

**CLIMATE SMART RICE CULTIVATION
SYSTEMS IN SOUTHERN KARNATAKA: AN
ECONOMIC ANALYSIS**



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UNIVERSITY OF AGRICULTURAL SCIENCES
BANGALORE**

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By

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BANGALORE**

2022




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CERTIFICATE

This is to certify that the thesis entitled “**CLIMATE SMART RICE CULTIVATION SYSTEMS IN SOUTHERN KARNATAKA: AN ECONOMIC ANALYSIS**” submitted in partial fulfillment of the requirement for the degree of **DOCTOR OF PHILOSOPHY in AGRICULTURAL ECONOMICS** to the University of Agricultural Sciences Bangalore is record of *bona fide* research work carried out by **Bindu, H. A., PALB 9006** during the period of her study in this University, under my guidance and supervision. The thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

Place: Bengaluru

December, 2022


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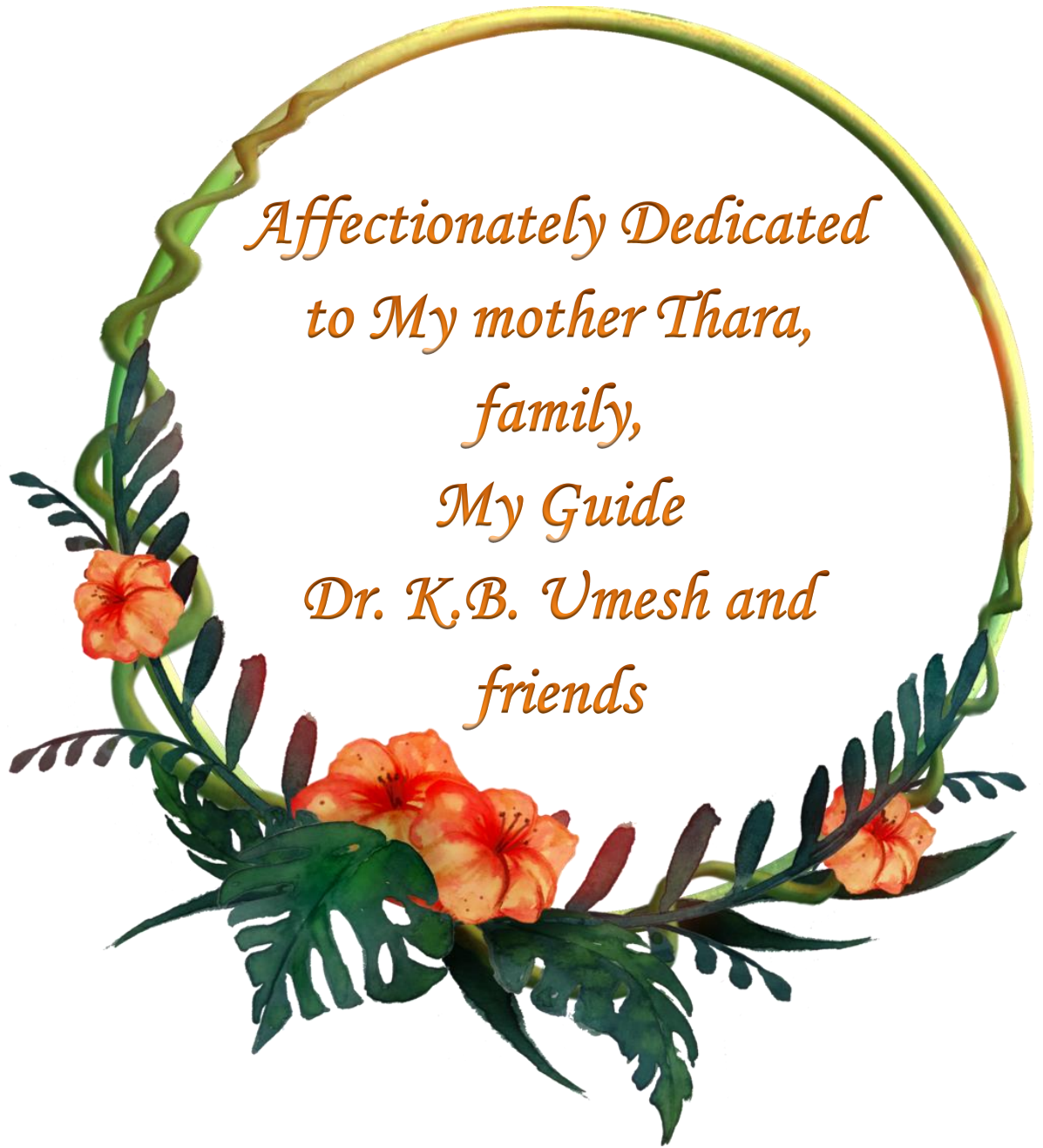
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*Affectionately Dedicated
to My mother Thara,
family,
My Guide
Dr. K.B. Umesh and
friends*

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CLIMATE SMART RICE CULTIVATION SYSTEMS IN SOUTHERN KARNATAKA: AN ECONOMIC ANALYSIS

BINDU, H. A.

ABSTRACT

The present study was undertaken in Mandya district of Karnataka to study the economics of climate smart rice cultivation systems. Farmers growing rice under conventional and climate smart practices such as System of Rice Intensification (SRI), aerobic and Drum Seeded Rice (DSR) system of cultivation were selected for the study. The data was collected from 30 farmers from each system and 80 consumers were selected to assess the trait preferences. The cost of cultivation was lowest in DSR method (Rs. 43,444/ac) and highest in conventional method (Rs. 50,926/ac). The farmers under SRI method obtained higher yield i.e. 33.20 q per acre. Farmers under SRI method were technically efficient and those under aerobic were allocatively efficient. Physical and economic Water Use Efficiency (WUE) was higher in SRI method of cultivation. Partial budgeting of cultivations systems over conventional revealed that, net gain from SRI method was maximum and was Rs. 17,236 per acre. Farmers perceive there are positive and negative externalities from rice cultivation. The negative externalities identified were irrigation subsidy, GHGs and environment damage cost emissions and was quantified at Rs.1,808 per acre which was highest in conventional method. Farmers' trait preferences for rice, which is an input for breeders was assessed and revealed that, high yield, resistance to pests and diseases and market oriented aspects were the major traits preferred by farmers. While, consumers preferred size, colour and shape traits for rice consumption. The farmers across different cultivation systems followed only some of the adaptation and mitigation strategies such as applying of potash, agro-forestry, use of organic manure etc. The study emphasizes climate smart practices for rice cultivation such as SRI and aerobic method to reap the benefits of higher yield, efficiency and to reduce the externalities and also suggests adoption of adaptation and mitigation strategies for sustainable production.

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ದಕ್ಷಿಣ ಕರ್ನಾಟಕದಲ್ಲಿ ಹವಾಮಾನ ನೈಪುಣ್ಯ ಭತ್ತದ ಬೇಸಾಯ ಪದ್ಧತಿಗಳ ಆರ್ಥಿಕ ವಿಶ್ಲೇಷಣೆ

ಬಿಂದು, ಹೆಚ್. ಎ.

ಸಾರಾಂಶ

ಹವಾಮಾನ ನೈಪುಣ್ಯ ಭತ್ತದ ಬೇಸಾಯ ಪದ್ಧತಿಗಳ ಆರ್ಥಿಕತೆಯನ್ನು ವಿಶ್ಲೇಷಿಸಲು ಪ್ರಸ್ತುತ ಅಧ್ಯಯನವನ್ನು ಕರ್ನಾಟಕದ ಮಂಡ್ಯ ಜಿಲ್ಲೆಯಲ್ಲಿ ಕೈಗೊಳ್ಳಲಾಯಿತು. ಸಾಂಪ್ರದಾಯಿಕ ಬೇಸಾಯ ಪದ್ಧತಿ ಹಾಗೂ ಹವಾಮಾನ ನೈಪುಣ್ಯ ಬೇಸಾಯ ಪದ್ಧತಿಗಳಾದ ಶ್ರೀ ಪದ್ಧತಿ, ಅರೆನೀರಾವರಿ ಪದ್ಧತಿ ಮತ್ತು ಕೂರಿಗೆ ಬಿತ್ತನೆ ಭತ್ತದ ಪದ್ಧತಿಗಳನ್ನು ಅನುಸರಿಸುತ್ತಿರುವ ತಲಾ 30 ರೈತರಿಂದ ಅಧ್ಯಯನಕ್ಕೆ ಬೇಕಾದ ದತ್ತಾಂಶವನ್ನು ಸಂಗ್ರಹಿಸಲಾಯಿತು. ಹಾಗೆಯೇ, ಭತ್ತದ ಗುಣಲಕ್ಷಣಗಳ ಆಧ್ಯತೆಯನ್ನು ಪರಿಶೀಲಿಸಲು 80 ಜನ ಗ್ರಾಹಕರಿಂದ ಮಾಹಿತಿಯನ್ನು ಪಡೆಯಲಾಯಿತು. ಬೆಳೆ ವೆಚ್ಚವು ಕೂರಿಗೆ ಬಿತ್ತನೆ ಭತ್ತ (ರೂ. 43,444 ಪ್ರತಿ ಎಕರೆಗೆ) ಪದ್ಧತಿಗಿಂತ ಸಾಂಪ್ರದಾಯಿಕ ಪದ್ಧತಿಯಲ್ಲಿ (ರೂ. 50,926 ಪ್ರತಿ ಎಕರೆಗೆ) ಅತ್ಯಧಿಕವಾಗಿತ್ತು. ಶ್ರೀ ಪದ್ಧತಿ ಅನುಸರಿಸುವ ರೈತರು ಅತ್ಯಧಿಕ ಇಳುವರಿಯನ್ನು ಪಡೆದಿರುತ್ತಾರೆ (33.20 ಕ್ವಿ/ಎ). ಶ್ರೀ ಪದ್ಧತಿಯ ರೈತರು ತಾಂತ್ರಿಕವಾಗಿ, ಅರೆನೀರಾವರಿ ಪದ್ಧತಿಯ ರೈತರು ಹಂಚಿಕೆಯಲ್ಲಿ ಹಾಗೂ ಶ್ರೀ ಪದ್ಧತಿಯ ರೈತರು ನೀರಿನ ಬಳಕೆಯಲ್ಲಿ ಭೌತಿಕ ಮತ್ತು ಆರ್ಥಿಕ ಸಮರ್ಥರಾಗಿರುತ್ತಾರೆ ಎಂದು ತಿಳಿದು ಬಂದಿರುತ್ತದೆ. ಸಾಂಪ್ರದಾಯಿಕ ಹಾಗೂ ಇತರೆ ಬೇಸಾಯ ಪದ್ಧತಿಗಳಿಗೆ ಹೋಲಿಸಿದರೆ ಶ್ರೀ ಪದ್ಧತಿಯಲ್ಲಿ ಪ್ರತಿ ಎಕರೆಗೆ ನಿವ್ವಳ ಆದಾಯವು ರೂ. 17,236 ರಷ್ಟು ಅಧಿಕವಾಗಿದೆ. ಭತ್ತದ ಬೇಸಾಯದಿಂದ ಸಕಾರಾತ್ಮಕ ಮತ್ತು ನಕಾರಾತ್ಮಕ ಬಾಹ್ಯತೆಗಳಿವೆ ಎಂದು ರೈತರು ಅಭಿಪ್ರಾಯ ಪಟ್ಟಿರುತ್ತಾರೆ. ನೀರಾವರಿ ಸಬ್ಸಿಡಿ, ಪರಿಸರ ಹಾನಿ ವೆಚ್ಚ ಮತ್ತು ಹಸಿರು ಮನೆ ಅನಿಲಗಳು ನಕಾರಾತ್ಮಕ ಬಾಹ್ಯತೆಗಳೆಂದು ಗುರುತಿಸಲಾಗಿದೆ ಮತ್ತು ಅವುಗಳ ವೆಚ್ಚವು ಪ್ರತಿ ಎಕರೆಗೆ ರೂ. 1,808 ಆಗಿದ್ದು ಮತ್ತು ಸಾಂಪ್ರದಾಯಿಕ ಪದ್ಧತಿಯಲ್ಲಿ ಅತ್ಯಧಿಕವಾಗಿದೆ ಎಂದು ಕಂಡುಬಂದಿರುತ್ತದೆ. ಹೆಚ್ಚಿನ ಇಳುವರಿ, ಕೀಟ ಮತ್ತು ರೋಗಗಳಿಗೆ ಪ್ರತಿರೋಧತೆ ಮತ್ತು ಮಾರುಕಟ್ಟೆ ಆಧಾರಿತ ಅಂಶಗಳಿಗೆ ರೈತರು ಹೆಚ್ಚಿನ ಆಧ್ಯತೆ ನೀಡುವ ಪ್ರಮುಖ ಗುಣಲಕ್ಷಣಗಳೆಂದು ಗುರುತಿಸಲಾಗಿರುತ್ತದೆ. ಈ ಮಾಹಿತಿಯು ತಳಿ ಅಭಿವೃದ್ಧಿಗಾರರಿಗೆ ಉಪಯೋಗಕರವಾಗಲಿದೆ. ಹಾಗೆಯೇ, ಗಾತ್ರ, ಬಣ್ಣ ಮತ್ತು ಆಕಾರ ಗುಣಲಕ್ಷಣಗಳು ಗ್ರಾಹಕರ ಆಧ್ಯತೆಗಳಾಗಿರುತ್ತವೆ. ರೈತರು ಅಳವಡಿಸಿಕೊಂಡಿರುವ ವಿವಿಧ ಬೇಸಾಯ ಪದ್ಧತಿಗಳಲ್ಲಿ, ಪೊಟ್ಯಾಷ್ ಬಳಕೆ, ಕೃಷಿ ಅರಣ್ಯ, ಸಾವಯವ ಗೊಬ್ಬರದ ಬಳಕೆ ಮುಂತಾದ ಕೆಲವು ಹೊಂದಾಣಿಕೆ ಮತ್ತು ಸರಳೀಕರಣ ತಂತ್ರಗಳನ್ನು ಅನುಸರಿಸಿದ್ದಾರೆ. ಹೆಚ್ಚಿನ ಇಳುವರಿ, ದಕ್ಷತೆ ಮತ್ತು ಬಾಹ್ಯ ಅಂಶಗಳನ್ನು ಕಡಿಮೆ ಮಾಡಲು ಹವಾಮಾನ ನೈಪುಣ್ಯ ಭತ್ತದ ಬೇಸಾಯ ಪದ್ಧತಿಗಳಾದ ಶ್ರೀ ಮತ್ತು ಅರೆನೀರಾವರಿ ಪದ್ಧತಿಗಳನ್ನು ಅಳವಡಿಸಲು ಒತ್ತಿಹೇಳಲಾಗಿದೆ. ಸಮರ್ಥನೀಯ ಉತ್ಪಾದನೆಗೆ ಹೊಂದಾಣಿಕೆ ಮತ್ತು ಸರಳೀಕರಣ ತಂತ್ರಗಳನ್ನು ಅಳವಡಿಸಿಕೊಳ್ಳುವುದನ್ನು ಪ್ರಸ್ತುತ ಅಧ್ಯಯನದಿಂದ ಶಿಫಾರಸ್ಸು ಮಾಡಲಾಗಿದೆ.

