes	274	85.9
	Total	325	100.0
Safe Disposal of waste	No	8	2.5
	Yes	317	97.5
	Total	325	100.0
Cover head	No	20	6.2
	Yes	305	93.8
	Total	325	100.0
Protect mouth by using mask	No	18	5.5
	Yes	307	94.5
	Total	325	100.0
Wear gloves	No	14	4.3
	Yes	311	95.6
	Total	325	100.0
Wash hands with soap	No	13	4
	Yes	312	96
	Total	325	100.0
Wash body	No	3	.9
	Yes	322	99.1
	Total	325	100.0
Prevent animals going into sprayed area	No	12	3.7
	Yes	313	96.3
	Total	325	100.0

Source: Primary Survey

The replies from farmers about the steps they have taken to reduce the health hazards connected to pesticide use are compiled in the table 5.32. When using pesticides, 88.6% of farmers adhere to the label's instructions. Following the application of pesticides, 85.9% of farmers sanitize the equipment. 97.5% of farmers dispose of pesticide waste in a safe manner. The majority of farmers—93.8%—cover their heads when using insecticides. 95.6% of farmers use gloves, while 94.5% wear masks. 96.4% of farmers wash their hands with soap after handling insecticides on the farm. After using pesticides, 99.1% of farmers wash their bodies. 96.3%of farmers keep animals out of sprayed areas.

- **Measures adopted to avoid environmental risks associated with pesticides**

The table 5.33 illustrates measures adopted by farmers to reduce the environmental risks associated with use of pesticides Farmers adopt various measures to protect the environment and these measures are crucial for maintaining sustainable mixed farming system.

Table 5.33 Measures adopted to avoid environmental risks associated with pesticides

Measures		Frequency	Percent
Follow label directions	No	35	10.8
	Yes	290	89.2
	Total	325	100.0
Adjustment of planting time	No	12	3.7
	Yes	313	96.3
	Total	325	100.0
Appropriate timing of pesticide application	No	9	2.8
	Yes	316	97.2
	Total	325	100.0
Timely removal of weeds	No	17	5.2
	Yes	308	94.8
	Total	325	100.0
Planting pest tolerant varieties	No	30	9.2
	Yes	295	90.8
	Total	325	100.0
Correct dose of appropriate pesticide	No	10	3.1
	Yes	315	96.9
	Total	325	100.0
Balanced doses of fertilizers	No	14	4.3
	Yes	311	95.7
	Total	325	100.0
Application of crop spacing	No	22	6.8
	Yes	303	93.2
	Total	325	100.0
Application of crop rotation	No	134	41.2
	Yes	191	58.8
	Total	325	100.0
Biological pest control	No	252	77.5
	Yes	73	22.5
	Total	325	100.0
Bio- pesticides	No	257	79.1
	Yes	68	20.9
	Total	325	100.0
Adopting pasture rotation	No	83	25.5
	Yes	242	74.5
	Total	325	100.0
Systematic removal of plant parts attacked by pests	No	28	8.6
	Yes	297	91.4
	Total	325	100.0
Pest monitoring	No	14	4.3
	Yes	311	95.7
	Total	325	100.0
Use one pesticide not more than two times	No	161	49.5
	Yes	164	50.5
	Total	325	100.0

Source: Primary Survey

This table 5.33 summarizes the responses of farmers regarding the measures adopted by them to mitigate environmental risks associated with use of pesticides. 89.2% of farmers follow label directions while applying pesticides. 96.3 % of farmers adjust their planting time to reduce crop damage by disrupting pest life cycle. 97.2% of farmers apply pesticides in appropriate time. 94.8% of farmers remove weeds, which are undesirable plants that grow along with crops that reduce the use of chemicals to kill weeds. Pest tolerant varieties are planted by 90.8% farmers. The correct doses of pesticide are applied by 96.9% farmers. The appropriate doses of fertilizers are applied along with the use of pesticides by 95.7 % farmers. Crop spacing and crop rotation are practiced by 93.2 and 58.8 farmers respectively. Biological pest control methods are used by only 22.5% farmers and only 20.9% of farmers use bio pesticides to control pests. Pasture rotation which interrupts life cycle of pests are adopted by74.5% farmers. Pest monitoring and systematic removal of plant parts affected by pests are practiced by 95.7% and 91.4 % farmers respectively. 50.5% of farmers apply pesticides not more than two times.

➢ **Sustainability level of Mixed Farming in terms of Management of Pesticides**

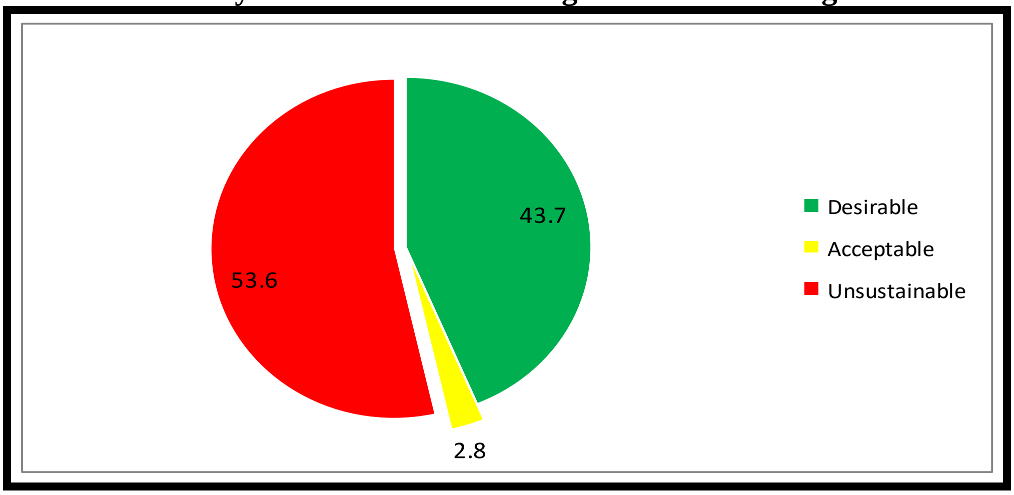
The table 5.34 highlights sustainability level of mixed farming in term of management of pesticides. On the basis of management of pesticides by mixed farmers, sustainability level of mixed farms is classified as Desirable, Acceptable and Unsustainable.

Table 5.34 Sustainability level of Mixed Farming in terms of Management of Pesticides

Sustainability Level	Frequency	Percent	Chi-square Test Results	P value
Desirable	94	43.7	196.848	.000
Acceptable	41	2.8		
Unsustainable	211	53.6		
Total	394	100.0		

Source: Primary Survey

Figure 5.9 Sustainability level of Mixed Farming in terms of Management of Pesticides



Source: Primary Survey

The table 5.34 and figure 5.9 summarizes the sustainability status of mixed farming in terms of management of pesticides. 53.6% of farms are classified as “Unsustainable” and 43.7 % of farms are classified as “Desirable”. Only 2.8 % farms are deemed as “Acceptable”. Chi-square test has been performed to examine whether there was any significant difference in the sustainability level of management of pesticides. The results indicate that there is statistical significant difference in the sustainability level of management of pesticides among mixed farmers, $\chi2 = 196.848$, $p < .000$ (Exact p-value). Hence it is inferred that the level of sustainability regarding management of pesticides among farmers are different in Palakkad district.

5.2.2.5 Use of agro-biodiversity-supportive practices

The sub-indicator measures how much the mixed farm has embraced more environmentally friendly farming methods that enhance biodiversity at the species, ecological, and genetic levels. This indicator addresses both crops and livestock in mixed farming system. In particular, the reference area for this sub-indicator is the complete farm holding, as opposed to the mixed farming area used for the other ten sub indicators.

- **Criteria for assessing bio diversity practices in mixed farming system**

1. At least 10% of the holding area is left for or surrounded by natural or diverse vegetation to support biodiversity.
2. Organically certified products are produced by the farm
3. No antimicrobials is used by the farmer as growth promoters
4. At least two of the following contribute to mixed farm production: 1) temporary crops, 2) pasture, 3) permanent crops, 4) trees on farm, 5) livestock or animal products, and 6) aquaculture.
5. Crop or crop/ pasture rotations is practiced by the farmer.
6. Locally adapted breeds of livestock are reared by the farmer.

Sustainability status:

Green (Desirable): At least three of the above requirements are met by the mixed farm

Yellow (Acceptable): At least two of the above requirements are met by the mixed farm

Red (Unsustainable): No above requirement is met by the mixed farm

Number of farms covered by natural vegetation

The extent of mixed farming area covered by natural vegetation plays an important role in maintaining biodiversity and ecosystem health. It reflects the extent to which mixed farming area are integrated with natural habitats, supporting both conservation and sustainable farming practices.

Table 5.35 Number of farms covered by natural vegetation

Sl No	Natural vegetation	Frequency	Percent
1	Number of farms covered by natural pasture or grasslands	182	46.2
2	Wildflower strips	63	16
3	Stone or wood heaps	47	11.9
4.	Trees	71	18
5	Natural ponds or wetlands	124	31.5

Source: Primary Survey

The table 5.35 indicates farms covered by natural vegetation. The natural vegetation is classified as natural pasture or grasslands, wildflower strips, stone or wood heaps, trees natural ponds or wetlands. 46.2 farms are covered by pasture or grasslands. 16% of farms are covered by wildflower strips, stone or wood heaps, trees and natural ponds or wetlands.

- **Usage of antimicrobials and growth promoters by mixed farms**

The usage of antimicrobials and growth promoters in cattle farming is aimed at improving animal growth rates and preventing infections in cattle. However, overuse or misuse of these substances in cattle can lead to endangering animal and human health.

Table 5.36 No of farms using antimicrobials

Sl No	Number of farms using antimicrobials growth promoters	Frequency	Percent
1	Yes	0	0
2	No	394	100.0

Source: Primary Survey

From the table 5.36 it is clear that no farms are using antimicrobials growth promoters. This may reflect a growing awareness of the potential risks associated with such substances and a shift towards more sustainable and health-conscious approaches to cattle management in mixed farming.

- **Number of farms with organic certification**

The process by which farms and goods are formally acknowledged as fulfilling accepted organic farming standards is known as organic certification. It promotes environmental sustainability and consumer health by guaranteeing that the food is produced without the use of artificial pesticides, fertilizers, or genetically modified organisms.

Table 5.37 Number of farms with organic certification

Sl No	Number of farms have organic certification	Frequency	Percent
1	Yes	0	0
2	No	394	100.0

Source: Primary Survey

No farms are organically certified, as can be seen from the table 5.37, suggesting that the mixed farms have lack of certification. This raises the possibility of gap in organic farming practices in mixed farming system or may have not applied for certification.

- **Practice of crop rotation**.

  The table 5.38 highlights the practice of crop rotation in mixed farming system. That means paddy crop is supported by cover crops, pasture, tree products in a year. These complementary practices in mixed farming system help improve soil fertility, prevent erosion, and support biodiversity, contributing to more sustainable and resilient mixed farming systems.

Table 5.38 Practice of crop rotation

	N	Mean	Std. Deviation
Value of output of temporary crops in a year	394	925.13	2248.008
Value of output of pasture in a year	394	666.24	2313.453
Value of output of tree products in a year	394	2752.54	18444.375
Total value of on farm activities in a year	394	4343.91	18670.75453

Source: Primary Survey

The table 5.38 shows the contribution of other farm activities to income of the farmer, that is the value of output produced other than paddy cultivation and cattle rearing by the mixed farmer. The average value of output of temporary crops in a year of a mixed farmer is ₹925.13 and value of pasture in a year is ₹666.24. The average value of output of tree products in a year is ₹2752.54. The average value of all on farm activities in a year of a mixed farmer is ₹4343.91.

- **Number of farms includes livestock of locally adapted breeds**

The number of farms includes those that raise livestock of locally adapted breeds, which are better suited to the local environment and climate. These breeds tend to be more resilient, requiring fewer resources and offering greater sustainability in farming systems.

Table 5.39 Number of farms includes livestock of locally adapted breeds.

Category	Frequency	percent
No	355	90.1
Yes	39	9.9
Total	394	100.0

Source: Primary Survey

From the table 5.39 it is clear that only 9.9 farms have livestock of locally adapted breeds. Only a few mixed farms have local breeds, it may be because these breeds are perceived as less profitable compared to higher-yielding, international breeds. Farmers might prefer breeds that offer quicker returns or better market value, leading to limited adoption of locally adapted livestock.

- **Sustainability Level of Mixed Farming in terms of Use of Agro- Biodiversity Practices**

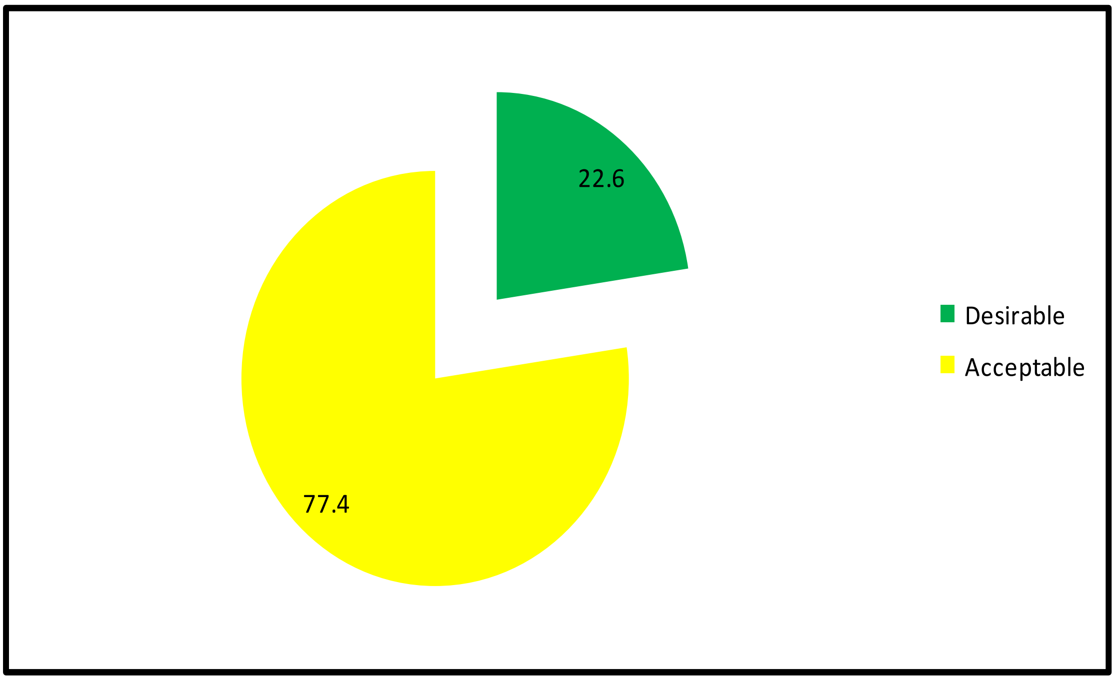
The table 5.40 highlights sustainability level of mixed farming in terms of use of agro-biodiversity practices. In the above tables, five criteria have been mentioned and one more criteria to assess use of agro-biodiversity practices in mixed farming system is atleast two agricultural activity have to be contributed to mixed farm production. This is clear from the table 5.3. On the basis of use of agro-biodiversity practices by mixed farmers, sustainability level of mixed farms is classified as desirable, acceptable and unsustainable

Table 5.40 Sustainability Level of Mixed Farming in terms of Use of Agro- Biodiversity Practices

Sustainability Level	Frequency	Percent	Chi Square	P value
Desirable	89	22.6	118.416	.000**
Acceptable	305	77.4		
Total	394	100.0		

** At 1% level of significance Source: Primary Survey

Figure 5.10 Sustainability Level of Mixed Farming in terms of Use of Agro- Biodiversity Practices



Source: Primary Survey

The table 5.40 and figure 5.10 summarizes the sustainability level of mixed farming system in terms of use of agro biodiversity practices. From the table and figure it is clear that 77.4% of mixed farms are classified as "Acceptable" and 22.6% of mixed farms are deemed as "Desirable". Chi-square test has been performed to examine whether there was any significant difference in the sustainability level of mixed farming in terms of use of agro biodiversity practices. The results indicate that there is statistical significant difference in the sustainability level of mixed farming in terms of use of agro biodiversity practices among mixed farmers, $\chi 2$ = 118.416, p value is .000. Hence it is inferred that the level of sustainability regarding use of agro biodiversity practices among farmers are different in Palakkad district.