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ಪ್ರಧಾನ ಸಲಹೆಗಾರರು

CONTENTS

CHAPTER	TITLE	PAGE No.
I	INTRODUCTION	1
II	REVIEW OF LITERATURE	12
III	METHODOLOGY	30
IV	RESULTS AND DISCUSSION	56
V	SUMMARY	101
VI	REFERENCES	107
	APPENDICES	i
	PUBLICATIONS	I

LIST OF TABLES

Table No.	Particulars	Page No.
1.	General features of study area	31
2.	Land use pattern of study area	33
3.	Cropping pattern in the study area during 2015	34-35
4.	Trait and traits of rice considered for conjoint analysis	49
5.	Coefficients for valuation of externalities caused by different rice cultivation systems	53
6.	Socio-economic characteristics of rice farmers under different rice cultivation system	56
7.	Cost and returns under different rice cultivation systems	58
8.	Yield and returns of paddy under different rice cultivation systems	60
9.	Resource use efficiency in rice cultivation	62
10.	Parameter estimates from stochastic frontier (SRI, Aerobic, DSR and pooled) and stochastic meta frontier (SMF)	65-66
11.	Estimation of technical efficiency scores and technology gap ratios	68
12.	Maximum likelihood estimates of the stochastic cost frontier of rice farmers (Conventional method)	70
13.	Maximum likelihood estimates of the stochastic cost frontier of rice farmers (SRI method)	71
14.	Maximum likelihood estimates of the stochastic cost frontier of rice farmers (Aerobic method)	73
15.	Maximum likelihood estimates of the stochastic cost frontier of rice farmers (DSR method)	74
16.	Distribution and summary statistics for cost efficiency scores of farmers under different rice cultivation systems	75

Table No.	Particulars	Page No.
17.	Water use efficiency of paddy under different rice cultivation systems	76
18.	Number of farmers under each category of bids under different rice cultivation systems	77
19.	Factors affecting willingness to pay for irrigation water for farmers (conventional method)	79
20.	Factors affecting willingness to pay for irrigation water for farmers (SRI method)	79
21.	Factors affecting willingness to pay for irrigation water for farmers (Aerobic method)	81
22.	Factors affecting willingness to pay for irrigation water for farmers (DSR method)	82
23.	Functional analysis for farmers' actual willingness to pay for irrigation water	83
24.	Externality in rice cultivation (SRI) using partial budgeting of rice farms	84
25.	Externality in rice cultivation (Aerobic) using partial budgeting of rice farms	85
26.	Externality in rice cultivation (DSR) using partial budgeting of rice farms	86
27.	Farmers' perception on externalities from paddy cultivation	87
28.	Economic valuation of externalities in different rice cultivation system	89
29.	Rank based quotient for the traits preferred by rice producers	91
30.	Socio-economic profile of the sample consumers	92
31.	Trait or attribute preferences of rice consumers	92
32.	Correlation between consumer preferences traits or attribute	93
33.	Results of conjoint analysis of consumer's preference for rice produce in the study area	94

Table No.	Particulars	Page No.
34.	Farmers' perception on change in climatic conditions	95-96
35.	Ranking of climate change effects as perceived by farmers using Garrett ranking technique	98
36.	Adaptation and mitigation strategies followed by farmers in the study area	99

LIST OF FIGURES

Figure No.	Title	Page No.
1.	Map showing location and study area	32
2.	Format of double bounded dichotomous CVM used to estimate willingness to pay	45

LIST OF PLATES

Sl. No.	Title	Between Pages
1.	Data collection at Mandya district of Karnataka	35-36

INTRODUCTION

I INTRODUCTION

The Indian economy has always been based on agriculture. It has to support almost 17 per cent of world population from 2.3 per cent of world geographical area and 4.2 per cent of world's water resources. The world has recognised Indian agriculture's accomplishment as food grain production rose from 50.8 million tonnes during 1950-51 to 316.06 million tonnes in 2021 (Anonymous, 2022), out of which 127.93 million tonnes is contributed by rice alone. Rice continues to hold the key component of sustainable production of food in the country. India has occupied the first place in area and second place in production of rice after China, contributing 28.53 per cent of the world's area and 14.61 per cent of world's production with 44.19 million hectares and 104.4 million hectares. (INDIASTAT, 2016). In the year 2020-21, India produced 124.37 million tonnes of rice and covered area of 45.77 million hectare with productivity of 2717 kg per hectare.

With respect to Indian scenario is concerned, the major states with highest area under rice cultivation are Uttar Pradesh (5.67 million ha), West Bengal (5.59 million ha), Odisha (4.04 million ha). In terms of production, the major rice producing states are West Bengal (16.524 million tonnes), Uttar Pradesh (15.52 million tonnes), Punjab (12.78 million tonnes) and Chandigarh has the highest productivity with 55q per hectare followed by Punjab (43.66 q/ha), Andhra Pradesh (33.93 q/ha).

In India, rice is grown in warm temperate, subtropical, and tropical regions between the latitudes of 8 and 25 degrees north and at altitudes ranging from sea level to roughly 2.5 km above sea level. It is a tropical plant and requires warm and humid conditions for its successful growth. At a mean monthly temperature of 24°C, the temperature should be fairly high. About 20° to 22° C should be the temperature for planting, 23° to 25° C for growth, and 25° to 30° C for harvest time. It is the dominant crop in areas of over 200 cm annual rainfall and is still an important crop in areas of 100-200 cm rainfall. The 100 cm isohyte forms the limit of rice in rain fed areas. In areas receiving less than 100 cm annual rainfall, rice can be grown with irrigation, as is done in

Punjab, Haryana and western U.P. About 40 per cent of rice crop in India is raised under irrigation

The most significant food crop in India, rice accounts for about one-fourth of the total land planted to crops and feeds almost half of the country's population. It is a staple food for those who are residing in the eastern and southern regions of the nation. Around 4,000 of the approximately 10,000 different rice kinds produced worldwide are in India. More than 2,000 million people in Asia alone get 60-70 per cent of their calories from rice and rice-derived products. The United Nations General Assembly proclaimed 2004 to be the "International Year of Rice"(IYR) in recognition of the significance of this crop. The IYR theme, "Rice is life," emphasises the value of rice as a main food source and is based on realizing the importance of rice-based systems for improving livelihoods, reducing poverty, and ensuring food security.

The USDA estimates that during the 2019–2020 marketing year, around 500 million tonnes of milled rice were produced worldwide. Over time, its production has remained constant (+1% anticipated for 2020–2021). Asia is the primary region for both production and consumption, particularly China and South-East Asia. With a production share of 30 per cent, China is the world's top producer, followed by India (24 %), Bangladesh (7 %), Indonesia (7 %), Vietnam (5 %) and Thailand (4 %). China consumes the most (29 % of the world's consumption), followed by India (21 %), Bangladesh (7 %), Indonesia (7 %), Vietnam (4 %) and the Philippines (3 %), in that order.

The 44 million tonnes of milled rice exported in 2019-2020 showed a slight variation in export patterns, with India leading the pack with 13 million tonnes, or 30 per cent of global exports. Thailand (13 %) and Vietnam (15 %) also made the top three. Following them are Pakistan (9 %) and the United States (7 %).

China is in sixth place (with 6% of the market), followed by Myanmar (with 5 %). There is no one importing nation that stands out above the rest, however the Philippines (6 % of global imports), the European Union (5 %), and China (5 %), followed by Malaysia (3

%), Côte d'Ivoire (3 %), Iran (3 %), and Iraq (3 %), Saudi Arabia (3 %), Senegal (3 %), Nigeria (3 %), and the United States (3 %) are noteworthy importers.

1.1 Rice production and Climate Change

The production, accessibility, and availability of food are under constant strain in many nations due to the growing global population, climate change, and depleting natural resources. According to reports, Asia's major rice-producing nations are adversely impacted by factors like rising temperatures, variable rainfall, intermittent access to water, and a variety of biotic and abiotic pressures that reduce output. Since more than 90% of the world's rice is produced and consumed in Asia, this economically significant commodity is high on the list of priorities for regional development. The use of suitable stress-tolerant varieties in combination with effective agronomic or management practises could double production, for example. Two of the many organisations that advocate for the hardship of rice-farming communities, with the ultimate goal of improving their situation, are Asian Development Bank (ADB) and International Rice Research Institute (IRRI). The goal is to increase productivity and strengthen food security on a sustainable basis, improving human wellbeing in the process. To handle the complexity of sustainable development, development activities are focused on providing well-targeted knowledge products, resources, and other solutions.

Rice cultivation is both an important sequester of carbon dioxide from the atmosphere and an important source of greenhouse gases (*e.g.* methane and nitrite oxide) emission. In 2004, for example, rice sequestered about 1.74 billion tonnes of CO₂ from the atmosphere to produce about 1.16 billion tonnes of biomass. Flooded rice fields emit methane (CH₄) which is second in importance to carbon-dioxide as a greenhouse gas. Under anaerobic condition of submerged soils of flooded rice fields, methane is produced and much of it escapes from soil into atmosphere via gas spaces in the rice roots and stems, and the remainder CH₄ bubbles up from the soil and/or diffuses slowly through the soil and overlying flood water.

Climate change poses a serious and growing threat to global food security. Climate change's effects include rising temperatures, an increase in extreme weather

occurrences, water shortages, and other things. Rising sea levels, ocean acidification, land degradation, ecosystem disruption, and biodiversity loss could seriously jeopardise agriculture's ability to feed the most vulnerable, impeding the eradication of hunger, malnutrition, and poverty.

For the security of the food supply, water is essential and it is also essential for the development of economy. This will not be possible without improving water use efficiency and integrated water resource management in the current scenario. Climate change is also projected to cause significant adverse impacts on the availability of water for irrigation and agriculture of tropical regions in India. Glaciers may melt quickly, precipitation patterns may alter, extreme weather events may occur more frequently, seasons may change, occurrence of pest and diseases and also effects on socio-economic factors.

Rice is fundamental for food security for three billion population, roughly 50 per cent of the world population, eating rice every day. Many of the poorest and most undernourished in Asia depend on rice for their staple food. Nearly 144 million ha of land is cultivated under rice each year. Most people throughout the world use rice as a staple food, and it is a crucial and integral part of the food system in many nations. It is the food cereal which made countries to overcome the problems of hunger and starvation and has certainly played a major role in taking out the people out of food insecurity. Despite its vital role, the rice cultivation system has become one of the major sources for greenhouse gas emission from agriculture and also a cause for higher water consumption. The various rice farming techniques that are regarded as climate-smart agricultural methods include aerobic, SRI (System of Rice Intensification), dry seeded rice farming, alternate wetting and drying, etc. help in yielding higher returns and reducing costs. Adopting a system which increases yield, reduces water consumption, reduces costs etc. will aid in sustainable rice production with increased efficiency.

1.2 Climate Smart Agriculture (CSA)

The FAO first introduced the idea of Climate Smart Agriculture (CSA) in a background paper created for the Hague Conference on Agriculture, Food Security, and Climate Change in 2010 to address national food security and development goals.

- Increasing productivity and income.
- Adapting to climate change.
- Reduce or remove greenhouse gases.

The CSA strategy enables fair income gains, food security, and the development of adaptive ability and resilience to climate change while sustainably increasing agricultural productivity, shocks on many scales (from local to national), lowering greenhouse gas emissions, and enhancing carbon sequestration whenever possible.

1.3 Different systems of rice cultivation

There is a need to practice a system other than conventional flooding method, which will increase productivity, adapt to the changing climatic conditions through adaptation strategies and reducing the GHGs emission through mitigation strategies which will help in sustainable rice production. The different rice cultivation systems studied are discussed in this regard.

Depending on the water supply, different conditions can be used to grow rice. Rice is often grown by flooding the fields, sloshing the dirt, and then transplanting the immature seedlings. Since human labour is becoming more expensive and scarcer every day, this method requires a lot of labour. According to Gujja and Thiyagarajan (2009), 3000 to 5000 L of water is needed to produce one kg of rice using the traditional transplanting method. According to Bouman *et al.* (2007), irrigated rice receives 34-43 per cent of the irrigation water used worldwide. However, rice cultivation can be a significant source of methane emission leading to global warming and enhanced greenhouse effect. When rice is grown under conventionally puddled transplanted conditions methane (CH₄) is released by the process of methanogenesis when rice is

cultivated under typically puddled transplanting settings since the soil is anaerobic (Anonymous, 2007). Following carbon dioxide, CH₄ is the second-most significant greenhouse gas, providing about 20 per cent to the enhanced greenhouse impact.

Direct sowing of rice into non-puddled soil is another way to grow rice. It is a practical method for planting rice that involves drilling dry seed without mucking up the soil. DSR minimises soil deterioration and enables timely establishment of rice and subsequent crops because the crop grows 10-15 days earlier and lowers production expenses by reducing labour, fuel, and seed prices. Due to the fact that direct seeded rice fields are not regularly irrigated and the soil is primarily aerobic, growing DSR may have a significant impact on CH₄ emission. On the other hand, rice soil nitrous oxide emissions may be significantly influenced by aerobic soil conditions. Growing direct seeded rice could have a significant negative influence on the world's food supply.

1.3.1 Operational definitions:

SRI (System of Rice Intensification): The SRI is a farming methodology aimed at increasing the yield of rice. It can be the most suitable method rice cultivation for poor farmers.

Aerobic Method: This cutting-edge method of agriculture uses less water. Rice is grown aerobically when it is directly sown on non-puddle aerobic soil with more irrigation and fertiliser while using optimal high yielding rice types.

Drum Seeded Rice (DSR): Direct seeding of rice or Direct seeded rice is a technique of rice cultivation where farmers directly sow the paddy seeds in the field, escaping transplanting process.

System of rice intensification (SRI) is best understood as a set of agronomic principles whose effects depend more on ideas than on inputs. Its principles, when put into practice, enable farmers to use their available resources more productively, getting higher-yielding, more robust crops just by changing some of their cultivation practices (Jana *et al.*, 2018).

There is evidence that SRI reduces water footprint of rice production by consuming 30 to 50 per cent less irrigation water, and 20 to 25 per cent less total water for irrigated production, which includes rainfall. The natural environment benefits when rice sector reduces its demand for water while raising crop yields because this diminishes the sector's competition with natural ecosystems for water. Also, SRI can counter dynamics and trends that erode biodiversity by lessening the pressures from agricultural sector to expand into uncropped natural areas. When rice areas are not kept continuously flooded, as in case with SRI, the net emission of greenhouse gases is reduced, particularly of methane (CH₄).

By using less water, aerobic rice farming is a cutting-edge method of agriculture. Rice is directly sown in non-puddle aerobic soil during the cultivation of aerobic rice using appropriate high yielding rice types and additional irrigation and fertiliser. It is the method of cultivation, where the rice crop is established by direct seeding (dry or water-soaked seed) in non-puddle field and un-flooded field condition. Rice is grown like an upland crop in soil that is unpuddled, non-flooded or saturated. The soil is therefore 'aerobic' or with oxygen through the growing season, as compared to traditional flooded fields, which are 'anaerobic'.

Direct seeding with drum seeder avoids raising nursery, pulling up seedlings and transplanting them so that labour requirement for crop establishment is negligible. In transplanted rice which is a labour intensive and expensive can be replaced by direct seeding that can reduce the labour needs by 20 per cent (Pradhan, 1969 and Santhi *et.al.*, 1998). Direct seeding in rice is identified as viable technology to overcome the problem of higher cost of production and to mitigate flood and drought situation in nursery season (Sudharani *et al.*, 2019).

The above cultivation systems are itself an adaptation and mitigation strategy, these systems along with other strategies has to be assessed, analysed and implemented.

1.3.2 Adaptation and mitigation strategies

Adaptation means anticipating the adverse effects of climate change and taking appropriate action to prevent or minimise the damage they can cause, or taking advantage of opportunities that may arise. In essence, adaptation can be understood as the process of adjusting to the current and future effects of climate change. Adaptation to climate change is typically characterised as an adjustment in ecological, social or economic systems in response to observed or expected changes in climatic stimuli and their effects and impacts, in order to alleviate adverse impacts of change or take advantage of new opportunities. Mitigation means making the impacts of climate change less severe by preventing or reducing the emission of GHGs into the atmosphere. Mitigation is achieved either by reducing the sources emissions or by enhancing the storage of emissions. In short, mitigation is a human intervention that reduces the sources of GHG emissions and/or enhances the sinks. So, adaptation and mitigation strategies help to prevent or to overcome the impacts of climate change and also the adoption of these strategies impact the yield, income, investment and other aspects of a farm business.

Thus, it is necessary to identify and follow adaptation and mitigation strategies because of the rising impacts of climate change such as warmer seasons, increased annual precipitation, cyclonic disturbances, rise in sea level, changes in fresh water supply, impact on forests, natural ecosystem and human health etc. According to recent estimates, it is projected that wheat yield is projected to reduce by 6 to 25 per cent by 2100 and maize yields would reduce by 18 to 23 per cent (Anon. 2019). Adaptation and mitigation strategies help to prevent or to overcome the impacts of climate change and also the adoption of these strategies impact the yield, income, investment and other aspects of a farm business. So, to overcome or to prevent or to reduce the impact of climate change, certain strategies are necessary which would lead to sustainable growth.

1.4 Statement of the problem:

Sustainable agriculture and the mitigation of climate change both benefit greatly from climate-smart agriculture. Agriculture plays a significant role in the low development strategy for emissions. Agriculture must be a part of efforts to reduce

greenhouse gas emissions because it has a significant mitigation potential in many nations.

Over three billion people worldwide depend on rice as a basic food supply, and millions of households use it as a source of income. Yet climate change is subjecting the world's rice production systems to a variety of shocks, such as increased water supply instability, rising temperatures that impair crop growth, increased susceptibility to damage from frequent extreme weather events, etc. On the one hand, there is a growing population whose majority of food needs must be supplied by rice cultivation, which is accompanied by an increase in water use. On the other hand, climate change is impeding agriculture, which lowers the amount of water available, raises the amount of water used to produce rice, and lowers the amount of water available for other crops. In order to meet the anticipated consumption needs of the expanding population as well as to lessen the consequences of climate change, it is therefore necessary to research the various rice cultivation systems.

Systems used for rice farming are linked to greenhouse gas emissions, which are a direct cause of climate change. Therefore, it is necessary to research various rice farming techniques and how they affect the environment by looking at externalities and resource management. Additionally, it is crucial to research the economics of various rice farming systems as well as consumer and producer preferences.

This study differs in approach where efficient management of resources and the externalities is analysed under different rice cultivation systems along with assessment of production needs of farmers and consumer preference. The study also makes an attempt to identify climate smart adaptive and mitigation strategies followed by farmers. Therefore, the present study addresses the problem of climate change associated with rice cultivation by studying the effects of different rice cultivation systems on environment and the economics of different rice cultivation systems. Also, the problem of management of resources, especially water, is also assessed in the study. In this regard, the different rice cultivation systems which would better suit the growing conditions; help in meeting the expected consumption needs of the growing population and also in

mitigating the effects of climate change have been studied. Thus, the cultivation systems returns, costs, efficiency, externalities associated, adaptation and mitigation strategies will be studied.

The research study would attempt to assess the climate smart rice cultivation systems in Southern Karnataka. The findings of this study provide valuable information to all private, public and government extension agents, researchers and policy makers in helping them to orient their efforts for understanding climate smart rice cultivation systems in southern Karnataka on a large scale.

1.5 Specific objectives of the study

In this background, the present study was conducted during 2021-22 in southern district of Karnataka state with the following specific objectives:

1. To assess the economics of different rice cultivation systems.
2. To assess physical and economic water use efficiency.
3. To identify and quantify the externalities associated with different systems of rice cultivation.
4. To assess the trait preferences of rice producers and consumers.
5. To document adaptive and mitigation strategies adopted by farmers.

1.6 Hypotheses

- a) Cost of cultivation is more in conventional rice cultivation compared to other systems.
- b) Returns realized is more in SRI method of rice cultivation than other methods.
- c) Water use efficiency is least in conventional method of rice cultivation.
- d) Negative externality associated with conventional method of rice cultivation is more than other systems.
- e) High yielding and good grain quality is the major trait preferred by the farmers.

- f) Consumers choose appearance and grain size as the major trait to make consumption decision.

1.7 Limitations of the study

The study has a wide reach, yet there aren't many inherent restrictions to it. The sample farmers' opinions on the numerous study topics may be influenced by their own biases and prejudices. Farmers give memory based answers which is the major drawback

1.8 Presentation of the study

The study has been presented briefly in six chapters,

- **Introduction:** This chapter provides a brief overview of the research problem, the purpose and significance of the study, as well as the specific goals and hypotheses.
- **Review of Literature:** In this section, a review of the pertinent theories and prior research that was helpful in performing the current study is offered.
- **Methodology:** This chapter includes a brief explanation of the study area, the sampling technique used, the types and sources of the data obtained, and statistical tools used to assess the study's goals.
- **Results and Discussion:** In this chapter, the data have been presented, meaningfully interpreted, and compared to earlier pertinent investigations.
- **Summary and conclusion:** Brief summary and major findings of the study along with policy recommendations drawn from the findings have been presented.
- **References:** The lists of referred journals, reports, etc., are presented in this section.

REVIEW OF LITERATURE

II REVIEW OF LITERATURE

A review of past research helps in identifying the conceptual methodological issues relevant to the study. This will enable the researcher to collect information and subject them to sound reasoning and meaningful interpretation. Considering the objectives of the present study, a brief review of the earlier research works is summarized and presented under the following headings:

2.1 Climate smart agriculture

2.2 Economics of different rice cultivation systems

2.3 Water use: Efficiency and willingness to pay

2.4 Externalities associated with different systems of rice cultivation

2.5 Trait preferences of rice producers and consumers

2.6 Adaptation and mitigation strategies

2.1 Climate smart agriculture

Chhetri *et al.* (2016) conducted a study on economic benefits of climate-smart agricultural practices to smallholder farmers in the Indo-Gangetic plain of India. The results revealed that 60 per cent of the households adopted at least one of the Climate Smart Agriculture (CSA) practice or technology. The major practices followed were use of improved crop varieties (80 %), laser land levelling (42 %), crop rotation (23 %) and zero tillage (11 %). In rice-wheat cultivation system, use of improved seeds, zero tillage and laser land levelling increased total production by 19, 6 and 10 per cent, respectively. The input costs decreased by 41 per cent by practising zero tillage.

Dey *et al.* (2018) studied on aerobic rice: a smart technology of rice cultivation. Aerobic rice was developed in response to water scarcity, climate change and unpredictable rainfall. Aerobic rice varieties have drought tolerance and high potential yield. Aerobic rice varieties save about 50 per cent of irrigation water in comparison to lowland rice. The aerobic rice will be better choice for present and future rice production.

Singh *et al.* (2020) in their study on direct seeded rice (DSR): purely a climate smart village technology, described DSR cultivation as one of the methods for rice cultivation in upland areas which avoids frequent puddling, inhibits soil degradation and pan formation, aids in timely establishment of rice, saves water and labour, decreases cost of production and increases yield. The findings revealed the cost of cultivation was low in DSR (Rs. 26,049/ha) compared to conventional method (Rs. 31,270/ha) and the BC ratio was found to be 1.40 and 1.16 for DSR and conventional method, respectively.

Tran *et al.* (2020) described the goal of climate smart agriculture is to sustainably increase income and agricultural productivity, to build resilience and capacity of agriculture and food systems to adapt to climate change, and to reduce and remove greenhouse gas emissions. The study considered climate smart agriculture technologies such as water saving technologies and improved stress tolerant varieties. The study identified the factors influencing adoption of climate smart agriculture technologies (CSATs) in rice production in Vietnam. Gender, rice area, soil fertility, income and willingness to take risks positively influence adoption of CSATs, whereas age, number of family workers and distance to markets negatively influence adoption of CSATs.

Onyeneke *et al.* (2021) identified the practices of climate smart agriculture in rice cultivation in Ebonyi state. The practices identified were planting of improved rice varieties, , planting different crops, livelihood diversification, soil and water conservation techniques, adjusting planting and harvesting dates, irrigation, availing insurance, reliance on climate information and forecasts, planting on the nursery, appropriate application of fertilizer and efficient and effective use of pesticides.

Kakraliya *et al.* (2022) conducted a study on economic efficiency of climate-smart agriculture practices in a rice-wheat cropping system of India. The findings revealed that the adoption of Climate Smart Agricultural Practices (CSAPs) increased the biomass yield, net farm income and economic efficiency by six to nine per cent, 18 to 23 per cent and 42 to 58 per cent, respectively as compared to conventional method.

The above studies identify some of the practices under climate smart rice cultivation as aerobic method of cultivation, direct seeded rice cultivation, planting of improved rice varieties, planting different crops, livelihood diversification etc. The adoption of climate smart agricultural practices in rice cultivation will help in increasing production, income, reduces costs of cultivation and also increases economic efficiency.

2.2 Economics of rice cultivation systems

Devi and Ponnarasi (2009) studied on rice production technology and its adoption behaviour in Tamil Nadu. The study compared the cost and return structure of rice production under conventional and SRI method of cultivation and identified that that the total cost of cultivation per hectare was lower by about 10 per cent in SRI method (Rs. 21,655) than conventional method (Rs 25,914). The seed rate was 10kg/ha in SRI method as compared with 30-60kg/ha in conventional method. The cost of irrigation of the total was 9.84 per cent, which is 9.30 in the conventional method. But the cost of machine labour was found to be higher in SRI method. The net returns were higher in SRI (Rs 27,009) than conventional (Rs 14,499) method which was attributed mainly to the higher productivity of paddy in the SRI method.

Durga and Kumar (2013) analyzed the efficiency of SRI cultivation in the state of Kerala. The study revealed that the average yield under SRI is 27 per cent higher than that of rice cultivated under the conventional method. The net returns and benefit-cost ratios (1.70) are higher for SRI farms due to higher productivity of paddy cultivation. The farmers who followed SRI demonstrated higher efficiency relative to their counterparts under the conventional method.

Hidayah *et al.* (2013) conducted a study on production and cost efficiency of paddy farming system in Buru district, Maluku province, Indonesia. The study estimated that mean technical efficiency was 85 per cent and 75 per cent of the farmers of the farmers operated in this level of efficiency. Similarly, the mean cost efficiency was 86 per cent and the farmers under this level of efficiency were 80 per cent.

Mwatete *et al.* (2015) conducted a study on technical efficiency differentials in conventional and SRI rice production methods in West Kano, Kenya. The estimates from the stochastic production frontier revealed that around 60 per cent technical efficiency was observed for 65 per cent of plots under conventional method and all the SRI plots had more than 60 per cent technical efficiency. The mean technical efficiency was higher in SRI (83 %) compared to the conventional method (75 %) which indicated the opportunity for conventional farmers to increase production capacity.

Vinay *et al.* (2016) analysed the impact of direct seeded rice (DSR) on economics of paddy crop in Haryana. The results showed that net return was higher in DSR (Rs. 60105/ha) as compared to transplanted rice (Rs. 57,532.5/ha) and BC ratio was also found to be 2.13 in DSR while it was only 1.94 in transplanted rice. Further, the net returns were 4 per cent higher in DSR than transplanted method as cost of cultivation was 15 per cent less in DSR.

Manohar *et al.* (2017) compared the economics of direct seeded rice (DSR) and transplanted rice cultivation in TBP (Tungabhadra) command area of Karnataka. The total cost of cultivation of paddy under DSR was found to be lower by 15.39 per cent (Rs.73661.1/ha) than transplanted rice (Rs.87,061.5/ha) cultivation. The maximum costs were incurred for the transplanted rice (Rs.62,548.6/ha) than that of direct seeded rice (Rs.50045.6/ha). The average yield was considerably high in DSR (64.18 q/ha) compared to transplanted rice cultivation (56.79 q/ha). The gross returns obtained were Rs.1,36,127 and Rs.1,19,755 per ha for DSR and transplanted rice cultivation respectively. The net returns were higher in DSR (Rs.62465/ha) than that of transplanted rice cultivation (Rs.32,693/ha) which was due to high cost of cultivation in transplanted rice. The returns per rupee spent was also found to be higher in DSR (1.85) than transplanted rice cultivation (1.38).

Agarwal *et al.* (2018) analysed the cost and return structure of paddy cultivation under traditional and SRI method in Burma block of Ranchi district. The study concluded that traditional method was more expensive (Rs. 14,014.54/ac) than SRI method (Rs. 12154.63/ac). The yield realized in traditional method was 1560.06 kg per acre, while it

was 1821.17 kg per acre in the SRI method of paddy cultivation. The BC ratio was found to be higher in SRI method (2.28) of paddy cultivation than traditional method (1.6).

Pankaj *et al.* (2018) compared the costs and returns from different methods of rice cultivation namely; manual transplanting, Direct Seeded Rice (DSR) method and drum seeding method. The study revealed that the cost of cultivation was found to be highest in manual transplanting (Rs. 29,950/ha) and lowest in DSR (Rs. 25,950/ha). Similarly, the net return was higher in DSR (Rs. 33,532/ha) as compared with manual transplanting (Rs. 31,751/ha) The B:C ratio was found to be 2.06, 2.29 and 2.18 for manual transplanting, DSR and drum seeding method respectively.

Kumar *et al.* (2019) analysed the economics of paddy production system in Raichur district of Karnataka. The share of variable cost was around 62 per cent, 64 per cent and 65 per cent for small, medium and large farmers, respectively. The average total cost of cultivation was Rs. 1,08,740.97 per hectare. The major cost accrued to the total costs was the hired labour (20.29 %). The average yield and gross returns were 74kg and Rs. 1,32,309.60 per hectare with net income amounting to Rs. 23568.69 per hectare.

Aboaba (2020) assessed the economic efficiency of rice farming and identified the factors influencing economic efficiency. Results revealed that seed, herbicides and pesticides significantly influenced rice output. Age, sex, farmers' association, type of labour, public market, public healthcare facilities and extension contract were the factors contributing positively to technical efficiency, whereas household size, level of education, farming experience, road conditions and distance to nearest marketplace had positive effects on technical inefficiency. The price of fertilizer and tractor rental cost significantly influenced cost efficiency. The factors such as age, marital status, farmers' association, farming experience and extension contract positively influenced cost efficiency, while sex, household size, level of education, type of labour, public market, public healthcare facilities, road conditions and distance to nearest marketplace had positive effects on cost inefficiency.