5.2.2.6 Environmental Sustainability of Mixed Farming –Summary

The table 5.41 highlights the summary of environmental sustainability. On the basis of environmental sustainability, mixed farms is classified as Desirable, Acceptable and Unsustainable

Table 5.41 Environmental Sustainability-Summary

Sustainability Level	Frequency	Percent	Chi- Square	p value
Desirable	164	41.6	76.528	.000**
Acceptable	50	12.7		
Unsustainable	180	45.7		
Total	394	100.0		

** At 1% Level of Significance Source: Primary Survey

The table 5.41 summarizes the environmental sustainability level of mixed farms.. From the table it is clear that 41.6% of mixed farms are classified as “Acceptable” while only 12.7% of mixed farms are classified as “Desirable” and 45.7% of mixed farms are “Unsustainable”. Chi-square test for goodness of fit has been performed to examine whether there was any significant difference in the environmental sustainability level of mixed farming. The results indicate that there is statistical significant difference in the environmental sustainability level of mixed farming, $\chi 2$ =76.528, p is .000 (Exact p-value). Hence it is inferred that the level of environmental sustainability among mixed farmers are different in Palakkad district.

The null hypothesis (H0b) discussed earlier is rejected because majority of the mixed farmers are at unsustainable level of environmental sustainability. This unsustainability is due to excessive pesticide use which leads to long term environmental challenges and threatens long term sustainability of mixed farming.

5.2.3 Social sustainability

Social sustainability of farming refers to practices and strategies that ensure farming systems contribute to the well-being, equity, and quality of life for individuals and communities. It focuses on creating fair, inclusive, and supportive conditions for farmers, workers, and local communities while maintaining the long-term viability of mixed farming practices. Social Sustainability is measured under three heads.

Table 5.42 Indicators of Social Sustainability

Sl No	Theme	Sub- indicator
1	Decent Employment	Wage rate in mixed farming system
2	Food Security	Food Insecurity Experience Index
3	Land tenure	Secure tenure rights to land

Source: FAO, 2020

Under the social sustainability the sub indicators used are wage rate in mixed farming system, Food Security Experience Index and secure land tenure rights to land. The study presents a sub hypothesis which is outlined below

H0c: Mixed farmers maintain an acceptable level of social sustainability

5.2.3.1 Wage Rate in Mixed Farming System

To assess the social sustainability of agricultural holdings within a mixed farming system, the wage rate serves as a critical indicator of economic risks faced by agricultural workers. This measure compares remuneration against the minimum national wage, distinguishing between holdings that provide fair compensation to employees and those that fall short. Mixed farms offering wages below the minimum wage are classified as unsustainable; as such compensation fails to guarantee a decent standard of living for the workers.

- **Agricultural worker**: "Agricultural Worker" means a person who works as a labourer on being hired or works in exchange, whether in cash or kind or partly in cash and partly in kind, in any of the agricultural or related operations of an employer, farmer or other person.(The Agricultural and Other Rural Workers (Protection And Welfare) Bill, 2018
- **Daily wage rate of agricultural worker** $= \frac{\text{Total Annual Compensation}}{\text{Total Annual Hours Worked}} * 8$ (FAO, 2000)
- **Compensation**: Monetary and in kind payments made to agricultural worker expressed in Rupees.(FAO,2020)
- **Un-Skilled Work:** The work which involves simple operation, requiring little or no skill or expertise in the job.
- **National minimum wage rate** (**Rates of Wages including V.D.A per day (in Rs.)**: Rs.449 (1.03.2024) for unskilled workers in Area C. Palakkad belongs to Area C.(Government Order, Ministry of Labour and Employment dated 01.03.2024)

Sustainability criteria: Wage rate of male and female agricultural worker in relation to national minimum wage rate.

Green (Desirable): If the wage rate paid to male and female agricultural worker is above the minimum national wage rate

Yellow (Acceptable): If the wage rate paid to male and female agricultural worker is equals to the minimum national wage rate

Red (Unsustainable): If the wage rate paid to male and female agricultural worker is below the minimum national wage rate.

- **Wage Rate in Mixed Farming System**

From the study it is understood that agricultural workers are hired for paddy cultivation only. No workers are hired for cattle rearing. It is done by family itself. The family members handle all aspects of cattle rearing, including feeding, milking and healthcare. This method followed in mixed farming system suggests a more traditional farming practice, where labour is provided internally rather than relying on external workers.

Table 5.43 Wage Rate in Mixed Farming System- Descriptive Statistics

Variables	Mean	Std. Deviation
Full time working hours (in Hours)	6.20	0.54
Daily average wage for male agricultural worker (in ₹)	760.61	125.19
Daily average wage for female agricultural worker (in₹)	467.23	93.06
Average Annual compensation for male agricultural worker (in ₹)	11218.24	14069.96
Average Annual compensation for female agricultural worker (in ₹)	21047.64	28536.21
Average Annual hours of male agricultural worker (in Hours)	94.86	121.51
Average annual hours of female agricultural worker (in Hours)	299.76	452.25
Daily average wage of male agricultural worker (Standardized into 8 hours) (in ₹)	887.19	347.49
Daily average wage of female agricultural worker (Standardized into 8 hours) (in ₹)	574.23	172.97

Source: Primary Data

The data in the table 5.43 indicates that the average full-time working hours for agricultural workers is 6.20 hours per day. The daily average wage for male agricultural workers is Rs. 760.61, while for female agricultural workers, it is Rs. 467.23. The average annual compensation paid by the farm for male agricultural workers amounts to Rs. 11,218.24, whereas female agricultural workers receive an average annual compensation of Rs. 21,047.64.

When analyzing the average annual hours worked, male agricultural workers contribute approximately 94.86 hours, in contrast to 299.76 hours for female agricultural workers. When standardizing the working hours to an 8-hour day, the adjusted daily average wage for male agricultural workers rises to Rs. 887.19, while the adjusted daily average wage for female agricultural workers increases to Rs. 574.23

- **Sustainability Level of Mixed Farming in terms of Wage rate in mixed farming system**

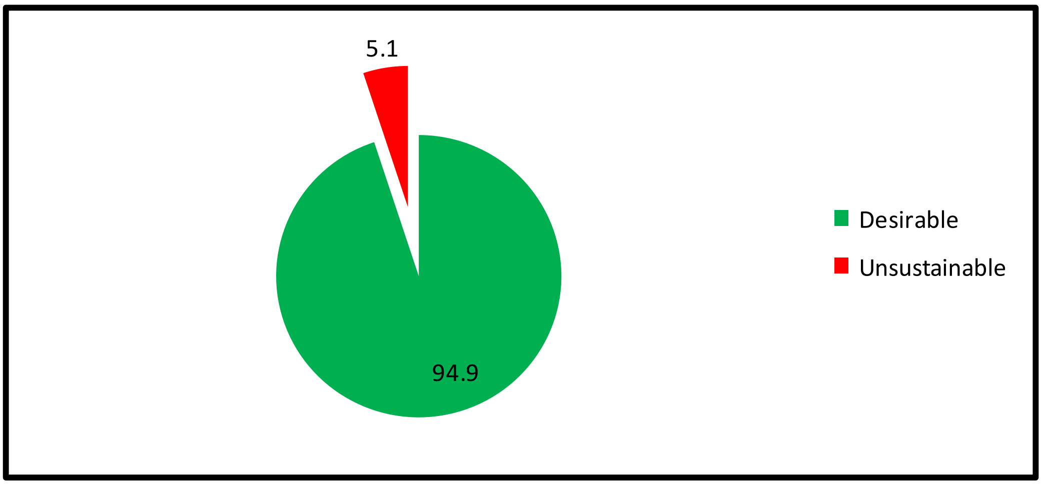
The table 5.44 highlights sustainability level of mixed farming in terms of wage rate in mixed farming system. On the basis of wage rate in mixed farming system, sustainability level of mixed farms is classified as desirable, acceptable and unsustainable

Table 5.44 Sustainability Level of Mixed Farming in terms of Wage rate in mixed farming system

Sustainability Level	Frequency	Percent	Chi square	P value
Desirable	374	94.9	318.061	.000**
Unsustainable	20	5.1		
Total	394	100.0		

** At 1% level of significance Source: Primary Data

Figure 5.11 Sustainability Level of Mixed Farming in terms of Wage rate in Mixed Farming System



Source: Primary survey

The table 5.44 presents the sustainability status of mixed farming operations based on the wage rate indicator within the mixed farming system. It reveals that 94.9% of these farms are classified as "Desirable," while 5.1% are deemed "Unsustainable" regarding wage rates. This unsustainability is attributed to the fact that female agricultural workers on these 5.1% of farms receive wages that fall below the national minimum wage rate. Chi-square test has been performed to examine whether there was any significant difference in the sustainability level of mixed farming in terms of in terms of wage rate. The results indicate that there is statistical significant difference in the sustainability level of mixed farming in terms of wage rate among mixed farmers, $\chi 2$ = 318.061, $p < .000$ (Exact p-value). Hence it is inferred that the level of sustainability regarding wage rate among farmers are different in Palakkad district

- **Variation in daily wage rate of female agricultural workers**

The table 5.45 depicts variation in daily average wage rate of female agricultural works. This variation often reflects disparities in gender pay, with women frequently earning lower wages compared to their male counterparts for similar tasks.

Table 5.45 Variation in daily wage rate of female agricultural workers

Variation in daily wage rate	N	Mean	Std. Deviation
Average Variation in daily wage rate of female agricultural worker that fall short of national minimum wage rate	49	25.4606	31.99

Source: Primary Survey

The analysis of the daily wage rates of female agricultural workers indicates that, on average, these workers earn average **25.46** rupees below the national minimum wage. This average variation is based on a sample size of **49** workers..

5.2.3.2 Food Insecurity Experience Index (FIEI)

Food Insecurity Experience Index is a metric used to assess the prevalence and severity of food insecurity among mixed farmers. It measures experiences related to access to food, reflecting the degree to which people face difficulties in obtaining sufficient and nutritious food. Eight brief yes/no questions make up the Food Insecurity Experience Index (FIEI), which is given to mixed farmers directly. The purpose of these questions is to gather self-reported food-related behaviors and experiences that show how mixed farmers are finding it more and more difficult to obtain food because of resource limitations. Three core domains—uncertainty and anxiety about food supply, changes in food quality, and variations in food quantity—are included in the FIEI framework, which is based on a well-established construct of food insecurity.

Calculation of FIEI: The index measures food security levels based on qualitative responses related to three key domains: uncertainty and anxiety regarding food availability, changes in food quality, and changes in food quantity.

Food Insecurity Experience Index = $\Sigma \mathbf{Q}_{\mathbf{i/n}}$ Where:

Qi represents the numerical value of each response

n is the total number of qualitative indicators used.

The Food Security Index ranges from 0 to 1 and is classified into three distinct categories:

- **0 to 0.33**: Mild Food Insecurity
- **0.34 to 0.66**: Moderate Food Insecurity
- **0.67 to 1.00**: Severe Food Insecurity

These classifications provide a framework for understanding varying levels of food insecurity among the mixed farmers

Sustainability criteria: Level on Food Insecurity Experience Index (FIEI)

Green (Desirable): Mild food insecurity

Yellow (Acceptable): Moderate food insecurity

Red (Unsustainable): Severe food insecurity

Table 5.46 Responses of Food Insecurity Experienced by Households

	Frequency		Percent
Worried about not having enough food to eat in a day	Yes	382	97.0
	No	12	3.0
	Total	394	100.0
Unable to eat healthy and nutritious food in a day	Yes	382	97.0
	No	12	3.0
	Total	394	100.0
Only ate a few kinds of food in a day	Yes	373	94.7
	No	21	5.3
	Total	394	100.0
Skipped a meal in a day	Yes	373	94.7
	No	21	5.3
	Total	394	100.0
Ate less than he/she thought in a day	Yes	379	96.2
	No	15	3.8
	Total	394	100.0
Ran out of food in a day	Yes	382	97.0
	No	12	3.0
	Total	394	100.0
He/she was hungry but not eating in a day	Yes	382	97.0
	No	12	3.0
	Total	394	100.0
Did not eat for a whole day	Yes	385	97.7
	No	9	2.3
	Total	394	100.0

Source: Primary Survey

The table 5.47 depicts the food insecurity experienced by the mixed farmers.97% of mixed farmers have not worried about not having enough food to eat in a day and able to eat food when he/she was hungry.97% are able to eat healthy and nutritious food in a day. But

5.3% of mixed farmers ate only few kinds of food in a day and skipped a meal in a day.3% mixed farmers have ran out of food in a day and 3.8% mixed farmers have ate less than he/she thought in a day. 2.3% mixed farmers had not eaten food for a whole day.

- **Sustainability Level of Mixed Farming in terms of Food Insecurity Experience Index**

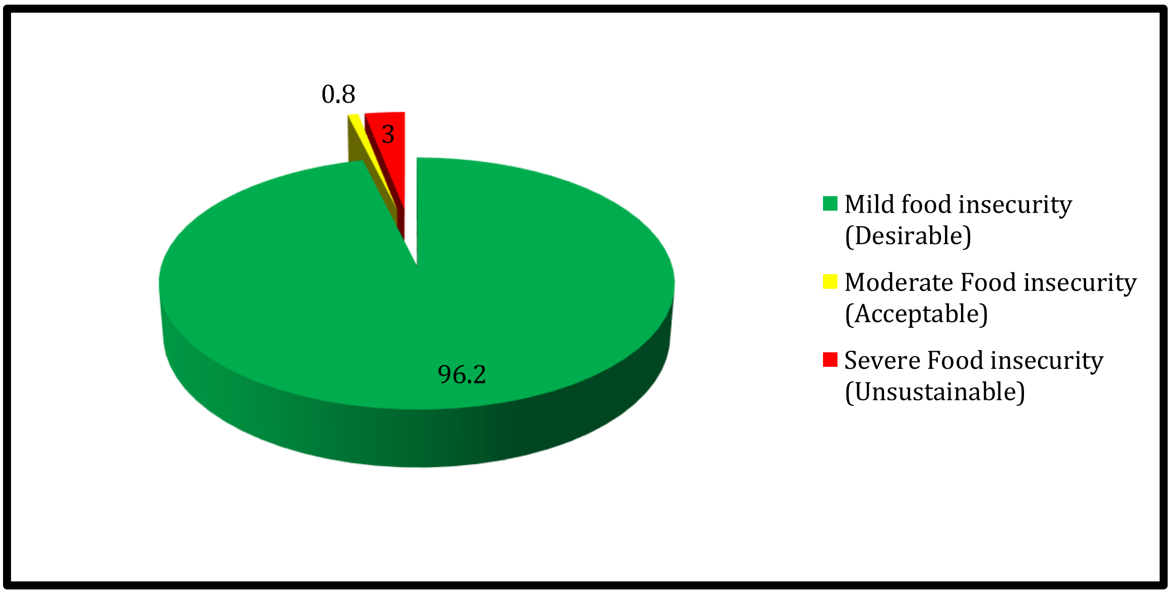
The table 5.47 highlights sustainability level of mixed farming in terms of Food Insecurity Experience Index in mixed farming system. On the basis of Food Insecurity Experience Index in mixed farming system, sustainability level of mixed farms is classified as Desirable, Acceptable and Unsustainable.

Table 5.47 Sustainability Level of Mixed Farming in terms of Food Insecurity Experience Index

SustainabilityLevel	Frequency	Percent	Chi Square	P value
Mild food insecurity (Desirable)	379	96.2	700.878	.000**
Moderate Food insecurity (Acceptable)	03	.8		
Severe Food insecurity (Unsustainable)	12	3.0		
Total	**394**	**100.0**		

**At 1% level of significance Source: Primary survey

Figure 5.12 Sustainability Level of Mixed Farming in terms of Food Insecurity Experience Index



Source: Primary survey

The table 5.47 and figure 5.12 illustrate the sustainability status of food security among farm households. It is observed that 96.2% of farm households experience mild food insecurity, while 0.8% faces moderate food insecurity. Additionally, 3% of farm households are categorized as experiencing severe food insecurity. Chi-square test has been performed to examine whether there is any significant difference in the sustainability level of mixed farming in terms of food insecurity experience level. The results indicate that there is statistical significant difference in the sustainability level of mixed farming in terms of food insecurity experience among mixed farmers, $\chi 2$ =700.878, p is .000 (Exact p-value). Hence it is inferred that the level of sustainability regarding food insecurity experience among farmers are different in Palakkad district.

5.2.3.3. Secure tenure rights to land

The sub-indicator assesses sustainability in mixed farming concerning the rights to use agricultural land. Secure tenure rights are crucial for agricultural production, as they ensure that farming operations maintain control over this essential asset and are not at risk of losing access to the land used for cultivation. The various studies indicate that farmers with limited access to and control over economic resources, especially land, tend to be less productive. Long-standing inequalities in economic and financial resources have placed certain farmers at a disadvantage, affecting their ability to engage in, contribute to, and benefit from broader developmental processes. Thus, an equitable distribution of economic resources, particularly land, is vital for fostering inclusive economic growth. It enhances economic efficiency and positively influences key development outcomes, including poverty alleviation, food security, and overall household welfare.

Sustainability Criteria: Level of Security of Access to Land

- Green (Desirable): The individual has a formal document that contains the name of the holder or holding, authority to sell any portion of the holding or bequeath any portion of the holding.
- Yellow (Acceptable): The individual has a formal document, even if the name of the holder or holding is not included.
- Red (Unsustainable): The individual has no positive responses to any of the four prerequisites mentioned above.

➢ **Responses of Farmers Regarding Secure Land Tenure Rights**

The table 5.48 shows the responses of farmers regarding secure land tenure rights. The necessity of having explicit and legally recognized ownership or rental agreements for sustainable farming is highlighted by mixed farmers' replies about secure land tenure rights Secure land tenure, according to many farmers, boosts their general stability and productivity and gives them more confidence to make long-term investments.

Table 5.48 Responses of Farmers Regarding Secure Land Tenure Rights

Variables	Frequency		Percent
Formal Document for the agricultural holding	Yes	328	83.2
	No	66	16.8
	Total	394	100.0
Formal Document with the name of the Holder	Yes	322	81.7
	No	72	18.3
	Total	394	100.0
Right to sell the agricultural holding	Yes	316	80.2
	No	78	19.8
	Total	394	100.0
Right to bequeath the agricultural holding	Yes	319	81.0
	No	75	19.0
	Total	394	100.0

Source: Primary Survey

➢ **Sustainability Level of Mixed Farming in terms of Secure Tenure Rights to Land**

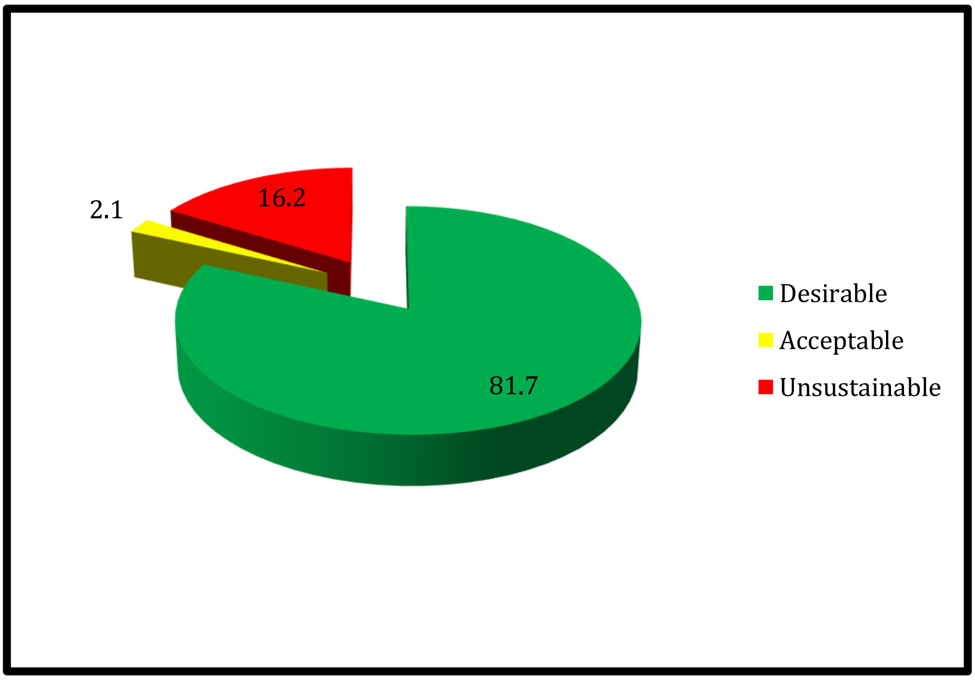
The table 5.49 highlights sustainability level of mixed farming in terms of secure tenure rights to land in mixed farming system. On the basis of secure tenure rights to land in mixed farming system, sustainability level of mixed farms is classified as Desirable, Acceptable and Unsustainable.

Table 5.49 Sustainability Level of Mixed Farming in terms of Secure Tenure Rights to Land

Sustainability Level	Frequency	Percent	Chi square	P value
Desirable	322	81.7	427.147	.000**
Acceptable	08	2.1		
Unsustainable	64	16.2		
Total	394	100.0		

**At 1% level of significance Source: Primary survey

Figure 5.13 Sustainability Level of Mixed Farming in terms of Secure Tenure Rights to Land



Source: Primary survey

The sustainability status of land access is categorized as follows: 81.7% of individuals have a "Desirable" status, indicating secure rights to land. Only 2.1% are classified as "Acceptable," reflecting limited security. In contrast, 16.2% fall under the "Unsustainable" category, suggesting a lack of secure access to land. Overall, these figures highlight the predominance of secure land tenure among the assessed population. Chi-square test has been performed to examine whether there is any significant difference in the sustainability level of mixed farming in terms of secure tenure rights of land. The results indicate that there is statistical significant difference in the sustainability level of mixed farming in terms of secure tenure rights of land among mixed farmers, $\chi 2$ =700.878, p is .000 (Exact p-value). Hence it is inferred that the level of sustainability regarding secure tenure rights of land among farmers are different in Palakkad district.

5.2.3.4 Social Sustainability of Mixed Farming –Summary

The table 5.50 highlights the summary of social sustainability. On the basis of social sustainability, mixed farms are classified as Desirable, Acceptable and Unsustainable

Table 5.50 Social Sustainability-Summary

Sustainability Level	Frequency	Percent	Chi- Square	p value
Desirable	319	81	412.147	.000**
Acceptable	63	16		
Unsustainable	12	3		
Total	394	100.0		

** At 1% Level of Significance Source: Primary Survey

The table 5.50 summarizes the social sustainability level of mixed farms. From the table it is clear that 81% of mixed farms are classified as "Desirable" while only 3% of mixed farms are classified as "Unsustainable" and 16% of mixed farms are "Acceptable". Chi-square test for goodness of fit has been performed to examine whether there was any significant difference in the social sustainability level of mixed farming. The results indicate that there is statistical significant difference in the social sustainability level of mixed farming, $\chi 2$ =412.147, p is .000 (Exact p-value). Hence it is inferred that the level of social sustainability among mixed farmers is different in Palakkad district.

The null hypothesis (H0c) discussed earlier is rejected because majority of the mixed farmers are at desirable level of social sustainability. Majority mixed farms are socially sustainable contributing to well being of the community by ensuring food security, land tenure rights and fair wages.

5.3. Sustainability Index (SI)

A sustainability index is a measure or tool used to assess the sustainability of a system, such as an agricultural farm, a business, or even an entire economy. It is typically a composite index that takes into account various environmental, social, and economic factors to evaluate how well a system or practice aligns with sustainability goals. The index helps stakeholders understand the current state of sustainability and track improvements or declines over time.

In the context of mixed farming, a sustainability index could evaluate the sustainability of farming practices based on multiple criteria that contribute to long-term viability without compromising the environment, society, or economy. Below are key components that are included in a sustainability index for mixed farming:

5.3.1 Indicators of Sustainability of Mixed Farming

The table 5.51 shows the brief description about the dimensions, themes and sub indicators to assess the sustainability of mixed farming.

Table 5.51 Indicators of Sustainability of Mixed Farming

Dimensions	No.	Theme	Sub-indicators
Economic	1	Land productivity	Farm output value per hectare
	2	Profitability	Net farm income
	3	Resilience	Risk mitigation mechanisms
Environmental	4	Soil health	Prevalence of soil degradation
	5	Water use	Variation in water availability
	6	Fertilizer pollution risk	Management of fertilizers
	7	Pesticide risk	Management of pesticides
	8	Biodiversity	Use of agro-biodiversity-supportive practices
Social	9	Decent employment	Wage rate in agriculture
	10	Food security	Food insecurity experience Index (FIEI)
	11	Land tenure	Secure tenure rights to land

Source: FAO, 2020

In order to capture the concept of continuous progress towards sustainability, a 'traffic light' approach is followed, in which three sustainability levels are considered for each sub-indicator:

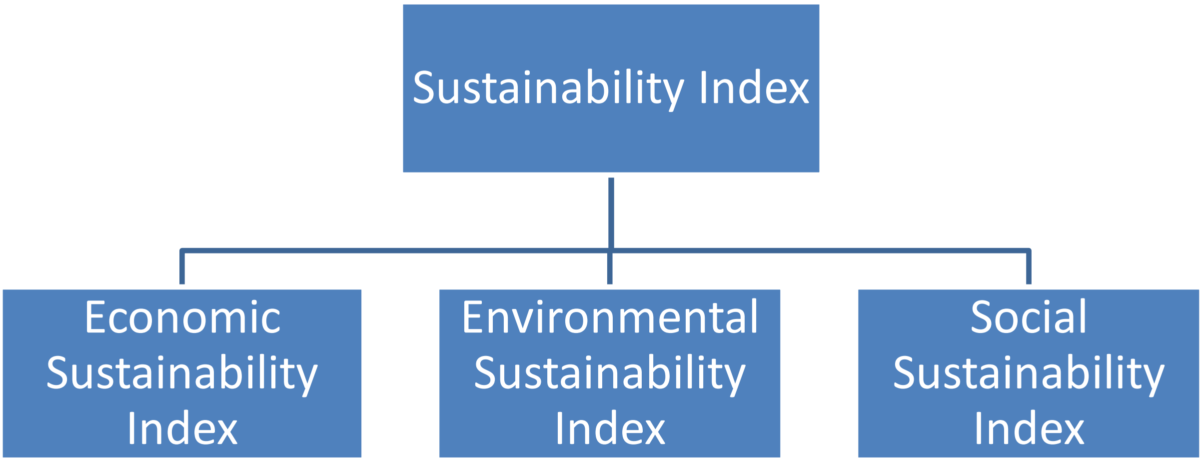
- Green: Desirable
- Yellow: Acceptable
- ·Red: Unsustainable. (FAO, 2020)

The UNDP method of HDI calculation is used to construct the Sustainability Index of mixed farming. The economic dimension is assessed by farm output value per hectare of mixed farm, net farm income of mixed farm and risk mitigation mechanisms of mixed farm. The environmental dimension is assessed by prevalence of soil degradation, variation in water availability, management of fertilizers, management of pesticides and use of agro-diversity-supportive practices. The social sustainability is assessed by wage rate in mixed farming system, food insecurity experience and secure tenure rights to land. Each dimension score is computed and these scores are converted into Z scores. Then dimension indices are calculated as:

$$\text{Dimension Index} = \frac{\text{Actual Value-Minimum Value}}{\text{Maximum Value-Minimum Value}}$$

The sustainability index is the geometric mean of normalized indices for each of the three dimensions.