The studies reviewed above shows that the various systems of cultivation in rice production such as direct seeded rice, System of Rice Intensification (SRI), Drum seeded rice (DSR) are superior as compared to conventional or flooding method. There is increase in yield, decrease in input costs especially for the inputs such as seeds, labour, irrigation etc. The studies also indicate that there is increase in gross returns as well as net returns and BC ratio was high in other systems of cultivation than conventional method. The other systems were also found to be technically efficient.

2.3 Water Use: Efficiency and willingness to pay (WTP)

Bouman and Tuong (2000) conducted a study on field water management to save and increase its productivity in irrigated lowland rice. The analysis revealed that water productivity in continuous flooded rice was 0.2-0.4 g grain per kg water and 0.3-1.1 g grain per kg water in India and Philippines respectively. Study also found that water productivity through water-saving irrigation up to 1.9 g grain per kg water, but decreases yield.

Grassi *et al.* (2009) assessed cultivation of the upland rice variety Apo under different water conditions in 2004-2005 at the IRRI (International Rice Research Institute) farm in both the dry and wet seasons. The water treatments considered were aerobic and flooded condition, aerobic and alternated flooding condition and aerobic after fallow conditions. The results indicate that the aerobic rice yield (3 t/ha) was lower than rice production under flood treatment (5.8 tonnes/ha). However, when the aerobic condition was alternated with the anaerobic condition, or a fallow period, the production under aerobic treatment provides good yields (respectively 4.2 and 4.4 tonnes/ha). Water productivity was higher in aerobic fields, especially after fallow (0.88 g/kg). The nitrogen application induced an increase in yield and water productivity, partially compensating for the lack of water in aerobic fields.

Mahajan *et al.* (2011) conducted a study on performance and water use efficiency of rice relative to establishment methods in North-western Indo-Gangetic plains. The study compared the crop performance and water-use efficiency of ten selected rice cultivars between aerobic direct-seeded rice (ADSR) and conventional puddled

transplanted rice (CPTR) on a sandy loam soil in Punjab Agricultural University (PAU), Ludhiana, India. The study revealed that grain yields were similar between ADSR and CPTR for cultivars PR-120, Punjab Mehak 1, Fang-ai-zan and RH-664. The grain yields of the other cultivars decreased significantly in ADSR compared with CPTR. The highest grain yields were observed in PAU-201, a medium-duration cultivar in each crop establishment method, followed by PR-120. Water-use efficiency (WUE) values for Fang-ai-zan (0.48 kg/m^{-3}), RH-257 (0.47 kg/m^{-3}) PAU-201(0.45 kg/m^{-3}) and PR-120 (0.45 kg/m^{-3}) were significantly higher than the WUE of any other cultivars and these cultivars also had high values for stress-tolerance index (STI). Averaged across cultivars, WUE was similar in ADSR and CPTR as yield reduction in ADSR over-weighed the benefit of water saving.

Rohith and Chandrakanth (2011) examined the factors influencing the willingness to pay for additional water for assured irrigation during summer season in Krishnarajasagar and Kabini command areas of Cauvery basin. It was observed that landholding of the farmer and distance of farm from the canal outlet were positive and significant factors influencing farmers willingness to pay for irrigation water. The mean willingness to pay for assured irrigation was Rs.178.

Basha and Sarma (2017) studied on yield and water use efficiency of rice cultivation. The study showed that aerobic rice significantly required less water (67.91 cm/ha) to produce higher or on par yield as compared to transplanted puddled rice (122.59 cm/ha). Similarly, water use efficiency was significantly higher in aerobic rice ($81.31 \text{ kg ha}^{-1} \text{ cm}$) as compared to transplanted rice ($36.12 \text{ kg ha}^{-1} \text{ cm}$).

Ravi and Umesh (2018) estimated the willingness to pay for assured irrigation and equity in distribution of tank water in central zone of Karnataka. The study revealed that the mean willingness to pay under farmers managed tank regime was Rs. 894 per acre per year, while it was Rs. 809 per acre per year for minor irrigation department managed tank regime. Education, area under tank irrigation, location of the farm and gross farm income were the major factors influencing willingness to pay for assured irrigation.

Yubing *et al.* (2018) assessed yield-water use relations under furrow and micro irrigation systems in wheat and cotton cultivation and meta-regression analysis was used to evaluate the effect of influencing factors. The results revealed that to achieve maximum WUE rather than maximum yield, water use for wheat can be reduced by 30.4 per cent with a yield loss of 14.8 per cent, and water use for cotton can decrease by 51.4 per cent with a yield decrease of 51.7 per cent. Adoption of micro irrigation systems and farm management practices on soil and water significantly enhances WUE in wheat and cotton.

Kumar *et al.* (2019) in their study on gross economic efficiency of water use in paddy– wheat–milk production system and water-saving farm plans in Punjab, estimated the gross economic water use efficiency (GEE) of paddy for different districts. Among the districts, the GEE of paddy was higher in Ludhiana (Rs. 10.09/m³) and the lowest was in Jalandhar (Rs. 5.32/m³) and Amritsar (Rs. 5.71/m³) districts. The reason attributed to the yield of paddy which was lower in Jalandhar (3.5 tons/ha) and Amritsar (2.6 tons/ha) than the state average (4.3 tons/ha).

Biswas *et al.* (2021) studied on water use efficiency of rice under alternate wetting and drying (AWD) for Kharagpur, West Bengal, India. The study compared the performance of AWD practice with the conventionally (CON) irrigated rice cultivation. The findings revealed that crop water use efficiency significantly increased by 27-33 per cent and 20-29 per cent in the kharif and rabi seasons respectively under AWD system.

Kumar *et al.* (2021) estimated physical and economic water use efficiency among aerobic and conventional rice farms in eastern dry zone of Karnataka. The findings of the study revealed that physical water use efficiency in aerobic farms (3.84 q/acre inch) was higher than conventional farms (1.64 q/acre inch). The economic water use efficiency was also found to be higher in aerobic farms (Rs. 1643.54/acre inch) compared to conventional farms (Rs. 269.41/acre inch).

From the above reviews it can be concluded that conventional method of rice cultivation has lower physical and economic water use efficiency. The studies suggest

that farmers are willing to pay for irrigation water if there is equitable distribution of water.

2.4 Externalities associated with different systems of rice cultivation

Bhatia *et al.* (2013) reported the all-India level methane and nitrous oxide emissions from paddy cultivation, agricultural soils and crop residue burning. The study used state-wise inventory based on IPCC (Intergovernmental Panel on Climate Change) guidelines. The rice ecosystem considered were upland, rain-fed, irrigated and deep-water ecosystem. The results reveal that total emission from rice fields was 84.35 Tg CO₂ equivalents. The emission of nitrous oxide and methane from agricultural soils were 138.16 Gg and 3369.74 Gg, respectively and the burning of crop residue emit around 250 Gg of CH₄ and 6 Gg of N₂O.

Natuhara (2013) studied the ecosystem services of paddy cultivation in Japan. The results revealed that the major ecosystem services provided are flood control, groundwater recharge, water purification, local climate mitigation, culture and landscape and biodiversity. The total value of services or functions such as flood control, groundwater recharge, landslide prevention, organic waste treatment, local climate mitigation and recreation was valued at 72.8 billion US dollars.

Rajkishore *et al.* (2013) examined the methane emission patterns associated with SRI and conventional method of rice cultivation. The study considered four key stages of plant growth, i.e., active tillering, panicle initiation, flowering, and maturity along with temporal changes in methane emission. The results depicted that cumulative methane emission was lower in SRI (31.8 and 37.7 kg/ha) than conventional cultivation (44.6 and 55.5 kg/ha) in the summer and kharif seasons, respectively and concluded that with SRI management, total methane emissions were reduced by 29 per cent and 32 per cent during the summer and kharif seasons, respectively.

Nishantha *et al.* (2015) made an effort to study the impact of external costs and benefits of paddy farming in Sri Lanka. The study considered human health problems and human poisoning as the major negative externalities which includes cost of kidney

disease and tooth disease, the loss of man days, expenses of medical treatment and lost wealth and assets of people. The benefits include flood mitigation, groundwater recharge and purification and increased highland crop yields. The elasticity of revenue was higher than elasticity of production cost indicating the profitability of rice production in the absence of externalities. Further, total external benefit (TEB) was higher than total external costs (TEC) in all the major irrigated, minor irrigated and rainfed schemes. The total social benefits (TSB) was also more than the total social costs (TSC) and the net social effect was positive, signifying the opportunity to maximise the benefits of paddy farming.

Maulana (2016) estimated the cost of environmental externalities internalize them into the production cost of SRI method which is based on organic practices. The study used life cycle assessment and damage cost approach for estimation of externalities. The production cost of unhulled rice was Rp 9.54 million per hectare per season with SRI method, whereas for conventional production system it was 7.41 million per hectare. With SRI production system, CH₄ emissions reduced from 31.5kg per hectare to 18.94 kg and N₂O emissions decreased to 0.293kg from 1.383kg. The total damage cost (Rp 58.363/ha) was lower in SRI production system compared to the conventional (Rp 2,80,899/ha). The study suggested the Government can receive Rp 44.51 billion per 2,00,000 hectare of SRI production system by using carbon trading mechanism.

Mohamad (2016) studied on externalities inclusion into production cost of system of rice intensification in Dlingo village, Central Java Province. CH₄, N₂O, SO₂ and PM₁₀ are the externalities measured in the study. Life Cycle Analysis (LCA), damage cost approach was used. The results shows that cost incurred for producing one kg unhulled rice in System of Rice Intensification (SRI) was Rp 1,529 per kg, by applying SRI method farmer could decrease 40 per cent of CH₄ emission and also damage cost of CH₄ and N₂O produced by SRI system was relatively low.

Nayak *et al.* (2019) assessed the ecosystem services of rice farms in India. Regulating services (biocontrol of pests, carbon flow, soil erosion, nitrogen fixation), provisioning services (food and by-products), and supporting services (soil fertility,

hydrological flow, nutrient cycling, and soil formation) were examined through soil sampling. The results indicated that the total economic value of ecosystem services ranged from US\$ 1238 to 1688 per hectare per year. The marketed (primary production) and non-marketed ecosystem services values ranged from 66-89 per cent to 11-34 per cent of the total, respectively.

Rasheed *et al.* (2021) made an effort to value the ecosystem services from traditional paddy ecosystem in Kerala. The findings revealed that micronutrient provisioning, flood mitigation, groundwater recharge, nitrogen fixation, soil erosion prevention are the ecosystem services (ES) and GHG emission is the major ecosystem disservice from paddy cultivation. The ES from soil erosion prevention (39 %) had the major share followed by groundwater recharge (25 %), marketed goods (23 %), flood mitigation (10 %) and micronutrient provisioning (3 %). The total economic value of the ES was US\$ 8,391 per hectare and was US\$ 16 per hectare for ecosystem disservice. The net ES from paddy cultivation was valued at US\$ 8,375 per hectare.

The studies reviewed above illustrate that there are both positive and negative externalities from rice cultivation. Further the adoption of other cultivation practices will help in reducing the negative externalities from rice cultivation thereby decreasing the methane emissions in to the atmosphere.

2.5 Trait preferences of rice producers and consumers

Asante *et al.* (2013) assessed the influence of grain quality attributes and other factors on farmers' preference for improved rice varieties using probit regression model. The study was conducted in 6 communities from the three districts of the Ashanti region of Ghana with total sample amounting to 180. High yield potential was the most preferred trait in all districts except Atwima Nwabiagya followed by good grain quality which was the most preferred trait in Atwima Nwabiagya. Resistance to pests and diseases was the third and was followed by resistance to abiotic stress the least preferred traits. Overall, the Kendall's W of 0.650 was significant at 1 per cent level suggesting that 65 per cent of the farmers agree on the outcome of the ranking. The marginal effects of the grain quality attributes revealed that cooking quality of the grain had a positive

significant effect on farmers' preference for improved rice variety. An improvement in cooking quality increased the probability of farmers' preference for an improved variety by 32.07 per cent, presence of fragrance by 66.34 per cent, grain length and shape by 50 per cent, white grain colour by 44.65 per cent. Absence of foreign material had a positive significant influence it increased the probability of farmers' preference for improved rice variety by 56.51 per cent.

Sudha *et al.* (2013) carried out Consumer Acceptance and Preference Study (CAPS) on brown and under milled Indian rice varieties in Chennai. They used parameters such as demographic, anthropometric, medical history, physical activity, dietary intake data and willingness of the consumers to switch over to brown rice and used dehusked (unmilled, 0 0% polish), milled to 2.3 per cent and 4.4 per cent and polished (undermilled) forms of these varieties for the study. The results concluded that colour, appearance, texture, taste, and overall quality of the 4.4 per cent polished rice was strongly preferred by consumers in both varieties and forms. However, most of the consumers (93 %) expressed willingness to substitute brown or 2.3 per cent polished rice, if affordable, after the taste tests and education on nutritional and health benefits of whole grains.

Basavaraj (2015) classified seven different utility attributes of post rainy season sorghum for the farmers. Conjoint analysis was used to estimate the farmer preference towards the attribute and the results revealed that majority (22.42 %) of the farmers prefer yield as the major attribute followed by grain size (20.85 %) grain colour (18.71 %) and around ten per cent of farmer prefer stover quality, maturation and plant colour.

Tena *et al.* (2016) studied on sugarcane farmers traits based on the farmers' preferences the study identified six traits, among the identified traits drought tolerance (21 %) is the major preferred trait for sugarcane farmers followed by increased cane yield (20 %), early maturity (18 %), marketability (17 %) and high biomass (14 %) high cane and juice yields, early maturity, marketability, high biomass production and drought tolerance.

Mehar *et al.* (2017) examined the preferences of farmers' in rice variety selection in Eastern India using data from 5,601 sample farmers. The study identified attributes such as high yield, stress tolerance (varieties with short duration and tolerance to pests and diseases, drought, and submergence), market-oriented reasons (marketable grains, affordable seeds, available seeds, easily threshed, and good for storage), and cooking quality (good taste, high cooking quality, and good straw quality) as the major reasons for selection of particular variety by farmers. The assessment of the proportion of farmers who selected rice varieties for different reasons revealed that decisions were based mainly on high yield (55.3 %), followed by market-oriented reasons (10.7 %), cooking quality (9.9 %), and stress tolerance (7.3 %).

Senarath and Samaraweera (2017) identified the consumers preference for rice types in Hambantota district, Sri Lanka. The study revealed that rice colour preferred by most of the consumers was red coloured rice, with respect to rice grain size log slender Basmati rice (50) had highest rank order score and partially milled rice (75 %) was most preferred physical attribute with respect to degree of milling. The type of rice highly preferred was raw rice than parboiled rice.