Figure 5.14 Sustainability Index of Mixed Farming



5.3.1.1 Sustainability of Mixed Farming

The table 5.52 shows overall sustainability level of mixed farming that is distribution of mixed farms based on 11 sub indicators across sustainability levels. Sustainability of mixed farming refers to the capacity of mixed farming system to endure over the long term while maintaining environmental health, economic viability, and social well-being.

Table 5.52 Distribution of Mixed Farms based on Sub indicators across Different Sustainability Levels

Sustainability Level of the holding	Farm output value per hectare	Net farm income	Risk mitigation mechanisms	Prevalence of soil degradation	Variation in water availability	Management of fertilizers	Management of pesticides	Use of biodiversity supportive practices	Wage rate in agriculture	FIEI	Secure tenure rights to land
Desirable	73	149	109	338	331	216	172	89	374	379	322
Acceptable	102	106	285	20	19	155	11	305	0	03	8
Unsustainable	219	139	0	36	44	23	211	0	20	12	64
Total	394	394	394	394	394	394	394	394	394	394	394

Source: Primary survey

The table 5.52 depicts categorisation of mixed farms based on 11 sub indicators across sustainability levels that is desirable, acceptable and unsustainable. There are 11 indicators for measuring the sustainability of mixed farming. Concerning the sub indicator, the farm output value per hectare the desirable mixed farms are only 73 but at the same time unsustainable mixed farms are 219 and 102 farms are acceptable. In the case of net farm income 149 mixed farms are desirable, 106 mixed farms are acceptable and 139 mixed farms are unsustainable. Regarding the indicator risk mitigation mechanism, 109 mixed farms are desirable and 285 are acceptable. 338 farms are desirable, 20 mixed farms are acceptable and 36 mixed farms are unsustainable regarding the indicator prevalence of soil degradation. Sustainability level in terms of indicator variation in water availability shows that 331 mixed farms are desirable 19 farms are acceptable and 44 farms are unsustainable. In the case of management of fertilizers 216 mixed farms are desirable, 155 mixed farms are acceptable and 23 mixed farms are unsustainable. Sustainability level with respect to management of pesticides, 172 mixed farms are desirable, 11 farms are acceptable and 211 mixed farms are unsustainable. Regarding the indicator, use of biodiversity supportive practices 89 mixed farms are desirable and 305 are unsustainable. In the case of wage rate in agriculture, 374 mixed farms are desirable and 20 mixed farms are unsustainable. 379 mixed farms are desirable, 3 mixed farms are acceptable and 12 mixed farms are unsustainable regarding the indicator Food Insecurity Inexperience Index. Regarding the indicator, secure tenure rights to land, 322 mixed farms are desirable, 8 mixed farms are acceptable and 64 mixed farms are unsustainable.

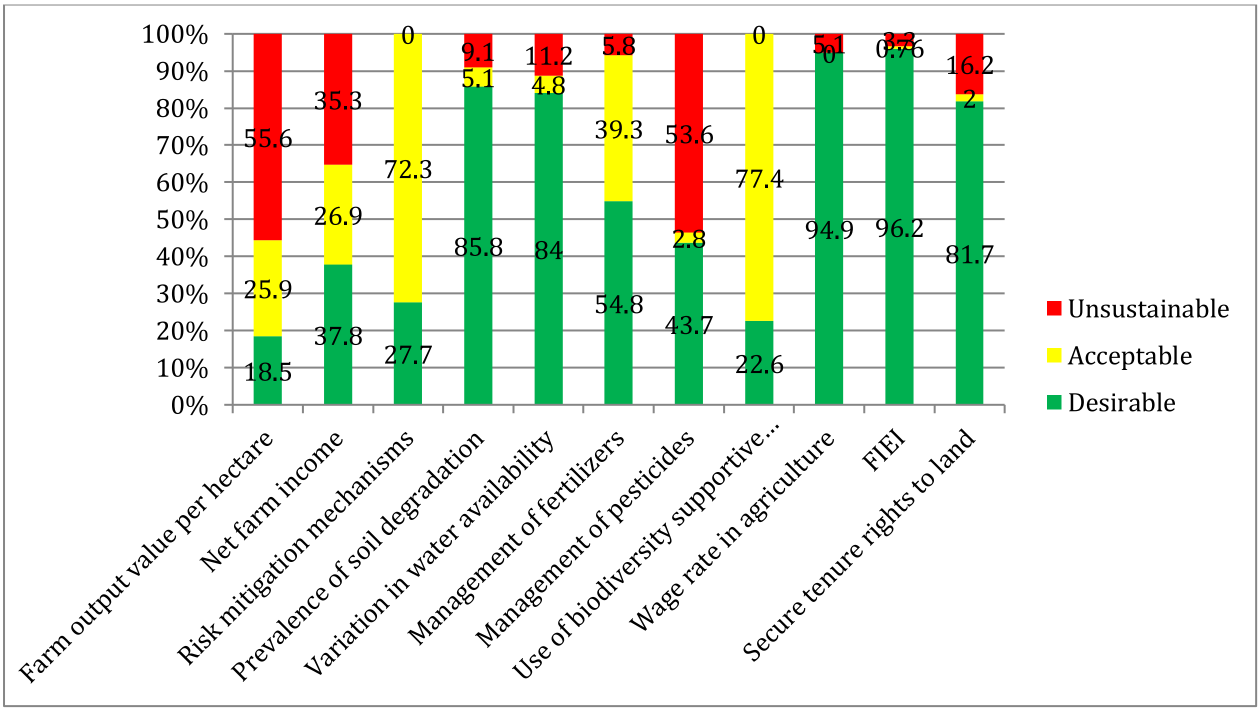
Table 5.53 Dashboard of Sustainability of Mixed Farming

Sustainability Level of the holding	Farm output value per hectare	Net farm income	Risk mitigation mechanisms	Prevalence of soil degradation	Variation in water availability	Management of fertilizers	Management of pesticides	Use of biodiversity supportive practices	Wage rate in agriculture	FIEI	Secure tenure rights to land
Desirable	18.5	37.8	27.7	85.8	84	54.8	43.7	22.6	94.9	96.2	81.7
Acceptable	25.9	26.9	72.3	5.1	4.8	39.3	2.8	77.4	0	.76	2.1
Unsustainable	55.6	35.3	0	9.1	11.2	5.8	53.6	0	5.1	3.3	16.2
Total	100	100	100	100	100	100	100	100	100	100	100

Source: Primary survey

The table 5.53 summarizes distribution of mixed farms based on 11 sub indicators across sustainability levels. There are 11 indicators for measuring the sustainability of mixed farming. The sustainability level in terms of farm output value per hectare is that the desirable mixed farms are only 18.5% but at the same time unsustainable mixed farms are 55.6% and 25.9% farms are acceptable. In the case of net farm income 37.8% mixed farms are desirable 26.9% mixed farms are acceptable and 35.3 mixed farms are unsustainable. Regarding the indicator risk mitigation mechanism, 27.7% mixed farms are desirable 72.3% are acceptable and no mixed farms are unsustainable. With respect to the indicator prevalence of soil degradation 85.8% forms are desirable, 5.1% mixed farms are acceptable 9.1% mixed farms are unsustainable. Sustainability level regarding the indicator variation in water availability shows that 84% mixed farms are desirable 4.8% farms are acceptable and 11.2% farms are unsustainable. In the case of management of fertilizers 54.8% mixed farms are desirable, 39.3% mixed farms are acceptable and 5.8 percentage mixed farms are unsustainable.43.7% of mixed farms are desirable, 2.8% farms are acceptable and 53.6% mixed farms are unsustainable with respect to management of pesticides. Sustainability level regarding the indicator, use of biodiversity supportive practices 22.6% of mixed farms are desirable and 77.4% are unsustainable. In the case of wage rate in agriculture 94.9% of mixed farms are desirable and 5.1% of mixed farms are unsustainable. Regarding the indicator Food Insecurity Inexperience Index, 96.2% mixed farms are desirable, .76 mixed farms are acceptable and 3.3% mixed farms are unsustainable. Sustainability level with respect to the indicator, secure tenure rights to land, 81.7% of mixed farms are desirable, 2% mixed farms are acceptable and 16.2% mixed farms are unsustainable.

Figure 5.15 Dashboard of Sustainability of Mixed Farming



Source: Primary survey

It is evident from the above table 5.53 and figure 5.15 that, of the 11 indicators, mixed farms are the least sustainable in terms of the indicator farm output value per hectare, which represents 55.6% of unsustainable farms. In addition, mixed farms are unsustainable in terms of the indicator pesticide management. In terms of indicator risk reduction strategies and use of biodiversity supportive practices, no farm is unsustainable.

5.3.2 Sustainability level of Mixed Farms

The table 5.54 illustrates the sustainability level of mixed farms. Eleven indicators are used to create a sustainability index. Mixed farms are categorized as Desirable, Acceptable, and Unsustainable based on the calculation of the 33 and 66 percentiles of SI.

Table 5.54 Sustainability level of Mixed Farms

Sustainability Level		Desirable	Acceptable	Unsustainable	Total	Chi Square	P value
Economic Sustainability	Frequency	24	298	72	394	326.030	000**
	Percent	3.1	75.6	18.3	100.0		
Environmental Sustainability	Frequency	164	50	180	394	76.528	000**
	Percent	41.6	12.7	45.7	100.0		
Social Sustainability	Frequency	319	63	12	394	412.147	000**
	Percent	81	16	3	100.0		
Overall Sustainability	Frequency	151	108	135	394	7.193	.027*
	Percent	38.3	27.4	34.3	100.0		

**At 1% level of significance * At 5% level of significance Source: Primary survey

It is evident from the table 5.54 that the farms' sustainability status presents a diverse image. Of the total, 151 farms are deemed Desirable, meaning they successfully apply best practices and satisfy strict sustainability standards. In the meantime, 108 farms are classified as Acceptable, indicating that while they still show some encouraging sustainability initiatives, they still have space for improvement. Nevertheless, 135 farms have been found to be Unsustainable, indicating serious issues that require attention. This distribution highlights the need for targeted interventions and support for the unsustainable farms while also acknowledging and promoting the practices of the desired farms in order to improve overall sustainability in the mixed agricultural system

From the data presented, it can be concluded that the majority of the farms are sustainable. With 151 farms classified as Desirable and 108 as Acceptable, a total of 259 farms demonstrate sustainable practices. In contrast, the 135 farms categorized as Unsustainable represent a smaller portion of the overall total. This indicates that most farms are either meeting or approaching sustainability standards, highlighting a positive trend in sustainable farming practices. However, the presence of unsustainable farms emphasizes the need for continued support and interventions to improve practices across the board.

Chi-square test has been performed to examine whether there is any significant difference in the sustainability level of mixed farming. The results indicate that there is statistical significant difference in the sustainability level of mixed farming among mixed farmers, $\chi2$ =7.193, p is .027 (Exact p-value). Hence it is inferred that the level of sustainability of mixed farming among farmers are different in Palakkad district.

The null hypothesis (H0) presented earlier that mixed farmers maintain an acceptable level of economic, environmental and social sustainability is rejected as majority of mixed farms maintain desirable level of sustainability. This involves balancing economic, environmental, and social factors of mixed farming to ensure long-term viability. That means mixed farmers promote resource conservation, minimize environmental degradation, and support the well-being of local communities. They use eco-friendly farming methods, reduce waste, and maintain fair labour practices. By doing so, mixed farming not only protect the environment and improve profitability but also contribute to the society, ensuring that future generations can continue to flourish.

5.4 Distribution of Sustainability Index Across agricultural Characteristics of Mixed Farming

This involves the process of analyzing and describing the various attributes and features of mixed farming system across the distribution of sustainability index. This include evaluating mixed farming area, number of in milk cattle owned by the mixed farmer, category of mixed farms based on dominance of agricultural activity, various size of mixed farming and farm diversification. The goal of agricultural characterization is to gain a comprehensive understanding of level of sustainability across different agricultural characteristics of mixed farming system. The descriptive statistics of agricultural characteristics are already discussed in Chapter 4. (See table 4.27, 4.28, 4.29, 4.30 and 4.31) The study has formulated one main hypothesis and several sub hypotheses. The main hypothesis is as follows.

Null Hypothesis-H0: Sustainability Index remains same across various agricultural characteristics of mixed farming system.

Null Hypothesis-H0a: Sustainability Index remains same across various categories of mixed farming area.

For testing the hypothesis Independent-Samples Kruskal-Wallis Test is conducted. The results of hypothesis testing is given below in the table 5.55

Table 5.55 Hypothesis Test Summary

	Land	Mean rank	Z	Sig	Decision
Sustainability Index	Below 1 Hectare	216.24	22.729	.000	Reject H0a
	1-2 Hectare	166.43			
	2-4 Hectare	138.80			
	4-10 Hectare	141.83			
	Above 10 Hectare	141.50			

Source: Primary survey

Interpretation

The p value is .000 and it is less than .01 (at 1% level of significance). Therefore we reject the null hypothesis and conclude that sustainability index varies across categories of mixed farming area. The test statistic is 22.729. The land area below 1 Hectare has highest mean rank 216.24 suggesting that it leads to higher level of sustainability. The land classification 2-4 hectare has lowest mean rank suggesting that it leads to lowest level of sustainability.

Null Hypothesis-H0b: Sustainability index remains same across crop dominant and livestock dominant mixed farms.

For testing the hypothesis Independent-Samples Mann-Whitney U Test is conducted. The results of hypothesis testing is given below in the table 5.56

Table 5.56 Hypothesis Test Summary

	Category of Mixed farming	Mean rank	Z	Sig	Decision
Sustainability Index	Livestock dominant Mixed farming	204.49	-2.515	.012	Reject H0b
	Crop dominant Mixed farming	167.76			

Interpretation

The p value is .012 and it is less than .05 (at 5% level of significance). Therefore we reject the null hypothesis and conclude that sustainability index varies across crop dominant and livestock dominant mixed farms. The livestock dominant mixed farms have highest mean rank 204.49 suggesting that it leads to higher level of sustainability. The crop dominant mixed farms has lowest mean rank 167.76 suggesting that it leads to lowest level of sustainability.

Null Hypothesis-H0c: Sustainability index remains same across various categories of in milk cattle

For testing the hypothesis Independent-Samples Kruskal-Wallis Test is conducted. The results of hypothesis testing is given below in the table 5.57

Table 5.57 Hypothesis Test Summary

	Number of in milk cattle owned by the mixed farmer	Mean rank	Z	Sig	Decision
Sustainability Index	Upto 2	196.64	4.843	.089	Retain H0c
	3-5	207.54			
	6-8	102.50			

Source: Primary Survey

Interpretation

The p value is .089 and it is greater than than .05 (at 5% level of significance). Therefore the study retain the null hypothesis and conclude that sustainability level remain same across groups of in milk cattle.

Null Hypothesis-H0d: Sustainability index remains same across various groups of mixed farmers on the basis of farm diversification.

For testing the hypothesis Independent-Samples Mann-Whitney U Test is conducted. The results of hypothesis testing is given below in the table 5.58

Table 5.58 Hypothesis Test Summary

	Category of Mixed farming on the basis of farm diversification	**Mean rank**	**Z**	**Sig**	**Decision**
Sustainability Index	No	182.74	-4.161	.167	Retain H0d
	Yes	236.10			

Interpretation

The p value is .167 and it is greater than .05 (at 5% level of significance). Therefore the study retain the null hypothesis and conclude that sustainability index remain same across categories of mixed farming on the basis of farm diversification

Null Hypothesis-H0e: Sustainability index remains same across various size of mixed farming

For testing the hypothesis Independent-Samples Kruskal-Wallis Test is conducted. The results of hypothesis testing is given below in the table 5.59

Table 5.59 Hypothesis Test Summary

	Size of mixed farming	**Mean rank**	**Z**	**Sig**	**Decision**
Sustainability Index	Small Size	217.70	6.163	.046	Reject H0e
	Medium Size	189.14			
	Large size	185.97			

Source: Primary Survey

Interpretation

The p value is .046 and it is less than .05 (at 5% level of significance). Therefore we reject the null hypothesis and conclude that sustainability level varies across different size of mixed farming. The test statistic is 6.163. The small size mixed farming has highest mean rank 217.70 suggesting that it leads to higher level of sustainability. The large size mixed farms has lowest mean rank 185.14 suggesting that it leads to lowest level of sustainability.

5.5 Conclusion

A sustainability index for mixed farming is an essential tool for assessing and promoting sustainable agricultural practices. It evaluates a farm's ability to balance environmental health, economic profitability, social well-being, and cultural preservation. By using such an index, farmers can enhance the long-term sustainability of their operations and contribute to a more sustainable food system.

From the data presented, it can be concluded that the majority of the farms are sustainable. With 151 farms classified as desirable and 108 as acceptable, a total of 259 farms demonstrate sustainable practices. In contrast, the 135 farms categorized as unsustainable represent a smaller portion of the overall total. This indicates that most farms are either meeting or approaching sustainability standards, highlighting a positive trend in sustainable farming practices. However, the presence of unsustainable farms emphasizes the need for continued support and interventions to improve practices across the board.

The study affirms Robert McNetting's Theory of "The Ecology of Small Scale Sustainable Agriculture" and Modern Portfolio Theory. There is a clear association between mixed farming and sustainable agricultural practices. Crops being expected to behave as assets, risk may be reduced by combining it with livestock in a portfolio of farmer.

The significance of mean difference is tested with respect to sustainability index across various agricultural characteristics of mixed farming. The agricultural characteristics include mixed farming area, number of in milk cattle owned by the mixed farmer, category of mixed farms based on dominance of agricultural activity, various size of mixed farming and farm diversification. The results indicate that the Sustainability Index remains consistent across different categories of farm diversification among mixed farmers and across categories of in milk cattle. However, the sustainability index varies between crop-dominant and livestock-dominant mixed farms. Finally, the sustainability index also differs across various size of mixed farming, and across different mixed farm area highlighting the dynamic nature of sustainability within agricultural practices.

CHAPTER 6
DETERMINANTS OF SUSTAINABILITY

6.1 Introduction

The chapter explores the key determinants of sustainability in mixed farming systems. In constructing a sustainability index for mixed farming, several determinants are typically considered to provide a comprehensive assessment of sustainability. In addition to the commonly recognized factors, features of mixed farming itself influence the sustainability of mixed farming. To provide a deeper understanding of these determinants, a Tobit regression analysis is used, allowing for the exploration of the relationship between factors of mixed farming and sustainability outcomes. The chapter aims to identify and quantify the key drivers of mixed farming that promote or hinder sustainable farming practices, offering insights that can inform policy decisions and agricultural strategies.

6.2 Determinants of Sustainability in Mixed Farming

The sustainability of mixed farming is influenced by several key determinants, each playing a critical role in the systems overall resilience and efficiency. In constructing a sustainability index for mixed farming, several determinants are typically considered to provide a comprehensive assessment of sustainability. Beyond the commonly recognized factors, other important determinants include experience in mixed farming, imputed expenses of mixed farming, cattle output share to mixed farming income, contribution of family labour, mixed farming output, paid out expenses and cattle value.

6.2.1 Description of Explanatory Variables

6.2.1.1 Experience in Mixed farming: Farming experience and sustainability of mixed farming go hand in hand. Farmers gain expertise in managing resources like soil, fertilizer, and water as they gain years of experience. Sustainable mixed farming depends on their ability to maximize the use of these resources, limit waste, and lessen environmental degradation.

Table 6.1 Descriptive Statistics of Farming Experience

Farming Experience in Years	N	Mean	Std. Deviation
Farming experience in paddy production	394	34.05	14.900
Farming experience in cattle rearing	394	30.16	13.851
Experience in mixed farming	**394**	**29.50**	**14.451**

Source: Primary Survey

From the table it is clear that the average farming experience of farmers in paddy production 34.05 years and in cattle rearing is 30.16 years. In mixed farming, average experience of farmers is 29.50 years.

6.2.1.2 Imputed Expenses: Imputed expenses can significantly influence the sustainability of mixed farming. Here imputed expenses exclude family own labour. These expenses on own inputs help farmers integrate crops and livestock in a way that supports long-term sustainability. The average imputed expenses of mixed farming in a year are ₹ 61588.32. These expenses could influence overall sustainability of mixed farming if it is overused or undermanaged.

Table 6.2 Imputed expenses of Mixed Farming

Item	N	Mean	Std. Deviation
Imputed expenses of seeds	394	1675.66	3686.056
Imputed expenses of bio fertilizers	394	625.38	1694.270
Imputed expenses of manure	394	4995.05	6311.306
Imputed expenses of Pesticides	394	64.21	409.199
Imputed expenses of bio pesticides	394	132.87	722.295
Imputed expenses of cattle feed in a year	394	6889.34	37946.347
imputed expenses of green fodder in a year	394	18597.26	22028.069
imputed expenses of straw in a year	394	20866.42	37266.099
Imputed expenses of concentrates in a year	394	7742.13	36630.188
Total Imputed expenses of mixed farming in a year	**394**	**61588.32**	**91826.554**

Source: Primary Data

6.2.1.3 Cattle output share to mixed farming: Livestock contributes to the sustainability of mixed farming by enhancing soil fertility, improving resource use efficiency, promoting diversification and building resilience to external risks. These benefits collectively support the long-term environmental, economic, and social sustainability of mixed farming systems. However, it's important to note that livestock must be managed responsibly in mixed farming, as overgrazing or poor animal husbandry can lead to negative environmental impacts like soil degradation or overuse of water resources.

6.2.1.4 Contribution of Family Labour: Family labour force of the agricultural holding in mixed farming refers to family workers. Persons who assist another family member in managing an agricultural holding are known as family workers, even though they are not regarded as employees. The contribution of family labour towards mixed farming is represented in aspect of time that is in hours per day of family members. In the study, contribution of a male and female member is taken for analyzing the contribution of family labour towards mixed farming. The average hours of work per day contributed by family members is 10.24 hours per day.

Table 6.3 Contribution of family Labour towards mixed farming

Time spend by male and female member for mixed farming	N	Mean	Std. Deviation
No of hours spend for crop activity per day during peak season by a male member in family	394	5.9594	3.16764
No of hours spend for crop activity per day during peak season by a female member in family	394	4.2817	3.53454
No of hours spend for crop activity per day during off peak season(routine) by a male member in family	394	1.9556	2.50393
No of hours spend for crop activity per day during off peak season (routine) by female member in family	394	.8832	1.46210
No of hours spend for cattle farming per day by male member in family	394	3.4061	2.13836
No of hours spend for cattle farming per day by female member in family	394	3.9975	2.33950
Total time spend by family in mixed farming (Normal Days)	394	10.24	4.845

Source: Primary Data

6.2.1.5 Mixed Farming Output: Mixed farming output encompasses the combined yield from both crops and livestock, offering diverse products that can be sold or used for household consumption. When discussing mixed farming output as a measurement of the scale, the focus shifts to the quantity of products produced (both paddy and cattle) and how this output reflects the size and intensity of the farming system. The size of mixed farming can be measured by the volume of output, which typically includes both output from paddy production and output from cattle rearing. The output-based measurement of size in mixed farming provides insights into how much is produced in terms of both crops and livestock. The integration of different agricultural activities on the same farm supports sustainability, resilience, and food security. Small size mixed farming often focuses on subsistence and local markets, while larger mixed farming operations can provide higher outputs but may also face challenges related to environmental sustainability and over-reliance on external inputs. By balancing both crops and livestock, mixed farming can be a highly efficient and adaptable agricultural system that supports both ecological and economic sustainability. The average output from a mixed farm is ₹ 297726.33 (As shown in Table No: 5.3, page no. 94)

6.2.1.6 Paid out expenses: Paid out expenses in mixed farming refers to the extent to which a farming system depends on resources and materials that are sourced from outside the farm, such as synthetic fertilizers, pesticides, herbicides, commercial feeds for livestock, irrigation systems, machinery, and energy sources. The sustainability of mixed farming, on the other hand, refers to the farm's ability to maintain its productivity, environmental health, and economic viability over the long term without depleting resources or harming the ecosystem. The average paid out expenses of mixed farming in a year is ₹ 184558.18

Table 6.4 Paid out expenses of mixed farming in a year

Item	N	Mean	Std. Deviation
Paid out expenses of seeds	394	2003.95	4588.115
Paid out expenses of chemical fertilizers in a year	394	11948.06	18102.310
Paid out expenses of bio fertilizers	394	1087.61	4042.627
Paid out expenses of manure	394	809.90	4256.751
Paid out expenses of Pesticides	394	2469.82	5565.296
Paid out expenses of bio pesticides	394	355.74	2011.817
Expenses of transportation charges	394	1730.24	4670.663
Expenses of diesel	394	590.10	2531.507
Expenses of electricity	394	57.11	530.171
Expenses of irrigation	394	496.91	1469.831
Paid out expenses of human labour	394	32090.74	38507.213
Expenses for minor repair and maintenance of machinery and equipment used in crop production	394	778.63	4885.939
Interest charges	394	1825.76	3683.318
Expenses for machine hiring	394	16641.88	22311.924
Cost of Crop Insurance	394	579.65	1186.500
lease rent for land used for crop production	394	3228.43	8881.427
Marketing cost	394	349.89	1844.990
Subsidy	394	3429.77	6597.902
Other expenses for paddy cultivation	394	478.48	1862.761
Paid out expenses of cattle feed per year	394	71696.10	53307.201
Paid out expenses of green fodder in a year	394	8106.02	45099.039
paid out expenses of dry fodder in a year	394	6033.38	16943.523

Paid out expenses of concentrates in a year	394	6100.51	43031.658
Expenses for breeding in a year	394	1378.55	2702.532
Expenses for health services in a year	394	2313.96	4145.384
Interest on loans utilized for farming of animals in a year	394	1499.52	4982.464
Labour charges in a year	394	5157.36	28714.783
Cost of livestock insurance	394	2935.43	10705.175
Marketing cost in a year	394	1621.07	6305.596
other expenses for cattle rearing in a year	394	193.40	1752.311
Total paid out expenses of mixed farming	**394**	**184558.18**	**133502.137**

Source: Primary Data

6.2.1.7 Cattle value: The cattle ownership refers to number of heads at the end of the year. The number of cattle owned can have significant implications for the farm's overall productivity, sustainability, and economic viability. Mixed farmers own cattle worth an average of ₹ 88452.12. at the end of the year.

Table 6.5 Cattle ownership

Cattle value in ₹	N	Mean	Std. Deviation
Average price of all heads of cattle at the end of the year	394	88458.12	60156.022

Source: Primary Data

6.2.2 Determinants of Sustainability of Mixed Farming: Tobit Regression Approach

A regression analysis is used to trace out the variables that affect mixed farming's sustainability. The value of the Sustainability Index ranges between 0 and 1 and 20.5% of farmers have a zero score for Sustainability Index (SI). Thus, a censored regression model is used. Consequently, the factors influencing the sustainability can be explained by the Tobit Model of Regression. The following is a Tobit regression model with the Sustainability Index (Yi) as the dependent variable and the factors as the explanatory variables.

The Tobit Regression model used for the purpose of analysing the determinants of sustainability is illustrated in Model 6.1

$$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + U_i \text{ ....6.1}$$

Where Yi = Sustainability Index

X_1 = Experience in Mixed Farming (in yrs)

X_2 = Imputed Expenses

X_3 = Cattle output share to mixed farming

X_4 = Contribution of Family labour

X_5 = Mixed Farming Output

X_6 = Paid out expenses

X_7 = Cattle value

Ui = Stochastic random variable.

6.2.2.1 Checking for basic assumptions: The basic assumptions of no perfect multi-collinearity and normality of residuals are checked before proceeding with the Tobit Regression Model (6.1). Using the Variance Inflation Factors, the assumption of no perfect multi-collinearity is checked and the result is presented in Table 6.6

Table 6.6 Variance Inflation Factors

Explanatory Variables	**VIF**
Experience in Mixed Farming	1.102
Imputed Expenses	1.167
Cattle output share to mixed farming	1.291
Contribution of Family labour	1.095
Mixed Farming Output	1.484
Paid out expenses	1.628
Cattle value	1.053

Estimated from Primary Data

No such collinearity exists between the explanatory variables of regression model 6.1 (See Table 6.6) because the Minimum possible value of VIF = 1.0 and Values > 10.0 may indicate a collinearity problem. Thus Table 6.6 shows that since the value of VIF of all explanatory variables is near to 1, no variables are highly collinear.

The normality of the residual is another Tobit regression model assumption that is crucial for hypothesis testing. The Chi-Square test of normality is used to verify this. The value of the test statistic is 6.0947 with a p-value 0.053. This demonstrates the normal distribution of residuals of the regression model 6.1. Given that these two assumptions are met, the study used the regression model to trace out the determinants of sustainability.