Bellundagi *et al.* (2018) studied producer and consumer preference for finger millet in Karnataka. Tumakuru and Hassan districts were selected for producer preference and Bengaluru urban was selected for consumer preference. The study revealed that among all the producer attributes considered, yield was found to be more significant (18.33 %) for Tumakuru farmers, whereas colour was most significant with red colour having the utility of 0.34 for Hassan farmers. As far as concerned with consumer preference, taste was considered as most significant attribute considered for consumption in Bengaluru urban district.

Najeeb *et al.* (2018) studied on farmer's participatory selection of new rice varieties to boost production under temperate agro-ecosystems and chose SKUA-408, SR3, and SKUA-403 varieties for their study in Kashmir valley. The study showed that SKUA-408 and SR3 were significantly preferred by farmers ($P < 0.05$ or 0.01) in terms of

pre-harvest traits namely, tillering ability, general phenotypic acceptability, early maturity and biomass and for post-harvest trait such as general cooking quality.

Agbas and Ceballos (2019) examined the preference of consumers on quality attribute of rice using conjoint analysis. The results revealed that among the intrinsic attributes, texture and colour were the most important rice attributes with relative importance score of 31.22 per cent and 29.51 per cent, respectively. Among, extrinsic attributes varieties (29.37 %) and price (27.74 %) were the most preferred. The utility estimates revealed consumers placed higher utility for plain white, sticky, tasty and aromatic rice, respectively for intrinsic attributes such as colour, texture, taste and aroma. For extrinsic attributes, such as packaging, variety, label and price, the highest utility was for sack, local variety, with rice information and lower price between Php 35 to 49, respectively.

Naseer *et al.* (2019) analysed the consumer preferences for different rice varieties in Punjab, Pakistan. The findings revealed that 60 per cent in Faisalabad region and 45 per cent in Jhang region indicated aroma as the reason for preference of specific variety. The attribute price was preferred by 30 per cent and 33 per cent consumers in Faisalabad and Jhang region, respectively. Size or appearance was the third most reason preferred in both the regions.

Bhatt *et al.* (2020) conducted a study on farmers' preferences for improved wheat varieties in Kailali district of Nepal. The study identified 17 different traits of wheat to study the farmers; preference and estimated average weightage of each of the wheat varietal trait. The data from 60 respondents was analysed using wheat preference index. The study revealed that Vijay was preferred for most of the characteristics. Flour quality (3.37), pest tolerance (2.57), and stem thickness (2.05) were the most desired characteristics of Vijay. Similarly, NL-971 (3.4721) is ranked II with the preference trait of drought tolerance, indicating the importance of the NL-971 variety in the years with very low precipitation. Aditya (3.38) and Gautam (3.39) varieties were least preferred because of low tillering capacity and poor flour quality respectively. Likewise, HD-2967 was preferred for its higher yield and high tillering capacity.

The studies show that farmers' preference for particular variety depends upon the attributes or traits of the rice grains. The consumers' preference for rice purchase will also depend on the characteristics of rice. The studies show there are various characteristics preferred by farmers such as high yield, pest resistance, high tillering capacity etc. whereas consumers choose characteristics such as colour, variety, appearance, packaging, labelling etc.

2.6 Adaptation and mitigation strategies

Abid *et al.* (2015) worked on farmers' perceptions of and adaption strategies to climate change and their determinants in Punjab province of Pakistan. The results demonstrate that awareness of climate change is widespread throughout the area, and farm households make adjustments to adopt their agriculture in response to climate change. Overall 58 per cent of the farm households adopted their farming to climate change. Changing crop varieties, changing planting dates, planting of shade trees and changing fertilizers were the main adaptation methods implemented by farm households.

Oselebe *et al.* (2016) identified the adaptation measures used by rice farmers to overcome climate change effects in rice production in south eastern Nigeria. The adaptation strategies followed were mulching for water conservation especially during nursery preparation, preparation of nursery prior to planting, use of zero tillage, proper site selection, use of fertilizer and agrochemicals, early planting and construction of bonds and drainage to conserve water. But very few famers used strategies. However, the strategies such as early planting and use of fertilizers were followed by 38.6 and 30.4 per cent of farmers respectively.

Shrestha *et al.* (2016) investigated the impact of climate change on winter and summer rice yield and evaluated several adaptation measures to overcome the negative impact of climate change on rice production in the Quang Nam province of Vietnam. The study projected that climate change will reduce rice yield from 1.29 per cent to 23.05 per cent during the winter season, whereas an increase in yield by 2.07 per cent to 6.66 per cent is expected in the summer season for the 2020s and 2050s. Hence, the study suggested that late shifting of transplanting dates to 18 June and 24 February to enhance

potential yield under climate change and shifting from the traditional cultivar CH207 to heat resistant cultivars TBR1 and OM6162 can enhance rice yield up to additional 9.58 per cent to 40.39 per cent and 6.82 per cent to 23.92 per cent for future time periods.

Palanisami *et al.* (2017) in their study on climate change and India's future rice production identified adaptation strategies such as direct seeding of rice, modified system of rice intensification, supplemental irrigation, alternate wetting and drying, and improved management practices to increase rice yield and weather based crop insurance products to rice crop to address the variability (risk) in rice production.

Maya *et al.* (2019) conducted a study to identify farmers' adaptation strategies to climate and weather changes in Khulna district, Bangladesh. The study collected data from 100 rice cultivating farmers. Almost 40 per cent of respondents converted from rice to fish production and 24 per cent of respondents cultivated salinity-tolerant rice varieties, along with it only few people practiced the strategy of changing planting dates. About 75 per cent of farmers increased the use of irrigation and also practiced crop diversification, used salinity-tolerant varieties, crop rotation and a few branched into agro-forestry. About 40 per cent relied on previous savings and 17 per cent sold livestock, whereas 16 per cent availed credit from money lenders. Other adaptations include obtaining institutional microcredit (5 %), migration of family members to urban areas for work or income generation (5 %), the sale of other assets (9 %) and the sale and mortgage of land (8 %). The study concluded that around 89 per cent of farmers have undertaken some form(s) of adaptation whereas 11 per cent of respondents did not adopt any strategy as they were landless and very poor.

Brar *et al.* (2020) studied on the adaptation strategies followed by paddy growers towards climate change in Punjab state. The study collected data from 148 sample farmers under five agro-climatic zones. Majority (91.21 %) of farmers adopted short duration crop varieties and 82.43 per cent farmers were availing weather forecasting services to combat climate change. More than three fourth of the respondents opined that by using laser land management practices like laser leveller they mitigate the effect of climate change during paddy production, while 26.35 per cent by using resource

conservation technologies, 28.37 per cent by adopting soil moisture conservation methods, 11.48 per cent by stopping the burning of crop residue and only 10.81 per cent by using insect pest management techniques mitigate the effect of climate on paddy production.

Shanabhoga *et al.* (2020) studied the indigenous practices followed by paddy growers in confronting the climate crisis in the Hyderabad-Karnataka region of Karnataka state. The study identified that cent per cent of the farmers adopted the construction of waterways along the slope for safe disposal of rainwater. An overwhelming portion of the farmers adopted levelling of the land in between the bunds (96.67 %) and construction of bunds to conserve moisture (95.56 %). The majority (76.67 %) of the farmers intensified agricultural activities on irrigated land. Nearly half of the (47.78 %) paddy growers were practised zero tillage to save time and money.

Kamble (2021) examined the perceptions, impact and adaptation strategies followed by paddy growing farmers. Farmers perceived a change in rainfall pattern was major cause for production losses and they also perceived forest cover has decreased over the years. Crop residue burning was the major cause for climate change and increase in insect or pest attack were the major impacts of climate change as perceived by farmers. Willingness for adaptation to climate change was around 88 per cent and the future adaptation strategies identified were adoption of high yielding varieties, crop diversification, irrigating crops, water use change, water storage method, livestock diversification, organic manure, early maturing crop varieties and drought resistant crop varieties.

Kanesh *et al.* (2021) studied on agricultural adaptation to climate change impacts under rice cultivation in Sri Lanka. The study identified growing diverse varieties, growing drought tolerant varieties, growing flood tolerant varieties, growing disease/pest resistant varieties, growing short duration varieties, growing less water intensive varieties, changing planting location of varieties, changing planting/harvesting time, changing planting methods, to increase or improve irrigation, to increase rainwater harvesting, to reduce tillage, to increase number of weeding, to improve or increase

farmyard manure use, to use more pesticides and switching to non-rice crops as the adaptation practices adopted by the farmers. Around 40 per cent of the farmers adopted growing diverse varieties as an adaptation strategy and the least adopted strategy for rice cultivation was use of more pesticides.

Suresh (2021) examined the adaptation strategies to climate change and its impact on rice production in Sri Lanka. The findings revealed that most of the farmers perceived there is increase in temperature in all the seasons due to climate change, there is increase in unpredictability of weather; and rainfall and its' intensity has either decreased or has remained the same. The most perceived impact of climate change was increase in intensity and duration of drought (66.9 %) followed by shortage of irrigation water (66.1 %) and crop pests and diseases (65.7 %). The adaptation strategies followed were growing flood tolerant varieties (64 %), drought tolerant varieties (62.9 %), disease or pest resistant varieties (59.4 %) and increase in number of weedings (50.6 %). The results from endogenous switching regression revealed education, rice plots size, natural disasters (drought/flood), membership in organization and information on climate change have positive and significant impact on adaptation to climate change. Land, labour, and seed has significant influence on rice yield of adapters, whereas labour and off-farm income have positive and significant influence on rice yield of non-adapters. The adapters had increase in output by 576 kg per hectare and would be increased by 192 kg for non-adapters if there was decision to adopt.

The above studies show that following various adaptation and mitigation strategies by the farmers will help in overcoming the effects of climate change. The rice cultivation has to be followed along with adaptation and mitigation strategies to reduce the impact of changing climatic variables such as temperature, rainfall etc. and also to reduce emissions in to the atmosphere.

METHODOLOGY

III METHODOLOGY

The chapter on methodology provides detailed information regarding the description of the study area, the sampling procedure, survey method, nature and source of data and various economic and statistical tools employed to analyse the data for realizing the objectives of the study. The methodology employed has been presented under the following sub headings.

3.1 Description of the study area

3.2 Sampling procedure

3.3 Nature and source of data

3.4 Analytical tools and techniques used in the study

3.5 Definition of terms and concepts

3.1 Description of the study area

Karnataka is one among the largest state in India having a geographical area of about 1,91,791 sq.km, which shares about 5.83 per cent of the total geographical area. The Karnataka state is situated within 11⁰30' North latitudes and 74⁰ East and 78⁰30' East longitude in the southern plateau. The state has divided in to ten agro climatic zones such as, North Eastern Dry Zone, Northern Dry Zone, Central Dry Zone, Eastern Dry Zone, Southern Dry Zone, Southern Transition Zone, Northern Transition Zone, Hilly Zone and Costal Zone. Karnataka receives rains from two monsoons viz. the North-East monsoon from October to December and the South-West monsoon from June to September and the average rainfall is about 1196 mm. The major cereal crops grown in the state are paddy, jowar, ragi, maize, bajra and wheat. Among pulses red gram, green gram, pigeon pea and bengal gram. Sunflower, safflower groundnut are the prime oilseed crops of the state while cotton, sugarcane and tobacco are the major commercial crops.

3.1.1 Selection of study region and study area

The study is aimed at assessing the economics of different rice cultivation systems in rice growing regions of Cauvery command area. Purposive sampling was employed for selection of rice growing regions of Cauvery command area in Southern Karnataka.

Mandya district was selected for the study as many cultivation systems are followed in Mandya district other than the traditional conventional method for rice cultivation. Rice is one of the major crops grown in Mandya district of Karnataka State hence, the study is confined to rice crop and Mandya district.

3.1.2 Study area - Mandya district

Mandya district is one of the most agriculturally prosperous districts in Karnataka state. Paddy and sugarcane are the main crops of the irrigated region. Ragi, horse gram are the major crops of dry land agriculture. The district is advent with irrigation from the Krishnaraja Sagar reservoir.

The total geographical area of the district is 4,98,244 hectares, out of which 2,48,825 hectares forms the sown area. More than half of the district total land area is used for agricultural purpose. The total irrigated area is 1,16,901 hectares out of which 88,000 (approx.) and 16,000 (approx.) is being irrigated by K.R.Sagar and Hemavathi reservoirs, respectively. The administrative center of Mandya district is Mandya city, it is bounded by Mysore district to the west and southwest, Tumakuru district to the northeast, Chamrajnagara district to the south, Hassan district to the northwest, and Ramanagara district to the east. Mandya district comprised of seven taluks, viz. Mandya, Maddur, Malavalli, Srirangapatna, Nagamanagala, Krishnarajapete and Pandavapura. The district has 1559 villages, seven taluks and 32 hoblies and population of district was 18,05,769 with literacy rate 70.40 per cent (Table 3.1)

Table 1: General features of study area

Sl. No.	Particulars	Mandya	Karnataka
1.	Geographical area (Sq. Km)	4962	1,91,791
2.	Taluks (No.)	7	176
3.	Hoblies (No.)	32	769
4.	Villages (No.)	1559	29,340
5.	Population (No.)	18,05,769	6,10,95,297
6.	Density of population (per sq. km)	365	319
7.	Literacy rate (%)	70.40	75.36
8.	Annual rainfall (mm)	700	1196

Source: ASCR (Annual Season and Crop Statistics Report) of Directorate of Economics and Statistics, Government of Karnataka.

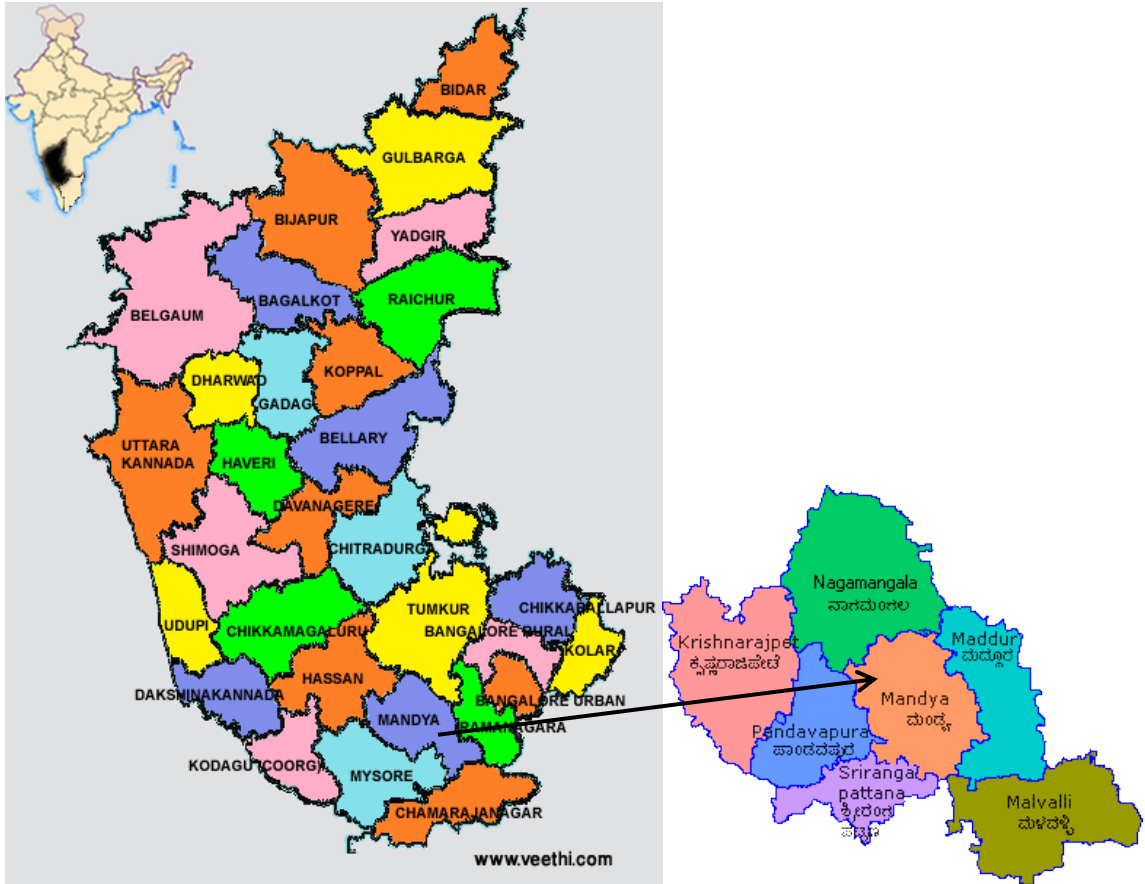


Fig. 1: Map showing location and study area

Rainfall:

Mandya district is having four seasons viz., summer (Mid-February to end of May), South -West monsoon season (June to September), north-west monsoon (October to November) and winter season (December to mid-February). The district receives average rainfall of 700 mm, which is below the average annual rainfall of Karnataka (1196 mm).