6.2.2.2 Regression results and Interpretation

The Maximum Likelihood approach is used by the Tobit model to estimate the regression parameters. Chi-Square is used in this model to analyze the regression model's overall significance. The Tobit regression model uses the log-likelihood ratio as the model's explanatory power rather than R square. The result of the Tobit regression model is exhibited in Table 6.7

Table 6.7 Regression Results of Determinants of Sustainability

Explanatory Variables	***Coefficient***	***Std. Error***	***z***	***p-value***
Constant	0.392788	0.0340218	11.55	<0.0001
Experience in Mixed Farming	0.000792326	0.000456310	1.736	0.0825
Imputed Expenses	5.86730e-08	7.38937e-08	0.7940	0.4272
Cattle output share to mixed farming	0.000933078	0.000270434	3.450	0.0006
Contribution of Family labour	−0.00627773	0.00135634	−4.628	<0.0001
Mixed Farming Output	−6.85560e-08	3.48185e-08	−1.969	0.0490
Paid out expenses	9.84700e-08	6.00298e-08	1.640	0.1009
Cattle value	1.64474e-08	1.07123e-07	0.1535	0.8780
Log- Likelihood ratio = 261.81		**Chi-Square =35.39**	**p value-9.45e-06**	

Source: Estimated from primary data

It is clear from the Table 6.7 that, the regression model with Chi Square value 35.39 is significant at 1 % level. Therefore regression model is useful for the analysis and helps in deriving insights about the factors determining the SI. The individual beta coefficients explain the influence of each explanatory variable on the dependent variable, Sustainability Index. It was clear that the variables are the cattle output share to mixed farming, mixed farming output, contribution of family labour and experience in mixed farming determining the SI. The changes in the dependent variable per unit change in the explanatory variables are not directly measured by the estimated β's from the Tobit regression model. The marginal effects are calculated to account for the distinct influences of each independent variable on the dependent. The Tobit regression model's marginal effects (dp/dx) indicate the extent to which the independent variables may account for changes in the dependent variable (Yi = Sustainability index). The marginal effects of the model 6.1 are shown in the Table 6.8

Table 6.8 Marginal Effects –Determinants of Sustainability

Explanatory Variables	***dp/dx***	***Std. Error***	***z***	***p-value***
Experience in Mixed Farming	0.00079196	0.00045610	1.7364	0.082498
Imputed Expenses	5.8646e-08	7.3860e-08	0.79402	0.42718
Cattle output share to mixed farming	0.00093265	0.00027031	3.4503	0.00055997
Contribution of Family labour	-0.0062748	0.0013557	-4.6284	3.6848e-06
Mixed Farming Output	-6.8524e-08	3.4803e-08	-1.9689	0.048959
Paid out expenses	9.8425e-08	6.0002e-08	1.6404	0.10093
Cattle ownership.	1.6440e-08	1.0707e-07	0.15354	0.87797

Source: Estimated from primary data

Table 6.8 reveals that, cattle output share to mixed farming, mixed farming output, contribution of family labour and experience in mixed farming are the variables significantly determines the SI of mixed farming. The result shows that, cattle output share to mixed farming and family labour are significant at 1% level where as mixed farming output is significant at 5% level and experience in mixed farming is significant at 10% level. From it, it can also be deduced that the cattle output share to mixed farming, and the experience in mixed farming positively influence the SI whereas, mixed farming output and family labour inversely influence sustainability index. It can also be noted that the other variables like imputed expenses, paid out expenses and cattle value are turned to be not significant to influence SI of mixed farming.

6.3 Conclusion

The study of the determinants of sustainability in mixed farming explores various factors that influence the long-term viability of agricultural systems. From it, it can also be deduced that the cattle output share to mixed farming, and the experience in mixed farming positively influence the SI whereas, mixed farming output and total time spend by the farmers for mixed farming the inversely influence sustainability index. It can also be noted that the other variables like imputed expenses, paid out expenses, cattle value are turned to be not significant to influence SI of mixed farming. By understanding these factors, the study aims to identify practices that can enhance economic, environmental, and social sustainability for mixed farmers.

Based on the above analysis, it is clear that experience in mixed farming plays a significant role in enhancing the sustainability of mixed farming systems. Livestock, particularly cattle, are crucial in mixed farming because the sustainability of the system heavily depends on the efficient management of cattle. However, there is a key relationship to consider: the more time of family labour is used in farming, the lower the sustainability of mixed farming. This suggests that when more family members are involved in manual labor, it could indicate inefficiencies or over-reliance on household resources, which negatively impacts the overall sustainability.

Furthermore, the relationship between mixed farming output and the sustainability index is inversely proportional. This means that as the level of output increases, sustainability tends to decrease. In other words, large-scale or commercial mixed farming may be less sustainable than small-scale, subsistence farming. Small-scale mixed farming, typically more labour-intensive and less reliant on external inputs, appears to contribute more positively to sustainable agricultural practices.

Hence the analysis suggests that the sustainability of mixed farming systems is most closely aligned with smaller-scale operations that prioritize efficiency, ecological balance, and local resource management, rather than maximizing output.

CHAPTER 7
SUMMARY OF FINDINGS AND IMPLICATIONS

7.1 Introduction

Agriculture in the 21st century faces multiple challenges. It has to produce more food and fibre to feed a growing population with a smaller rural labour force, more feed stocks for a potentially huge bioenergy market, contribute to overall development in the many agriculture-dependent developing countries, adopt more efficient and sustainable production methods and adapt to climate change.(FAO, 2009) In India, the population is predicted to reach over 1.6 billion people by 2030, but by 2050, the demand for food is predicted to reach over 400 million tonnes (MT). Hence, an agricultural growth rate of 4% per annum is necessary (as against 3.6% during the XI plan) not only to meet the demand of food, feed and fodder but to continue to have 8-9% growth in GDP to reduce poverty and support the overall economic growth of the country. (IARI, 2013). A viable way to allow agricultural systems to feed a growing population while adjusting to changing environmental conditions is through sustainable agriculture. Agriculture must meet the needs of current and future generations, while ensuring economic well being, environmental health, and social equity, to be sustainable

Sustainability in agriculture is becoming increasingly important as the world faces environmental challenges, resource depletion, and the need to feed a growing global population. Mixed farming, which combines crop cultivation with livestock rearing, has long been considered a versatile and resilient farming system. In the context of this study, mixed farming refers specifically to the integration of paddy cultivation and cattle rearing. This approach not only provides a diversified source of income for farmers but also plays a critical role in maintaining soil fertility, improving water use efficiency, and enhancing biodiversity. However, measuring the sustainability of mixed farming systems is essential to ensure that these practices contribute to long-term agricultural productivity while safeguarding environmental health.

The sustainability of mixed farming involves assessing both its environmental and socio-economic impacts. Practices that promote soil health, conserve water, and reduce chemical inputs are crucial for minimizing environmental degradation. Additionally, the integration of livestock and crops can offer benefits such as nutrient recycling and natural pest control, which contribute to sustainable farming systems. However, challenges such as overgrazing, water pollution from livestock waste, and land degradation must be carefully managed to ensure that mixed farming systems can remain viable in the long term. This study aims to evaluate the sustainability of mixed farming, particularly the integration of paddy cultivation and cattle rearing, to determine whether this practice can continue to meet both environmental and socio-economic needs for future generations.

7.2 Summary of Procedure

Recently mixed farming system receives increasing attention for its self sustainable feature. In the study mixed farming is defined as farming which practices paddy cultivation along with cattle rearing. Thus the study tried to understand better as whether mixed farming system could promote the attainment of three sustainability dimensions that is economic social and environmental and to what level. The study also aimed to explore the complementary relationship between two components such as paddy cultivation and cattle rearing within mixed farming system. The study also focused on determinants of sustainability of mixed farming.

For analyzing the stated objectives, the study was conducted in Palakkad District of Kerala and data was collected from 394 farmers practicing paddy cultivation along with cattle rearing. Two important indices are computed such as Complementarity Index – to measure the complementary relationship between paddy cultivation and cattle rearing and Sustainability Index – to measure the economic, environmental and social sustainability of mixed farming. To measure the sustainability of mixed farming the FAO's approach to evaluating Indicator 2.4.1 Sustainable Agriculture served as the basis with some modifications. To trace out the determinants of sustainability in mixed farming, the Tobit model is used. The Tobit model is a special kind of statistical tool used to understand relationships in situations where some of the data is limited or censored.

7.3 Summary of Findings

7.3.1 Complementarity in Mixed Farming

Understanding the features of mixed farmers, such as their land ownership, experience, and farming practices, is essential as it helps in recognizing how the integration of paddy and cattle rearing can enhance complementarity and sustainability. The majority of mixed farmers are above 50 years of age, with male ownership of mixed farm area as predominant. Majority of mixed farmers belong to the OBC category and have educational qualifications below SSLC, with an average of 29.5 years of experience in mixed farming. Agriculture is the main occupation for most of the mixed farmers, and they typically belong to nuclear families with up to four members. Mixed farms are primarily managed by both male and female member of a family, typically husband and wife.

The primary technologies used in mixed farming include tractors, tillers, sowing machines, harvesting machines, winnowing machines, and milking machines, though milking machine usage is comparatively low. Despite fewer training programs attended by farmers for mixed farming activity compared to paddy cultivation, farmers integrate cattle rearing with paddy farming mainly to generate extra income and employment opportunities. Furthermore, the majority of farmers own less than one hectare of mixed farm area, classifying them as marginal farmers. Additionally, majority of mixed farmers adopt international breeds of cattle, with the majority owning up to two milking cattle. A smaller percentage own three to five, and even fewer own six to eight. Similarly, in young stock, most farmers own up to two heads, while very few own larger numbers. These findings imply that combining the cattle raising with paddy is viewed as advantageous, which benefits farmers.

The study aimed to explore the complementarity between two components such as paddy cultivation and cattle rearing within mixed farming system. Complementarity in mixed farming refers to how paddy cultivation and cattle rearing can work together to achieve better outcomes compared to when they are considered in isolation. The findings from the Complementarity Index (CI) which is computed by combining the methodology adopted by Choi, 2008 and Lee, 2011, reveal several key insights into mixed farming practices. The Complementarity Index indicates that 88.1% of mixed farms demonstrated complementarity between paddy cultivation and cattle rearing, enhancing both productivity and resource efficiency.

From the analysis it is clear that the mixed farming demonstrate significant complementarity. For example, livestock manure can be used to fertilize paddy fields, while paddy cultivation provide dry and green fodder for the animals, thus reducing input cost and creating a more efficient and sustainable farming system. Complementary practices reduce waste by utilizing byproducts from one part of the system (such as crop residues) in another part (e.g., livestock feed, composting), promoting a circular and more sustainable approach to farming. Therefore measuring complementarity in mixed farming is essential for optimizing resource use, enhancing productivity, and promoting sustainability. By understanding how mixed farming interact or complement each other, farmers, policymakers, and researchers can create more sustainable and profitable agricultural systems. The mixed farming systems can increase resilience to climate change, pests, and diseases, while also diversifying income streams for farmers and reducing environmental impacts. By understanding and applying complementarity, mixed farmers can improve yields, mitigate risks, and contribute to long-term food security and environmental sustainability

7.3.2 Economic, Environmental and Social Sustainability of Mixed Farming

Mixed farms are systems made up of several components that should work as a unit. To comprehend the system, they must therefore be examined as a whole rather than as discrete components. By effectively merging the production of crops and livestock, Mixed Farming System (MFS) may be able to reduce the need for outside inputs and alleviate some of the environmental issues facing agriculture today. However, MFS would have to show greater (or at least comparable) economic, environmental, and social benefits than specialized farming in order to be preserved or reintroduced. Therefore, more research is required to determine whether MFS could support the three sustainability criteria.

Sustainability index of mixed farming is an essential tool for assessing and promoting sustainable agricultural practices. It evaluates a mixed farm's ability to balance environmental health, economic profitability and social well-being. By using such an index, mixed farmers can enhance the long-term sustainability of their operations and contribute to a more sustainable farming system.

The sustainability level of mixed farms in terms of farm output value per hectare reveals that 25.9% of mixed farms are categorized as "Acceptable," 55.6% of mixed farms are categorized as "Unsustainable." The sustainability level of mixed farms in terms of net farm income shows that 26.9% of mixed farms are categorized as "Acceptable," while 37.8% are classified as "Desirable" and 35.3 % of mixed farms, however, are classified as "Unsustainable." The sustainability level of mixed farms regarding risk mitigation mechanisms, exhibits that 72.3 % of mixed farms are classified as "Acceptable" while 27.7 % of mixed farms are classified as "Desirable". The summary of the economic sustainability of mixed farms shows that 75.6 % of mixed farms are classified as "Acceptable" while only 6.1 % of mixed farms are classified as "Desirable" and 18.3% of mixed farms are "Unsustainable". The most significant sub indicator that hinders economic sustainability is farm output value per hectare followed by net farm income. All mixed farms have maintained sustainability standards regarding the sub indicator risk mitigation mechanisms. Concerning the sub indicator net farm income, if imputed costs of family labour are added upon, then the mixed farming is not profitable. Without considering own labour costs, the mixed farming system is profitable. That means the profitability of mixed farming depends on family labour.

So mixed farming can be considered as family farming. Moreover in Palakkad District, the mixed farming system is followed by many as a meaningful engagement to family members in addition to income earning. Moreover, it has become a part of culture to the peasant community since years back so far.

The sustainability status of prevalence of soil degradation in mixed farming system. shows that 85.8 % of mixed farms are classified as “Desirable,” while 5.1% are deemed “Acceptable”. But 9.1% of mixed farms are operating at “Unsustainable” levels. The sustainability status of variation in water availability in mixed farming system exhibits that 84% of mixed farms are classified as “Desirable” while 4.8% are deemed “Acceptable”. But 11.2 farms are operating at “Unsustainable” level regarding variation in water availability. The sustainability status of management of fertilizers in mixed farming system reveals that 54.8% of mixed farms are classified as “Desirable” while 39.3% are deemed “Acceptable”. But 5.8% farms are operating at “Unsustainable” level. The sustainability status of mixed farming in terms of management of pesticides summarizes that 53.6% of farms are classified as “Unsustainable” and 43.7 % are Desirable. Only 2.8 % farms are deemed as “Acceptable”. The sustainability level of mixed farming system in terms of use of agro biodiversity practices shows that 77.4% of mixed farms are classified as “Acceptable” and 22.6% of mixed farms are deemed as “Desirable”. The most significant barrier to environmental sustainability is management of pesticides. Majority of the farmers are using moderately hazardous and restricted pesticides. But all mixed farms have adhered to sustainability standards concerning the use of agro-biodiversity practices. The summary of environmental sustainability level of mixed farms shows that 41.6% of mixed farms are classified as “Acceptable” while only 12.7% of mixed farms are classified as “Desirable” and 45.7% of mixed farms are “Unsustainable”. The usage of manure of the cattle makes the mixed farmer less dependent on chemical fertilizers and so soil fertility and health is maintained. Thus paddy cultivation and cattle rearing is continuing as a balancing approach.

The sustainability status of mixed farming operations based on the wage rate indicator within the mixed farming system reveals that 94.9% of these farms are classified as “Desirable,” while 5.1% are deemed “Unsustainable” regarding wage rates. This unsustainability is attributed to the fact that female agricultural workers on these 5.1% of farms receive wages that fall below the national minimum wage rate. The sustainability status of food security among farm households observed that 96.2% of farm households are “Desirable”, while 0.8% of them are “Acceptable”. Additionally, 3% of farm households are categorized “Unsustainable”. The sustainability status of land access is categorized as follows: 81.7% of farmers have a "Desirable" status, indicating secure rights to land. Only 2.1% are classified as "Acceptable," reflecting limited security. In contrast, 16.2% fall under the "Unsustainable" category, suggesting a lack of secure access to land. The summary of the social sustainability level of mixed farms shows that 81% of mixed farms are classified as “Desirable” while only 3% of mixed farms are classified as “Unsustainable” and 16% of mixed farms are “Acceptable”.

Based on the data presented, it can be concluded that the majority of farms are maintaining sustainability. With 151 mixed farms classified as Desirable and 108 as Acceptable, a total of 259 that is 65.7% of mixed farms are demonstrating sustainable practices. In comparison, the 34.3% of mixed farms identified as Unsustainable make up a smaller portion of the overall total. This suggests that most mixed farms are either meeting or nearing sustainability standards, reflecting a positive trend in sustainable farming. However, the existence of unsustainable mixed farms highlights the ongoing need for support and interventions to further improve farming practices across the sector.

7.3.4 Determinants of Sustainability in Mixed Farming

The sustainability of mixed farming is influenced by several key factors, each playing a vital role in the overall resilience and efficiency of the system. When constructing a sustainability index for mixed farming, various determinants are considered to provide a comprehensive evaluation. Beyond the commonly recognized factors, other important determinants include experience in mixed farming, imputed expenses of mixed farming, cattle output share to mixed farming income, contribution of family labour, mixed farming output, paid out expenses and cattle value.

The study of sustainability determinants in mixed farming reveals that factors like cattle output share and farming experience positively influence sustainability, while mixed farming output and contribution of family labour negatively affect the sustainability index. Other variables, such as imputed expenses, paid out expenses and cattle value, were found to be insignificant in influencing the sustainability index. By examining these factors, the study aims to identify practices that can improve the economic, environmental, and social sustainability of mixed farming.

The analysis further highlights that experience in mixed farming plays a crucial role in enhancing sustainability. Livestock, especially cattle, are key to the sustainability of mixed farming, as their efficient management directly impacts the system. However, the use of more family labour tends to lower sustainability, suggesting that a heavy reliance on household resources for manual labour can lead to inefficiencies. Additionally, the relationship between mixed farming output and sustainability is inversely proportional, meaning that higher output levels tend to reduce sustainability. This implies that large-scale or commercial mixed farming may be less sustainable than small-scale, subsistence farming, which is more labour-intensive and less reliant on external inputs. In conclusion, the sustainability of mixed farming is more closely associated with smaller-scale operations that emphasize efficiency, ecological balance, and local resource management, rather than focusing on maximizing output.

7.4 Conclusion

In summary, the study on mixed farming and its sustainability emphasizes the significance of implementing methods that strike a balance between social well-being, environmental health, and economic viability. Sustainable farming methods protect natural resources, promote social justice in farming communities, and guarantee long-term food security. Through resource efficiency, revenue diversification, and inclusion, farmers may adapt to challenges such as labour shortages, market volatility, and climate change. Ultimately, sustainable farming not only ensures the resilience of agricultural systems but also advances the broader goal of creating a more equitable and sustainable future for all.

7.5 Policy Implications

The policy implications of the study are crucial for shaping agricultural practices, supporting farmers, and ensuring food security while protecting the environment. The study highlights a close affinity between mixed farming and sustainability, but noted the limited availability of government schemes to promote mixed farming practices. Therefore, policies need to encourage the adoption of mixed farming through subsidies or government schemes that support farmers implementing these practices. Additionally, providing training and education to farmers on effective mixed farming practices and better management techniques is important. It is also important to ensure a minimum wage rate for female agricultural labourers, promoting fair wages and improving labour conditions. The study highlights that low farm output value per hectare and improper use of pesticides remains a significant issue for many mixed farms, which needs to be addressed.

7.6 Further Scope of Research

The study has identified that in Kerala, paddy and fish are cultivated in Pokkali fields, which is similar to paddy cultivation combined with cattle rearing. This presents another mixed farming system that warrants further investigation for sustainability. While the current study focuses on two-component mixed farming system, there is potential to explore mixed farming systems involving three or more components. Additionally, the research scope can be extended beyond sustainability to areas such as labour allocation within mixed farming systems, and the role of mixed farming as a climate-smart agricultural practice. Investigating the role of mixed farming in enhancing soil health, water conservation, and resilience to climate change could also provide valuable insights.

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APPENDIX I
QUESTIONNAIRE

MIXED FARMING AND ITS SUSTAINABILITY: A STUDY ON PALAKKAD DISTRICT IN KERALA

BASIC INFORMATION

Name	
Name of Padasekharasamithi	
Position in Padasekharasamithi	
Taluk	

Section I – GENERAL INFORMATION

1	Age (Pls tick)	☐ 20-29 ☐ 30-39 ☐ 40-49	☐ 50-59 ☐ 60-69	☐ 70-79 ☐ Above 80
2	Gender (Pls tick)	☐ Male	☐ Female	☐ Others
3	Religion (Pls tick)	☐ Hindus ☐ Muslims	☐ Christians	☐ Others
4	Community (Pls tick)	☐ Gen ☐ OBC	☐ SC ☐ ST	☐ Others
5	Education			
6	Farming experience (IN YRS) in paddy production			
7	Farming experience in cattle rearing (IN YRS)			
8	Experience in mixed farming (IN YRS)			
9	Main occupation of the Farmer			
10	Annual income			
11	Family Type	☐ Joint		☐ Nuclear
12	Family Size	☐ Upto 4	☐ 5-8	☐ Above 8
13	State of health	☐ Excellent ☐ Good		☐ Normal ☐ Weak
14	Management of mixed farming (H-W, M-S, F-S, F-D, M-D, F-M-S, F-M-D, F-M-S-			

	D, F-M-S-S, F-M-D-D, etc)		
15	Peak(seasonal) labour period (no of days) in paddy production *		
16	No of hours spend for crop activity per day during peak season by male member or members in family *		
17	No of hours spend for crop activity per day during peak season by female member or members in family		
18	No of hours spend for crop activity per day during off peak season (routine) by male member or members in family		
19	No of hours spend for crop activity per day during off peak season (routine) by female member or members in family		
20	Distance between farm and the house (in kms):		
21	Is farmyard within the compound of the residing house	☐ Yes	☐ No

22. Land tenure type of the agricultural area of the holding

Tenure type	Area	Unit
Owned and operated		
Rented in		
Other		

23. Area of the holding

	Area	Unit
Farmyards		
Farm Buildings		

24. Paddy variety and season

	Name of Paddy	Area	Unit
Virippu (I crop)			
Mundakan (II crop)			
Puncha (III crop)			

25	Whether the holding has common area or embankment	☐ Yes	☐ No	
26	Area of commonly used or managed by the holding (Land shared by others)			
27	Purpose of common area	☐ Grazing land	☐ Cultivate grass	☐ Others
28	Categories of mixed farming			
28.1	Farmer use manure of livestock from own farmyard to fertilise his paddy field	☐ Yes	☐ No	
28.2	Farmer use paddy straw from own farm as feed	☐ Yes	☐ No	

		for cattle		
	If no, what are the reasons for non-integration? Are you any part of government scheme? If Yes, please mention the schemes			
29	Name the technologies used in mixed farming		1. ________________ 2. ________________ 3. ________________	
30	Have you attended any training programmes regarding paddy cultivation		☐ Yes	☐ No
31	Have you attended any training programmes regarding cattle rearing		☐ Yes	☐ No
32	Reason for raising livestock		☐ Extra income ☐ Gainful employment ☐ Others If others pls mention ____________	
33	Whether mixed farming is main occupation or subsidiary occupation of the farmer		☐ Main	☐ Subsidiary

Section II – Economic Sustainability

34. Particulars ofPaddy Production

		Annual Production Quantity(in kgs)	Disposal of Produce	Total value of production (in Rs.)

		Qty	Own Consumption	Avg price	Sales	Avg price	
I	Product						
	Bye-Product						
II	Product						
	Bye-Product						

36. Cost of Paddy production and marketing

Cost items	From where procured	Quantity	Paid out expenses	Imputed expenses
Seeds				
Chemical fertilisers				
Bio fertilisers				
Manures				
Plant protection materials-chemical				
Plant protection materials -bio pesticides				
Transportation charges				
Diesel				
Electricity				
Irrigation				
Labour human				
Labour animal				
Minor repair and maintenance of machinery and equipment used in crop production				
Interest charges				
Machine hiring				
Cost of crop insurance				
Lease rent for land used for crop production				
Marketing costs				
Subsidy				
Others (mention)				

37. Particulars of Cattle Production

Livestock name	Local or international breed	No ofheads at the beginning ofthe year	No of heads bought or received or live births	No of heads dead or slaughtered	No of heads sold during the year	No of heads at the end of the year	Average price per unit	Total value of production

38	No of days of milking in a year	
39	Avg litre of milk per day	

40. Disposal of produce and value of output on farming of animals during last YEAR

	Own consumption		**Disposal to**							
Item			**Other households**		**Cooperative**		**Private processors**		**Others**	
	Qty	**Value**	**Qty**	**Value**	**Qty**	**Value**	**Qty**	**Value**	**Qty**	**Value**
Milk(litre)										
Manure										
Other										

41. Cost of livestock production and marketing

Input item		**from where procured?**	**Quantity**	**Paid out expenses**	**Imputed expenses**
Animal feed (per month)	Cattle feed				
	Green fodder				
	Dry fodder				

	Concentrates				
	Others				
Veterinary expenses (per year)	For breeding				
	Health services				
Others	Interest on loans utilised for farming of animals				
	Lease rent for land used for farming of animals				
	Labour charges				
	Cost of livestock insurance				
	Marketing costs				
	Other expenses				

42	Are you aware of any risk mitigating mechanisms?	☐ Yes	☐ No
43	Did this holding have access to or avail any of the following mechanisms for protection against external shocks?		
	☐ This holding had access to or availed credit (i.e. formal and/or informal) for protection against external shocks ☐ This holding had access to or availed insurance for protection against external shocks ☐ Neither the holding had access to nor availed any of the above mechanisms for protection against external shocks		
44	What are self-adjustment strategies of risk management adopted by farmers?	☐ Income from livestock products ☐ Sale of livestock ☐ Others. If Others, please mention - ____________	

Additional Questions:

Rate of one roll of straw	
Rate of one machine roll of straw	

Kg of manure per basket or vessel or container	
Rate for one basket manure	
No of kilos per vessel of paddy	

Section III – Environmental Sustainability

45. Have you experienced any of the soil degradation threats experienced on the holding?

Threats	Yes	No	Area of the holding affected by threats
Soil erosion (loss of topsoil through wind or water erosion)			
Reduction in soil fertility			
Salinization of irrigated land			
Excessive Waterlogging			
Other (Specify)			

46	Did this agricultural holding use water to irrigate crops?	☐ Yes (area of irrigation) - ___________ ☐ No, I don't need irrigation ☐ No, I can't afford irrigation ☐ No there is no water available
47	Agricultural area irrigated	
48	Are you observing any reduction in water availability from well or other sources?	☐ No water is always available in sufficient quantity when I need it ☐ Yes, water level in my well is progressively going down ☐ Yes, water in river, lake or canal is getting scarce and I can't have reliable supply when I need it ☐ I do not know
49	Are there organisations dealing with water allocation in this area?	☐ Yes, they are working well ☐ Yes, they are not working well ☐ No there are none ☐ Idon't know

50. Did this agricultural holding use any fertilizer for crops?

Name of fertilizer	Nature of fertilizer

51	Are you aware of the environmental risks associated with excessive /misuse of fertilizer?	☐ Yes	☐ No
52	Did this agricultural holding take specific measures to mitigate the environmental risks associated with the use synthetic and mineral fertisers?	☐ Yes	☐ No

53. Specific measures taken to mitigate the environmental risks associated with the excessive use or misuse use of fertilizers as per list below:

MEASURES	**YES**	**NO**
Follow protocols as per extension service or retail outlet directions or local regulations, not exceeding recommended doses		
Use organic source of nutrients (including manure or composting residues) alone, or in combination with synthetic or mineral fertilizers		
Use legumes as a cover crop, or component of a multi/crop or pasture system to reduce fertilizer inputs		
Distribute synthetic or mineral fertilizer application over the growing period		
Consider soil type and climate in deciding fertilizer application doses and frequencies		
Use soil sampling at least every 5 years to perform nutrient budget calculations		
Liming of soil		
Use buffer strips along water courses. (planting of perennial plants to reduce water runoff from fields, including loss of pesticides and fertilizers)		

54	Did this agricultural holding use pesticides for crop or livestock	☐ Yes	☐ No

	by the agricultural holding			
55	If yes,	Please mention the name of pesticides	1. ____________ 2. ____________	
56		What type of pesticides did this agricultural holding used?	☐ Moderately or slightly hazardous	☐ Highly, extremely hazardous or illegal pesticides
57	Are you aware of the environmental and health risks associated with the use of pesticides?		☐ Yes	☐ No
58	Did this agricultural holding take specific measures to protect people from health-related risks?		☐ Yes	☐ No

59. Which of the following measures did this agricultural holding adopt to protect people from health-related risks?

Health measures	**Yes**	**No**
Adherence to label directions for pesticide use (including use of protection equipment)		
Maintenance and cleansing of protection equipment after use		
Safe disposal of waste (cartons, bottles and bags)		
Cover head		
Protect mouth by using mask		
Wear gloves		
Wash hands with soap		
Wash body		
Prevent animals from going into sprayed area		

60	Did this agricultural holding adopt scientific measures to avoid environment related risks?	☐ Yes	☐ No

61.Measures taken to avoid environment-related risks associated with pesticides:

MEASURES	**YES**	**NO**
Adherence to label directions for pesticide application		
Adjustment of planting time		
Appropriate timing of pesticide application		
Timely removal of weeds		

Planting pest tolerant varieties		
Correct dose of appropriate pesticide		
Balanced doses of fertilisers		
Application of crop spacing		
Application of crop rotation		
Perform biological pest control		
Use of biopesticides		
Adopting pasture rotation to suppress livestock pest population		
Systematic removal of plant parts attacked by pests		
Pest monitoring, removal of egg mass and uprooting affected plants		
Maintenance and cleansing of spray equipment after use		
Use one pesticide no more than two times or in mixture in a season to avoid pesticide resistance		

62. In this agricultural holding, are there areas covered by natural or diverse vegetation? including one or a combination of the following:

	Area		
Natural pasture or grasslands			
Wildflower strips			
Stone or wood heaps			
Trees or hedgerows			
Natural ponds or wetlands			
None of the above			

63	Did the holding produce crops and/or livestock that are certified organic or undergoing the organic certification process during the reference period?	☐ Yes	☐ No
64	Are you using antimicrobials as growth promoters for cattle? If yes, name the AGP?	☐ Yes	☐ No

65

Description	Quantity	Price	Farm output value	Percentage of contribution to total output
Crops				
Trees (products)				
Pasture				
Livestock or animal products				
Fish				
Others				

66	What is the percentage of the agricultural area on which crop rotation or crop/pasture rotation involving at least two different crops/pastures of two different plant genus is practiced	

67. Animal Species

Sl no	Animal species	Total number of animals under each animal species	Animal breed	Animal breed number	Share of animal breeds locally adopted or at risk of extinction

Section IV: Social Sustainability

68	Did this agricultural holding hire any worker for carrying out simple and routine tasks?	☐ Yes	☐ No
69	How much is average pay in-cash and/or in-kind paid to the hired unskilled worker per day (of 8 hours)	☐ Daily average wage: ________________ ☐ Daily average wage pays in kind and converted in rupees: ________________	

70. Food Insecurity Experience

STATEMENTS	YES	NO
Do you or any other adult worried about not having enough food to eat due to lack of money or other resources		
Are you or any other adult was unable to eat healthy and nutritious food because of lack of money or other resources		
Are you or any adult in the household able to ate a few kinds of food due to lack of money or other resources		
Did you or any adult in the household had to skip a meal because there was no enough money or other resources for food		
Did you or any adult in the household ate less than he/she thought he should due to lack of money or other resources		
Did you or your household ran out of food because of a lack of money or other resources		
Are you or any adult in the household was hungry but not eating due to lack of money or other resources for food		
Do you agree that you or any adult in the household did not eat for a whole day because of a lack of money or other resources		

71.