Land use pattern

The land utilization pattern of Mandya district vis-à-vis Karnataka is presented in Table 2. Out of 4.98 lakh ha of total geographical area of Mandya district, around 54.57 per cent i.e. 2.71 lakh ha was covered under net sown area (crops) during 2015. The total forest area reported in the study area was 24,768 ha which is 0.80 per cent of total forest area of Karnataka State. Around 82,425 ha was not available for cultivation while 1,26,875 ha is classified as fallow land.

Table 2: Land use pattern of study area

Sl. No.	Particulars	Mandya	Karnataka
1.	Total geographical area	4,98,244 (2.61)	1,90,50,068 (100)
2.	Forest area	24,765 (0.80)	30,73,376 (100)
3.	Land not available for cultivation	82,425 (3.69)	22,30,243 (100)
4.	Other uncultivable land	77,432 (4.84)	15,97,935 (100)
5.	Fallow land	1,26,875 (5.70)	22,25,175 (100)
6.	Net sown area	2,71,891 (2.73)	99,23,339 (100)

Note: Figures in the parentheses indicate percentage to total in row.

Source: ASCR (Annual Season and Crop Statistics Report) of Directorate of Economics and Statistics, Government of Karnataka.

Cropping pattern:

The cropping pattern in the Mandya district is presented in table 3 and the brief description is given below.

Table 3: Cropping pattern in the study area during 2015**(in ha)**

Sl. No.	Particulars	Mandya
I	Major cereal crops	
1.	Paddy	67,065 (26.73)
2.	Ragi	59,725 (23.80)
3.	Maize	4,490 (1.17)
4.	Others	1,329 (0.52)
	Total cereal crops	1,32,608 (52.86)
II	Major pulse crops	
1.	Horse gram	29,336 (11.69)
2.	Cowpea	4,243 (1.69)
3.	Avare	2,733 (1.08)
4.	Others	2,925 (1.16)
	Total pulse crops	39,237 (15.64)
III	Major oilseed crop	
1.	Groundnut	1,729 (0.68)
2.	Castor	1,081 (0.43)
3.	Niger seed	1,806 (0.71)
	Total oilseed crops	4,616 (1.84)

Sl. No.	Particulars	Mandya
IV	Major commercial crops	
1.	Sugarcane	22,228 (8.86)
2.	Sesamum	4,609 (1.83)
3.	Others	2,916 (1.16)
	Total commercial crops	29,748 (11.85)
V	Major plantation crops	
1.	Coconut	42,799 (17.06)
2.	Arecanut	1,501 (0.59)
3.	Others	347 (0.13)
	Total plantation crops	44,638 (17.79)
	Total area	2,50,847 (100)

Note: Figures in the parentheses indicate percentage to gross sown area.

Source: ASCR (Annual Season and Crop Statistics Report) of Directorate of Economics and Statistics, Government of Karnataka.

Cereal crops were the major crops grown in the Mandya district during 2015 which covers an area about 1,32,608 ha which is 52.86 per cent to the total cropped area, followed by plantation crops in 44,638 ha (17.79 %), pulse crop in 39237 (15.64 %), commercial crops in 29,746 ha (11.85 %) and oil seed crops in 4616 ha (1.84 %). Among the major crops covered in Mandya, paddy occupies major share in total area, which occupies about 26.73 per cent to the total cropped area followed by ragi (23.80 %), coconut (17.06 %), horse gram (11.69) and sugarcane (8.86 %).

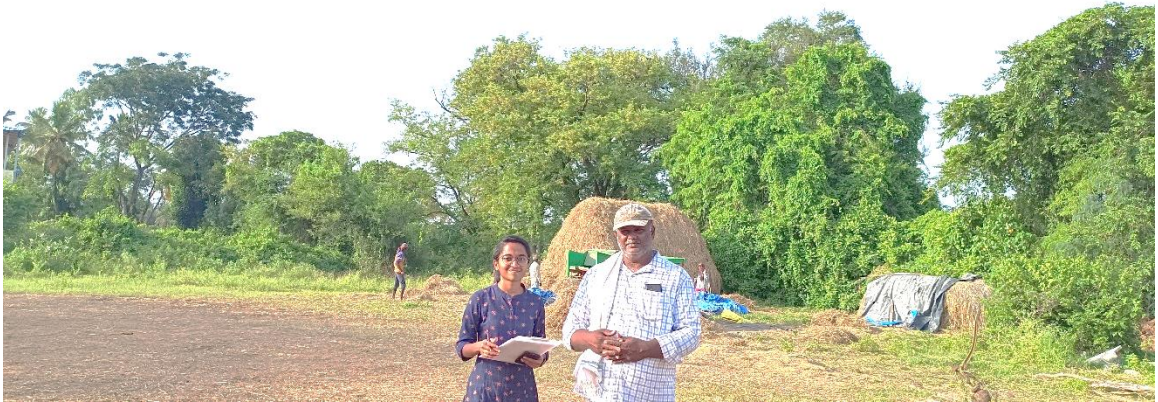


Plate 1: Data collection at Mandya district of Karnataka

3.2 Sampling procedure

The study is aimed at analyzing the economics of different rice cultivation systems, physical and economic water use efficiency, trait preferences, externalities associated with rice cultivation and to identify the adaptation and mitigation strategies followed by the rice farmers. The present study encompasses those involved in the production and consumption of rice. Farmers involved in rice cultivation and consumers were enlisted for data collection. The detailed procedure followed for the selection of sampling units in different groups are given below.

3.2.1 Farmers and consumers

The present study is taken up in Mandya district of Karnataka. Simple random and snowball sampling technique was employed for the selection of sample respondents under each of the cultivation system i.e. conventional, System of Rice Intensification (SRI), aerobic and drum seeded rice (DSR) method. Thirty farmers under each of the cultivation system were selected for the study. A total of 120 farmers and 80 consumers were selected for the study.

3.3 Nature and source of data

The data required for the study was collected from both primary and secondary sources. Primary data was collected from 120 farmers and 80 rice consumers as explained in the previous section. Information pertains to socio-economic characteristics, size of land holding, cropping pattern, cost and returns of rice cultivation, water used, trait preferences, perception on climate change adaptation and mitigation strategies in rice cultivation and other relevant data on variables required for fulfilling the objectives of the study were collected from the sample respondents using pre-tested, well-structured schedule through personal interview method.

3.4 Analytical tools and techniques used in the study

To achieve the objectives of the study, the data collected were subjected to various analytical tools are listed below.

- 3.4.1 Tabular presentation and descriptive statistics
- 3.4.2 Cost and return components in rice cultivation
- 3.4.3 Resource use efficiency
- 3.4.4 Stochastic frontier approach
- 3.4.5 Stochastic meta frontier method
- 3.4.6 Economic and physical water use efficiency:
- 3.4.7 Double bounded dichotomous Contingent Valuation Method (CVM)
- 3.4.8 Multinomial logistic regression
- 3.4.9 Tobit Analysis
- 3.4.10 Partial budgeting technique
- 3.4.11 Garret ranking technique
- 3.4.12 Conjoint analysis
- 3.4.13 Rank Based Quotient (RBQ)
- 3.4.14 Costing of irrigation water (Surface water)
- 3.4.15 Quantification of externalities

3.4.1 Tabular presentation and descriptive statistics

Tabular method of presentation was used to compile the socio-economic characteristics, cost and returns, mean willingness to pay, farmers' perception of climate change, adaptation and mitigation strategies followed etc. In order to assist the interpretation of findings, descriptive statistical measures like percentages, averages and ratios were worked out wherever necessary.

3.4.2 Cost and return components in rice cultivation

The costs and returns were worked out on per acre basis for rice crop.

3.4.2.1 Variable costs

The variables costs comprised of the following costs

1. Labour cost: The expenditure incurred on human labour, bullock labour, and machine labour constituted the labour costs. The different type of labour employed for each activity was recorded which includes both hired and family labours. The labour cost was obtained by multiplying physical units with wages paid by the producer of prevailed in the locality for owned labour input used.

a. Human labour

Human labour was estimated in terms of eight hours of work per day measured in man days. The prevailing average wage rates for male and for female labour in the study area are considered. Later based on the prevailing wages for male and female labour it was converted into number of man days and total expenditure on labour input.

b. Machine labour

The cost of machine labour both owned and hired was calculated at prevailing rates on hourly basis for the different type of operations prevailed in the study area.

c. Bullock labour

The bullock labour was measured in bullock pair days, both owned and hired and accounted at the prevailing rate paid per pair day (8 hours) in the study area.

2. Input costs: They include expenditure on seeds, fertilizer, FYM, plant protection chemicals, etc. The cost of material inputs was based on the quantity used and the prevailing market prices. For estimating the cost of FYM, the price prevailing in the locality was imputed even though many a times, part of it was produced on the farm itself. While computing the costs of fertilizers and chemicals, the actual price paid by the growers was considered.

a. Seed

The cost of seed was calculated at the market (purchase) price.

b. Farm Yard Manure (FYM)

The quantity of FYM used in the cultivation of rice was measured in terms of tractor loads which has been converted into tonnes as mentioned by the majority of respondent farmers that one tractor load approximately weighs two tonnes and the cost was imputed at the price prevailing in the village.

c. Fertilizers and plant protection chemicals

Cost of fertilizers and plant protection chemicals were taken at the actual expenditure incurred by the sample farmers.

3. Interest on working capital: The interest on working capital was calculated at the rate charged by institutional agencies, which is generally eight per cent per annum.

3.4.2.2 Fixed costs

The different items of fixed costs considered in the present study are as follows

1. Interest on fixed capital: This includes interest on the book value of asset/livestock and calculated at 12 per cent per annum.

2. Depreciation: Most widely used and simple method of depreciation calculation, the Straight-line method was used to arrive at depreciation of different durable assets used in the cultivation of rice, which is given by

$$\text{Depreciation} = (\text{Purchase value} - \text{Junk value}) / \text{Economic life of the asset}$$

The life span of the machineries, sprayers and other implements was taken as farmers configured.

3. Land rent: It was based on the value indicated by the rice producers in the region.

4. Land revenue: The land revenue for the study area was collected from the panchayat office.

3.4.2.3 Total cost of cultivation

Cost of cultivation included total variable cost and total fixed cost.

3.4.2.4 Returns concepts

1. Gross returns

The total quantity of rice produced was multiplied with its selling price gives the gross returns.

2. Net returns

It is the difference between gross return and total costs incurred in rice cultivation.

3. Gross returns per total cost of cultivation

It is calculated by dividing gross income with total cost of cultivation.

The results obtained from the analysis of data on socio-economic characteristics, cropping pattern, costs, returns, etc. are presented in the form of tables form using different measures of central tendency like averages and percentages for easy comparison and meaningful interpretation. Results are also presented in the form of figures and graphs wherever necessary.

3.4.3 Resource use efficiency

Resource use efficiency in the rice cultivation was studied by fitting the Cobb-Douglas type of production function to the farm level data. The following per acre production function was specified for estimation of production coefficients to assess the efficiency of resources.

$$Y = a X_1^{b_1} X_2^{b_2} X_3^{b_3} X_4^{b_4} X_5^{b_5} e^u$$

Where, Y= Yield (q)

X₁= Seed (kg)

X₂= FYM (t)

X₃= Fertilizer (kg)

X₄= Human labour (Man days)

X₅= Machine labour (hrs)

X₆=Irrigation (acre inch)

a=Constant

b_i indicates elasticity coefficients of X_i input for i=1 to 5.

The CD equation was converted into the logarithmic form for estimation of the parameters.

$$\ln Y = \ln a + b_1 \ln X_1 + b_2 \ln X_2 + b_3 \ln X_3 + b_4 \ln X_4 + b_5 \ln X_5 + u \quad \dots\dots\dots (1)$$

The equation 1 was used to estimate the production coefficients for different variables was finalised based on the apriori knowledge and the information gathered during survey with rice producers and similar studies reviewed and presented in the previous chapter.

In estimating the efficiency of different inputs used in rice cultivation, the Marginal Value Product (MVP) from each input, the Marginal Product (MP) and price of output (P_y) were used. The MP was calculated using the production function estimates (b_i) and the ratio of the geometric mean (GM) level of output and input. The MVP was then compared with the Marginal Factor Cost (MFC) of the respective input to estimate the efficiency of the resource used.

Economic Efficiency

The Economic Efficiency (EE) is the ratio between Marginal Value Product (MVP) and Marginal Factor Cost (MFC) of resources calculated using the following relationship.

$$EE \text{ or } r = MVP/MFC \quad \dots\dots\dots (2)$$

Where,

EE = Economic efficiency

MVP = Marginal value product of variable inputs (Rs.)

MFC = Marginal factor cost (price per unit of inputs) (Rs.).

Based on economic theory, a firm maximizes profits in input use when the ratio of its marginal value product to its marginal cost is unity. Thus, If

$r < 1$: indicate excess use or overuse indicating the need to reduce its use.

$r > 1$: indicates resource is underutilized hence increasing its present use level would increase profit.

$r = 1$: shows the optimum utilization of resource and point of profit maximization.

3.4.4 Stochastic frontier cost approach

Efficiency analysis orders decision-making units such as firm or a farm, by comparing all resources engaged in production and the costs incurred to produce a given set of outputs and building a frontier based on the input costs. The Cobb-Douglas Stochastic Frontier Cost (SFC) approach was used for assessing the cost efficiency of rice farmers under different rice cultivation system, following the Coelli (1996) model as follows:

$$\ln C_i = \alpha_0 + \sum_{j=1}^4 \alpha_j \ln X_{ji} + (v_i + u_i) \dots\dots\dots (3)$$

Where, \ln denotes natural logarithm. C_i is the total production cost of the farm i measured in rupees per acre, X_{1i} is the cost of seeds (Rs. /acre), X_{2i} is the cost of fertilizers used (Rs. /acre), X_{3i} is human labour cost and X_{4i} is the machine labour cost. v_i is a symmetric, identically and independently distributed $N(0, \sigma^2_v)$ error term. It represents random variation in production due to random exogenous factors, such as measurement errors and statistical noise. u_i is a non-negative error term. It reflects cost inefficiency relative to the stochastic frontier.

The computer programme FRONTIER Version 4.1 was used to estimate the model and to obtain the maximum likelihood estimates of the SFP function. The calculation of MLE requires (Coelli, 1996). $\sigma^2 = \sigma^2_v + \sigma^2_u$. This indicates total variance is due to variance in error term (v) and non-negative random variable (u), wherein v and u assumed to be independent of each other. The error term v_i represents the influence of factors outside the control of the farmer, while u_i represents the cost inefficiency factors because of poor

management practices which are under control of the farmer. This variance parameter in model is represented by Gamma value, calculated using the following equation:

$$\gamma = \frac{\sigma_u^2}{\sigma_v^2 + \sigma_u^2}$$

Factors affecting the cost inefficiency

In order to assess the factors associated with cost inefficiency, the cost efficiency scores were used. It was analysed taking the degree of cost efficiency scores as dependent variable. The empirical specification of the cost inefficiency model is given by (Bettese and Coelli, 1995).

$$u_i = \delta_0 + \sum_{m=1}^7 (\delta_m Z_m)$$

Where Z_{mi} are socio-economic characteristics, Z_{1i} is age of the farmer. Z_{2i} is education (years of formal education), Z_{3i} is landholding of the farmer, Z_{4i} is the size of the family, Z_{5i} is the experience in farming, Z_{6i} is a binary variable equal to one if the farmer has membership in any organization and zero otherwise and Z_{7i} is binary variable equal to one if the farmer has access to extension services and to zero otherwise.

3.4.5 Stochastic meta frontier method

The model proposed by Huang *et al.*, (2014) consists of two steps, the first step is to estimate the group-specific stochastic frontier. The second stage estimates the stochastic meta-frontier by pooling the data. This stage uses the estimate of the group-specific output. The investigation indicates the Cobb Douglas (CD) model was rejected in favor of the translog for SRI and pooled data except for the CRPS where CD is suitable. Then the two models are specified as (4) for translog function and (5) for CD.

$$\ln Y_i = \ln \beta_0 + \sum_{j=1}^6 \beta_j \ln X_{ji} + \frac{1}{2} \sum_{j=1}^6 \sum_{k=1}^6 \beta_{jk} \ln X_{ji} \ln X_{ki} + (v_i - u_i) \dots\dots\dots(4)$$

$$\ln Y_i = \ln \beta_0 + \sum_{j=1}^6 \beta_j \ln X_{ji} + (v_i - u_i) \dots\dots\dots(5)$$

where, Y_i =the level of output (quintals), X_1 =Area (ac), X_2 =Seeds (kg/ac), X_3 =Fertilizers (kg/acre), X_4 =Human labour (mandays), X_5 =Machine labour (hrs), X_6 =Irrigation (acre/inch). The deviation of obtained output to its maximum potential

depends on the non-negative random errors u_i , representing the technical inefficiency. If $u_i = 0$, then the observed output will be situated to its potential, if $u_i > 0$, then the observed output will be located below its maximum potential.

Thus, the meta-frontier model is expressed as:

$$\ln Y_{\text{hat}} = \ln \beta^*_0 + \sum_{j=1}^6 \beta^*_{j1} \ln X_{ji} + \frac{1}{2} \sum_{j=1}^6 \sum_{k=1}^6 \beta^*_{jk} \ln X_{ji} \ln X_{ki} + (v_i^* - u_i^*) \quad \dots (6)$$

3.4.6 Economic and physical water use efficiency:

The Physical and Economic water use efficiency (WUE) are calculated as follows;

$$\text{Physical WUE} = \frac{\text{Output (q/acre)}}{\text{Water used (acre inches / acre)}}$$

$$\text{Economic WUE} = \frac{\text{Net returns (Rs/acre)}}{\text{Water used (acre inches / acre)}}$$

3.4.7 Double bounded dichotomous Contingent Valuation Method (CVM)

In order to estimate the farmer's willingness to pay for assured irrigation and fairness in sharing of water, double bounded dichotomous Contingent Valuation Method (CVM) was employed. CVM is a survey method which rests in the creation of imaginary (hypothetical) market situation to elicit the preferences of the farmers towards the environmental goods and services. Irrigation water in many cases is undervalued or not at all valued. Water as a free gift of nature has both active [irrigation] as well as passive uses [option value] (Durba and Venkatachalam, 2015). In this particular study, active use value of surface irrigation water is elicited by using CVM (Durba and Venkatachalam, 2015).

Contingent valuation method suffers from many biases viz., strategic bias, starting point bias, hypothecation bias and vehicle bias. To avoid such biases, following steps were considered. To avoid the starting point bias, 500 per acre per year was taken as the initial bid amount based on the preliminary survey. The format of CVM is depicted in Fig. 2.

Based on the response from farmers, the farmers were grouped into four different categories viz., YY (Yes for first bid and Yes for second bid), YN (Yes for first bid and No for second bid), NY (No for first bid and Yes for second bid) and NN (No for first bid and No for second bid). Along with this, their actual willingness to pay (in Rs. per acre per year) for the assured and equity in distribution of water was also collected. These four different categories were used as endogenous variables and the exogenous variables like age, education, gross returns, land holding and dummy for the access to extension services (1 = YES and 0 = No) were considered to figure out the factors affecting the farmers willingness to pay. Multinomial logistic regression was used to elucidate the factors affecting the willingness to pay by the farmers cultivating rice by different cultivation systems.

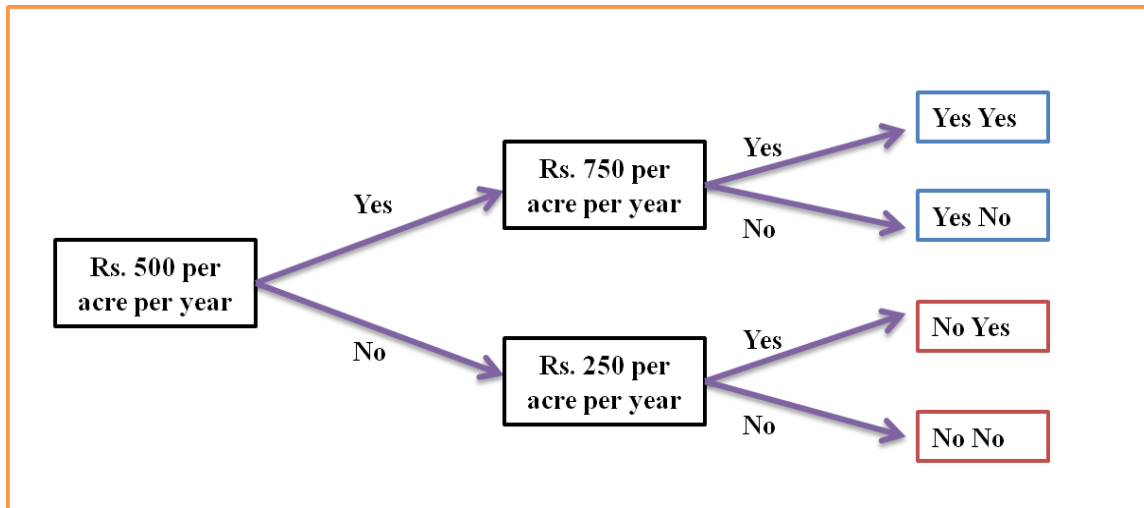


Fig 2: Format of double bounded dichotomous CVM used to estimate willingness to pay

3.4.8 Multinomial logistic regression

To elucidate the factors affecting the willingness to pay (WTP) for assured irrigation and fairness in sharing of water logistic regression was employed.

The regression was run YY=1, YN=2, NY=3 and NN=4 in case of multinomial logistic regression. The base category was YY in case of multinomial logistic regression.

The basic form of the logistic function is,

$$P_i = P_i \left(Y = \frac{1}{X_1, X_2, X_3, \dots, X_k} \right) = \frac{e^z}{1 + e^z} = \frac{\exp(Z)}{1 + \exp(Z)} \dots\dots\dots(7)$$

Where, $Z = \beta_0 + \beta_i X_i$ and X_i are set of predictor variables.

$$\frac{P_i}{1 - P_i} = e^{z_i} \dots\dots\dots(8)$$

$$L_i = \ln\left(\frac{P_i}{1 - P_i}\right) = Z_i = \beta_0 + \beta_i X_i \dots\dots\dots(9)$$

The quantity $\left(\frac{P_i}{1 - P_i}\right)$ is called the odds and hence, $\ln\left(\frac{P_i}{1 - P_i}\right)$ is logit. The coefficients β_i are logit regression coefficients. Odds ratio was computed using these coefficients. In the case of a dichotomous independent variable, the odds ratio can be interpreted as the increased odds of a positive outcome on the dependent variable for the affirmative category ($X=1$) over the negative one ($X=0$). Logistic regression commands in the Stata 14.2 version software was used to analyze the data.

3.4.9 Tobit Analysis

A sample in which information on the dependent variables are available only for some observations is known as a censored sample and in such cases tobit is used (Gujarati, 2004). In view of the fact that the actual willingness to pay was zero for few farmers, tobit model was estimated to find the factors affecting the actual WTP. Censored tobit regression commands in the Stata 14.2 version software were used to find the maximum likelihood estimation of the independent variables.

$$Y_i = \beta_0 + \beta_i X_i + u_i \text{ if } RHS > 0 \text{ and } Y_i = 0, \text{ otherwise} \dots\dots\dots (10)$$

The following model was used for each of the cultivation system

$$WTP (Rs.) = \beta_0 + \beta_1 (X_1) + \beta_2 (X_2) + \beta_3 (X_3) + \beta_4 (X_4) + \beta_5 D1 \dots\dots\dots (11)$$

Where,

$X_1 =$ Age (years)

$X_2 =$ Education (years of schooling)

$X_3 =$ Land holding (acres)

X_4 = Gross returns (Rs.)

D_1 = Dummy for access to extension services (1=YES, 0=NO)

3.4.10 Partial budgeting technique

Partial budgeting technique was used to estimate the relative profitability of technologies in water management and farming. Partial budgeting technique is most often used to estimate relative profitability for a minor change in the existing rice cultivation method. Partial budgeting considers only the changes in income and expenses that would result from an alternative rice cultivation method. Consequently, all other components which do not change by the decision can be ignored.

The format of partial budgeting is as follows,

Debit	Credit
Increase in the cost due to a particular rice cultivation method =A	Savings or reduction in cost due to particular rice cultivation method = C
Decrease in returns due to a particular rice cultivation method = B	Increase in gross return due to a particular rice cultivation method = D
Total Debit = A+B	Total Credit = C+D
Credit minus debit = Net gain / loss	

In the current study, profitability of other three rice cultivation methods over conventional rice cultivation was evaluated using the partial budgeting approach. The technique considers the additional costs, reduced costs, incremental returns and reduced returns realized by farmers.

3.4.11 Garret ranking technique

To rank the farmers' perception on the effects of climate change and its relative significance the Garret ranking technique is employed. The scoring technique, recommended by Garrett for converting the ranks into scores when a particular rank is reported by a different farmer for each effect, was used to analyze the perception on the effect of climate change that farmers confront. The conversion process is as follow:

First the per cent position of each rank was found out by the given formula:

$$\text{Per cent position} = 100 * (R_{ij} - 0.5) / N_j \quad \dots\dots\dots (12)$$

Where,

R_{ij} = Rank given for the i^{th} variable by j^{th} respondents

N_j = Number of variables ranked by j^{th} respondents

Scores are obtained by converting the estimated per cent position. The scores of each individual are then added together for each factor, and the sum of the scores as well as the mean scores are determined. The most significant factor is that which is having the highest mean value.

3.4.12 Conjoint analysis

The consumer purchase behaviour is mainly influenced by consumer quality preferences. Consumer preference is a marketing term meaning a consumer likes one thing over another. For instance, a trend may indicate consumers prefer using debit cards over credit cards to pay for goods. Companies rely on surveys, information and data in order to customize products and services based upon consumer preferences.

It is a statistical technique whereby respondents ranked preferences for different offers were decomposed to determine the persons' inferred utility function for each attribute and the relative importance of each attribute.

Conjoint analysis is a versatile marketing research technique that can provide valuable information for new variety development and forecasting, target a particular set of consumers, comparative analysis among varieties and its popularization. The conjoint analysis help select features to breed or offer on a new or modified variety; to help set prices; to predict the resulting level of demand, sales or usage. Conjoint analysis provides a quantitative measure of the relative importance of one attribute or traits as opposed to another.

Table 4: Trait and trait levels of rice considered for conjoint analysis

Sl. No.	Traits or attributes	Trait levels
1.	Size	Short Medium Long
2.	Shape	Bold (Coarse grains) Medium (Fine grains) Slender (Very fine grains)
3.	Colour	White Brown Red
4.	Kind of Polishing	Polished Medium polished Unpolished
5.	Aroma	Aromatic Non-aromatic
6.	Taste	Good taste Tasteful Delicious
7.	Cooking quality	Should require short time Volume expansion
8.	Texture	Sticky Non-sticky
9.	Nutritional contents	High fibre High iron
10.	Keeping quality	Very good Average Poor

The aims of conjoint analysis are

- i. To identify attribute/trait combinations which confer the highest utility to the consumers
- ii. To establish the relative importance of attributes/trait in terms of their contribution to total utility

The additive conjoint model formulated and used in the present study is as follows:

$$Y = \sum_{i=1}^n \sum_{j=1}^{6m} V_{ij} X_{ij} \dots\dots\dots (13)$$

Where,

Y = Consumers' overall evaluation of rice.

V_{ij} = Part worth estimates associated with 'j' (1,2,3, m) of attributes, 'i' (1,2,3,..., n)

X_{ij} = Dummy variable representing the preference of the jth level of ith attribute.