FOOD CONSUMPTION	YES	NO	NA
Do you require produced rice from mixed farming for your family?			
If yes, do you consume produced rice from mixed farming in your family?			
Do you require produced milk from mixed farming for your family?			
If yes, do you consume produced milk from mixed farming in your family?			
Do you buy rice from outside even if it is cultivated in your own farm?			
Do you buy milk from outside even if it is produced in your own farm?			

72	How many months your family can consume produced rice from mixed farming?	
73	How many months your family consumes rice from mixed farming?	
74	How many months your family can consume milk and milk products from mixed farming?	

75	How many months your family consume milk and milk products from mixed farming?	
76	Reasons for non-consumption of rice	
77	Reasons for non-consumption of milk	

78.Land Tenure Secure Rights

STATEMENTS	YES	NO
Do you have a formal document for any of the agricultural land of the holding that it holds issued by the register office?		
Is the name of any member of the holding listed as an owner or use right holder on any of the legally recognized documents?		
Is there the right of the holder/holding to sell any of the parcel of the holding?		
Is there right of the holder/holding to leave property to a person by a will any of the parcel of the holding?		

APPENDIX II

Computation of Complementarity Index

II.1 Introduction

The complementarity index is grounded in Edgeworth's classical definition of complementarity, which was modernized using the framework of supermodular functions as in Choi et al. (2008). By combining the methodology followed by Choi et al., 2008 and Lee, 2011 the study has tried to assess whether activities and practices in mixed farming system are mutually complementary and so tend to be adopted together, with each enhancing the contribution of the other. Therefore, the impact of a system of complementary practices will be greater than the sum of its parts because of the synergistic effects of bundling practices together. (Choi et al., 2008) Based on the concept of complementarity and its supermodularity functional representation, the study considered net farm income in the context of a supermodular function. Complementarity based on net farm income refers to the synergistic relationship between paddy cultivation and cattle rearing where their combined activity leads to higher net farm income than if they were managed independently. The study derived a functional equation—based on their framework—to model how two key activities in mixed farming, namely paddy cultivation and cattle rearing, interact. The key assumption is that the joint contribution of both activities to net farm income is greater than the sum of their separate contributions.

II.2 Complementarity

The original concept "complementarities" was first introduced by Edgeworth in which he defined activities as complements, if doing (more of) any one of them increases the returns to doing (more of) the others. (Choi et al., 2008) By drawing on lattice theory and supermodularity, Milgrom and Roberts proposed that some organizational activities and practices are mutually complementary and so tend to be adopted together, with each enhancing the contribution of the other. (Choi et al., 2008) Therefore, the impact of a system of complementary practices will be greater than the sum of its parts because of the synergistic effects of bundling practices together. (Choi et al., 2008)

II.3 Complementarity Analysis

Complementarity analysis in the study is based on the method developed by Choi et al. (2008). Suppose there are two knowledge management strategies adopted by a firm ($X1$ and $X2$). Each strategy can be adopted ($X1 = 1$) or not adopted ($X1 = 0$) and ($X2 = 1$) or not adopted ($X2 =$

0*)*. The performance function $Y = f\,(X1,X2)$ is supermodular and $X1$ and $X2$ are complements if and only if: (Choi et al., 2008)

$f\,(1, 1) - f\,(0, 1) \geq f\,(1, 0) - f\,(0, 0)$ ***(Choi et al., 2008***……………….. *1*

II.4 Computation of complementarity index

It has been attempted to determine whether the activities in mixed farming systems are mutually complementary and, thus, tend to be adopted jointly, with each one improving the contribution of the other, by integrating the methods used by Choi (2008) and Lee (2011). Because of the synergistic effects of combining practices, a system of complementary practices will have a greater impact than the sum of its parts. (Choi et al., 2008)

Based on the concept of complementarity and its supermodularity functional representation, the study considered net farm income in the context of a supermodular function. To analyze data in the context of a supermodular function, the study first need to clarify a few concepts. There are two agricultural activity within mixed farming system.(M_1 and M_2). Each agricultural activity can be adopted by the farmer $(M_1 = 1)$ or not adopted $(M_1 = 0)$ and $(M_2 = 1)$ or not adopted $(M_2 = 0)$. (Choi et al., 2008) The performance function $Y = f\,(M_1,M_2)$ is supermodular and $M1$ and $M2$ are complements if and only if:

$f\,(1, 1) + f\,(0, 0) \geq f\,(1, 0) + f\,(0, 1)$. ***(Choi et al., 2008)……………2***

i.e. adding a agricultural activity while already executing the previous activity has a higher net farm income than when using the first strategy in isolation. Even though the concept of complementarities offers a set of important implications for analyzing organizational performance, there is no well-established theory to conceptualize the association between M1 and M2. (Choi et al., 2008) Complementarity based on net farm income refers to the synergistic relationship between paddy cultivation and cattle rearing where their combined activity leads to higher net farm income than if they were managed independently.

Table 1 Complementarity Function

Performance Function	*Description*
$f(M_1,M_2)$	*Net farm income of agricultural activity ie mixed farming given that both paddy production and cattle rearing practiced simultaneously*
$f(0,0)$	*Net farm income of mixed farming without either paddy production or cattle rearing being practiced*
$f(M_1,0)$	*Net farm income of agricultural activity that only paddy production is practiced*
$f(0,M_2)$	*Net farm income of agricultural activity that only cattle rearing is practiced*

Source : (Choi et al., 2008)

$$\text{Complementarity Index (CI)} = \frac{f(M_1, M_2) + f(0,0)}{f(M_1, 0) + f(0, M_2)} \quad \text{----------- 3 (Choi et al., 2008)}$$

$$= \frac{(NFI_P + NFI_C) - \Delta C + NFI_0}{(NFI_P + NFI_C)} \quad \text{-----------4}$$

NFI_P = Net farm income of paddy cultivation

NFI_C= Net farm income of cattle rearing

NFI_0= Net farm income of on farm activities other than paddy cultivation and cattle rearing

ΔC = Change in costs due to mixing or Complementarity of these activities

NFI_P= CR+Y_K - OE -------5 (FAO, 2020)

NFI_C= CR+Y_K -OE------6 (FAO, 2020)

NFI_0= Farmer’s declaration of net farm income from on farm activities

CR = Total farm cash receipts including direct program payments (FAO, 2020)

Yk = Income in kind (FAO, 2020)

OE = Total operating expenses after rebates (including costs of labour) (FAO, 2020)

The complementarity index is based on the above equations. If the results of the index are greater than 1.0, two activities are decided as complementary to each other; otherwise, they are not. (Lee et al., 2011)

APPENDIX III

Computation of Sustainability Index

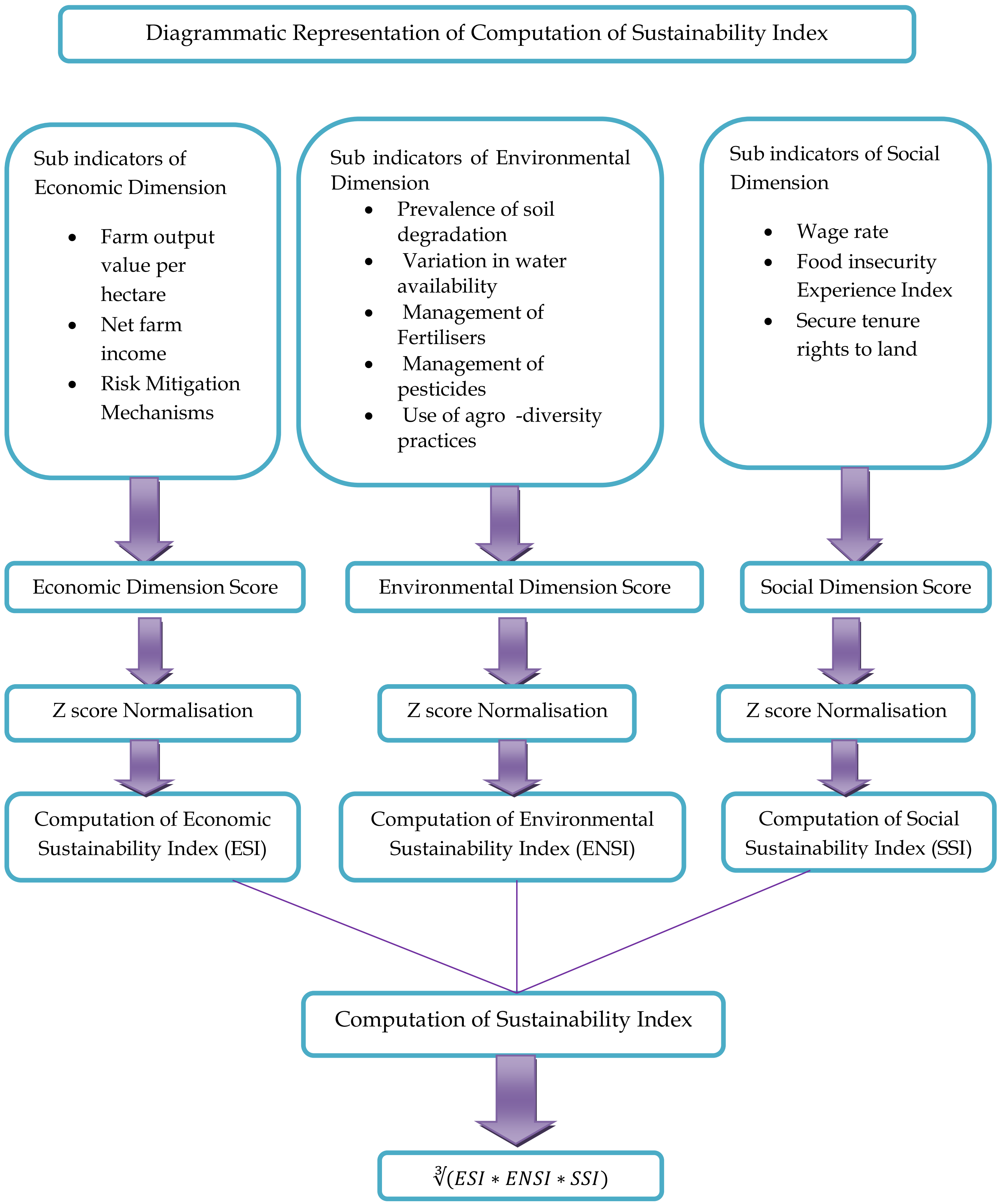
III.1 Computation of Sustainability Index

A sustainability index is a measure or tool used to assess the sustainability of a system, such as an agricultural farm, a business, or even an entire economy. It is typically a composite index that takes into account various environmental, social, and economic factors to evaluate how well a system or practice aligns with sustainability goals. The index helps stakeholders understand the current state of sustainability and track improvements or declines over time. In the context of mixed farming, a sustainability index could evaluate the sustainability of farming practices based on multiple criteria that contribute to long-term viability without compromising the environment, society, or economy.

The UNDP method of HDI calculation is used to construct the Sustainability Index of mixed farming. The economic dimension is assessed by farm output value per hectare of mixed farm, net farm income of mixed farm and risk mitigation mechanisms of mixed farm. The environmental dimension is assessed by prevalence of soil degradation, variation in water availability, management of fertilizers, management of pesticides and use of agro-diversity-supportive practices. The social sustainability is assessed by wage rate in mixed farming system, food insecurity experience and secure tenure rights to land. Each dimension score is computed and these scores are converted into Z scores. Then dimension indices are calculated as:

$$\text{Dimension Index} = \frac{\text{Actual Value-Minimum Value}}{\text{Maximum Value-Minimum Value}}$$

The sustainability index is the geometric mean of normalized indices for each of the three dimensions. Mixed farms are categorized as Desirable, Acceptable, and Unsustainable based on the calculation of the 33 and 66 percentiles of SI. The diagrammatic representation of computation of Sustainability Index with 3 dimensions and 11 sub-indicators is shown below**:**


Diagrammatic Representation of Computation of Sustainability Index
Sub indicators of Economic Dimension
• Farm output value per hectare
• Net farm income
• Risk Mitigation Mechanisms
Sub indicators of Environmental Dimension
• Prevalence of soil degradation
• Variation in water availability
• Management of Fertilisers
• Management of pesticides
• Use of agro -diversity practices
Sub indicators of Social Dimension
• Wage rate
• Food insecurity Experience Index
• Secure tenure rights to land
Economic Dimension Score
Environmental Dimension Score
Social Dimension Score
Z score Normalisation
Z score Normalisation
Z score Normalisation
Computation of Economic Sustainability Index (ESI)
Computation of Environmental Sustainability Index (ENSI)
Computation of Social Sustainability Index (SSI)
Computation of Sustainability Index
$\sqrt[3]{(ESI * ENSI * SSI)}$