3.4.13 Rank Based Quotient (RBQ)

Rank based quotient (RBQ) was calculated using following formula as given by Sabarathnam (1988):

$$RBQ = \frac{\sum f_i(n + 1 - i) * 100}{N * n}$$

Where,

i = Concerned ranks

N = Numbers of farmers

n = Numbers of ranks

f_i = Frequency of farmers for ith rank of the technological need

3.4.14 Costing of Irrigation water (Surface water):

Irrigation cost was calculated as follows:

$$\begin{aligned} \text{Irrigation cost} &= \text{Common water cess paid by the farmers} \\ &+ (\text{Water cost compounded at 2\% SDR (Rs./ac - inch)} ** \text{Water use (ac - inch)}) \end{aligned}$$

Where,

Common water cess paid by farmer = Rs. 45 per ac

Water cost= Rs. 12 per ac-inch (Nagaraj *et al.*, 2003)

Water cost compounded at 2 per cent SDR= Rs.17.48

3.4.15 Quantification of externalities

A) Flood mitigation: A paddy field mitigates flood by its bunds acting as barriers to water current and recharges ground water through water infiltration (Huang *et al.*, 2006; Kim *et al.*, 2006; Patle *et al.*, 2017). The extent of flood mitigation was calculated as follows:

- i. Volume of flood kept in paddy fields (V_f in m^3 per ac) = $(H-D) * 4000$, where (H-D) is in metres

Where,

Average height of ridges (H) between fields (as per primary survey) = 6 cm

Depth (D) of standing water (as per primary survey) in paddy fields

- ii. Economic value of flood mitigation (Rs./ac) = $V_f * C$

√ Cost of yearly depreciation and amortized cost (C) = Rs. 30.69 per m^3 which was calculated using the following details:

√ Cost of construction of Krishna Raja Sagar dam (reference dam) in 1932 = Rs. 10340000

√ Active capacity of dam = 124421000 m^3

√ Cost of construction of dam compounded at 10 per cent = Rs. 54936653806.50

√ Depreciation of dam (at 1.95% as per Depreciation under Companies Act, 2013) = Rs. 1071264749.23

√ Amortized cost of dam (at 10 %) = Rs. 5493665381.82 per year

√ Maintenance cost of dam (50 % of amortized cost) = Rs. 2746832690.91

B) Ground water recharge: The amount of ground water recharge was calculated as follows:

- i. Quantity of ground water recharge (Q_w in m^3 /ac) = $I * D_i * 4000$

where,

Infiltration rate (I) in m/day is mentioned in Table 5

D_i is number of days of irrigation (Table 5)

ii. Cost of water from ground water (Rs./m³) = Q_w * C_g

where,

$$\text{Ground water cost (C}_g\text{)} = \text{Rs.189 per ac-inch (Nagaraj et al., 2005)}$$

C) Greenhouse gas emissions: Rice fields are known to emit greenhouse gases, especially methane. Therefore, the valuation of these emitted greenhouse gases were estimated as follows:

i. GHG emission cost to the environment (Rs./ac)=CO₂ equivalent (kg/ac) * GHG cost (Rs./kg)

where,

$$\text{CO}_2 \text{ equivalent (kg/ac)} = \text{Methane emission(kg/ac)} * 25 \text{ (Anon., 2007)}$$

ii. GHG cost of 1 kg CO₂ (Rs./kg) = 0.4819 (Pardis, 2014)

D) Irrigation subsidy: This externality is the cost to the government and was calculated as follows:

$$\text{Irrigation subsidy (Rs.)} = \text{Economic cost of water (Rs./ac)} - \text{Common water cess paid by farmer (Rs./ac)}$$

where,

$$\text{Economic cost of water (Rs./ac)} = \text{Water use (ac-inch)} * \text{Water cost compounded at 2 per cent SDR (Social Discount Rate)}$$

√ Water use for different rice cultivation systems is mentioned in Table 5

E) Environment Damage Cost (EDC): The paddy cultivation systems use huge amount of nitrogen which adds to the economic damage cost and was the extent of damage was calculated as follows:

$$\text{Environment Damage Cost (EDC in Rs./ac)} = \text{N fertilizer usage (kg/ac)} * \text{Economic damage of 1 kg N}$$

where,

$$\text{Economic damage of 1 kg N} = \text{Rs. 7.28 (vontniz et al., 2013)}$$

N fertilizer usage (kg/ac) is given in Table 5

F) Micronutrient provisioning: Iron and zinc micronutrients were valued using replacement cost and benefit transfer methods (Hussain and Badola, 2008).

√ Micronutrients: Iron and zinc content in paddy is given in table 5

√ Yield of paddy = X kg/ac

√ Average micronutrient content = Y mg/kg

√ Price of nutrient = Rs. Z /mg

√ Value of micronutrient provisioning service = X * Y * Z (Rs./ac)

Table 5: Coefficients for valuation of externalities caused by different rice cultivation systems

Sl. No.	Particulars	Source	Conventional	SRI	Aerobic	DSR
1.	Water use (ac-inch)	Primary survey	38.00	25.00	18.00	30.00
2.	Depth of standing water in paddy fields (cm)	Primary survey	5.59	3.05	2.54	4.11
3.	Infiltration rate (m/day)	Primary survey	0.036	0.084	0.18	0.036
4.	No. of days if irrigation	Primary survey	112.00	56.00	11.00	26.50
5.	Methane emissions (kg/ac)	Bhatia <i>et al.</i> , 2013	64.80	15.12	7.20	26.40
6.	Nitrogenous fertilizer usage (kg/ac)	Primary survey	150.00	120.00	80.00	90.00
7.	Average micronutrients	Shylaraj <i>et al.</i> , 2018; Maganti <i>et al.</i> , 2019				
	a) Iron (mg/kg)		27.30	27.30	27.30	27.30
	b) Zinc (mg/kg)		16.00	16.00	16.00	16.00
8.	Price of Average micronutrients	Netmeds. 2020a,b				
	a) Iron (Rs./kg)		0.009	0.009	0.009	0.009
	b) Zinc (Rs./kg)		0.140	0.140	0.140	0.140

3.5 Definition of terms and concepts

Various terminologies used in the present study are defined and presented in this section.

Climate: Climate is the long-term pattern of weather in a particular area. Weather can change from hour-to-hour, day-to-day, month-to-month or even year-to-year.

Climate change: Climate change refers to long-term shifts in temperatures and weather patterns.

Climate change adaptation strategies: An adaptation strategy is a program, project or approach that has been developed to respond to anticipated climate change impacts in a specific area of potential concern.

Climate change mitigation strategies: Climate change mitigation means avoiding reducing emissions of heat-trapping greenhouse gases into the atmosphere to prevent the planet from warming to more extreme temperatures.

Climate smart agriculture (CSA): Food and Agricultural organization defines Climate-smart agriculture (CSA) as “agriculture that sustainably increases productivity, enhances resilience (adaptation), reduces GHGs (mitigation) where possible, and enhances achievement of national food security and development goals”.

Cost efficiency: It is the act of saving resources or money by changing the process to work in a better way.

Water use efficiency (WUE): is defined as the amount of carbon assimilated as biomass or grain produced per unit of water used by the crop.

Micronutrients: A chemical element or substance required in trace amounts for the normal growth and development of crop or plant.

Technical efficiency: According to Koopmans (1951) a producer is technically efficient if an increase in an output requires a reduction in at least one other or an increase in at least

one input, and if a reduction in any input requires an increase in at least one other input or a reduction in at least one output.

Economic efficiency: It is the capacity of a firm to produce a predetermined quantity of output minimum cost for a given level of technology.

Willingness to pay (WTP): Willingness to pay is defined as the maximum price a customer is willing to pay for a product or service.

Trait preferences: Preferences refer to certain characteristics any consumer wants to have in a good or service to make it preferable to consumer. This could be the level of happiness, degree of satisfaction, utility from the product, etc.

RESULTS AND DISCUSSION

IV RESULTS AND DISCUSSION

The results obtained from the analysis of the data collection from the sample respondents on economic analysis of climate smart rice cultivation system in Southern Karnataka are presented and discussed in this chapter in the following headings.

- 4.1 Socio-economic characteristics of sample farmers
- 4.2 Costs, returns and production and cost efficiency in rice cultivation
- 4.3 Water use: Efficiency and willingness to pay (WTP)
- 4.4 Externalities in rice cultivation
- 4.5 Traits preferences of producers and consumers
- 4.6 Adaptation and mitigation strategies

4.1 Socio-economic characteristics of sample farmers

Table 6: Socio-economic characteristics of farmers under different rice cultivation systems

Variables	Rice cultivation systems			
	Conventional (n=30)	SRI (n=30)	Aerobic (n=30)	DSR (n=30)
Age (years)	53.00	48.00	47.00**	43.00*
Education level (years of formal education)	8.00	8.00	10.00*	10.00**
Landholding (acres)	4.83	3.08**	3.33**	3.40**
Experience (years)	25.00	22.00**	20.00*	20.00*
Family size (No.)	5.00	5.00	5.00	5.00
Membership (No.)	13.00 (43)	21.00* (70)	19.00 (63)	20.00** (67)
Access to extension services (No.)	6.00 (20)	25.00* (83)	23.00* (77)	27.00* (93)

Note: Figures in parentheses indicate percentage to total, *, ** indicate significance at 5 and 10 per cent level

The socio-economic characteristics of the farmers are given in table 6. The results indicated that average age of the farmers under conventional rice cultivation was 53 years and with respect to SRI, aerobic and DSR farmers, the average age was 48, 47 and 43 years, respectively. The average landholding was more than 3 acres for SRI, aerobic and DSR farmers but was more than 4 acres for farmers under conventional rice cultivation. The conventional farmers had around 8 years of formal education and SRI, aerobic and DSR farmers had 8, 10 and 10 years of formal education, respectively. The farmers under all the cultivation system had more than 20 years of experience in farming. It was also found that majority of the farmers belonged to the family size of five across all the systems.

It was noticed that around 43 per cent of the farmers under conventional rice cultivation had membership in organizations and 70, 63 and 67 per cent of the farmers under SRI, aerobic and DSR cultivation had membership in organizations, respectively. It was also noted that more than 70 per cent of the farmers under SRI, aerobic and DSR had access to extension services but it was only 20 per cent for farmers under conventional method.

4.2 Costs, returns and production and cost efficiency in rice cultivation

4.2.1 Costs and returns analysis of different rice cultivation systems

Cost of rice cultivation

The estimation of total cost of cultivation took into account explicit costs on inputs, labour cost, imputed costs of family labour and other owned factors. The table 7 depicts the details on cost of cultivation per acre for rice across different cultivation systems. The following section gives the information on different items of costs involved in rice cultivation such as variable cost and fixed cost.

Variable cost

It was found that the cost of seeds were Rs. 816 in conventional method, Rs. 640 in SRI method, Rs. 573.75 in aerobic method and Rs. 646.67 in DSR method. The quantity of seed used was highest in DSR method i.e. 18.50 Kg followed by the aerobic method which requires 18.13 Kg.

Table 7: Cost of cultivation under different rice cultivation systems**(Rs. /acre)**

Sl. No.	Particulars	Conventional		SRI		Aerobic		Drum seeded Rice	
		Qty	Cost	Qty	Cost	Qty	Cost	Qty	Cost
I	Variable costs								
	Seed (kgs)	13.00	816.00	7.30	640.00	18.13	573.75	18.50	646.67
	FYM (Tractor load)	2.86	5296.30	1.80	4000.00	2.12	4937.50	1.93	4666.67
	Fertilizers (Kgs)	170.33	3601.33	156.00	3680.00	160.50	3348.00	175.17	3655.33
	Plant protection chemicals		2343.07		2610.69		2740.56		3663.98
	Micronutrients		937.50		580.00		580.00		400.00
	Irrigation (acre inch)		709.20		482.00		359.00		569.00
	Human labour (Man days)	36.22	14730.37	33.40	14028.00	19.90	8457.50	22.20	8991.00
	Bullock labour (BP days)	1.00	1371.43	1.00	1200.00	0.00	0.00	1.00	1040.00
	Machine labour (Hours)	5.53	6077.78	5.64	7096.67	2.95	5275.00	6.71	7888.70
	Interest on WC @ 7 %		2511.81	14.36	2402.22	14.25	1838.99	15.79	2206.49
	Total variable costs		38394.78 (75.39)	219.50	36719.58 (75.01)	217.85	28110.30 (64.70)	241.29	33727.85 (73.31)
II	Fixed costs								
	Depreciation		1788.98		1019.95		1290.87		1059.72
	Land revenue		400.00		400.00		400.00		400.00
	Rental value of land		9000.00		9500.00		12000.00		9500.00
	Interest on fixed capital @ 12 per cent		1342.68		1310.39		1642.90		1315.17
	Total fixed costs		12531.66 (24.61)		12230.35 (24.99)		15333.78 (35.30)		12274.89 (26.69)
III	Total cost of cultivation		50926.44	219.50	48949.92	217.85	43444.07	241.29	46002.74

Overall, the seed cost was high in case of conventional method because the different varieties have been used in different cultivation systems whose prices vary across cultivation systems. FYM required for rice cultivation vary from one to 3 tractor loads. Cost of FYM was highest in case of conventional i.e. Rs.5296.30, Rs 4000 in case of SRI method, Rs.4937 in aerobic method and Rs. 4666.67 in DRI method. The quantity of fertilizer used was highest in conventional and DRI method which was 170.33 Kg and 175.17 Kg respectively.

But the cost of fertilizer vary marginally across different cultivation systems and it was found lowest in case of Rs.3348, this is because of comparatively lower quantity of fertiliser was used in aerobic method. It also observed that cost of plant protection chemicals was highest in case of DSR method i.e. Rs. 3663.98 and this is due to more usage of weedicide because of higher weed incidence. The cost of plant protection chemical in case of conventional, SRI and aerobic was found to be Rs. 2343.07, 2610.69 and 2740.56 respectively. The cost of micronutrients in conventional method was found to be highest which was Rs. 937.50 followed by SRI (Rs. 580), aerobic (Rs. 580) and DSR method (Rs. 400). The results also revealed that the irrigation cost was found to be highest in conventional method which was 709.20 because of higher water usage which was around 38.40 acre inches. Irrigation water cost was lowest in aerobic rice cultivation method that is around Rs. 359 with water use of 18.36 acre inch. In SRI and DSR method irrigation cost was Rs.482 and Rs.569 respectively with water usage was 25.16 acre inch and 30.18 acre inch per acre respectively.

It was also found that human labour cost was major components of variable cost in specific and total cost in general. The number of human labour was used highest in conventional method i.e. 36.22 man days, which costs around Rs.14730.37. The reason for this would be, farmers might be less mechanised. It was found lowest in aerobic method of rice cultivation i.e. Rs. 8457.50 that uses 19.90 man days. The human labour cost in SRI and DSR method was found to be Rs.14028 and Rs.899. The results also reveals that, across all the rice cultivation systems bullock labour was used marginally, zero utilisation in case of aerobic and DSR method. The farmers in DSR method were more mechanised than their counterparts which was found to be 6.71 hours and total machine labour cost in this method was Rs.7888.70. The machine labour cost in

conventional was Rs. 6077.78, in SRI and aerobic method it was around Rs. 7096.67 and Rs. 5275 respectively. Overall, it was concluded that the rice cultivating farmers in the study area were well mechanised.

The share of total variable cost in total cost was highest in conventional method which was around Rs.38394.78 and it accounts for 75.39 per cent. It was also found that the total variable cost in SRI method was Rs.36719.58, in aerobic method it was Rs.28110.30 and in DSR method the variable cost was Rs.33727.85.

Fixed cost

The total fixed cost incurred by the farmers practicing aerobic cultivation method was highest than their counterparts, which was Rs.15333.75. It was noticed that cost incurred by the farmers in other systems vary marginally across different cultivation systems. The major component of fixed cost was the rental value of land in all the cultivation systems. Rental value in conventional, SRI, aerobic and DSR method was Rs.9000, Rs.9500, Rs.12000 and Rs.9500 respectively. Land revenue was found to be Rs.400 across all the system and it accounts small share of total fixed cost. The depreciation cost of conventional, SRI, aerobic and DSR method was Rs.1788.98, Rs.1019.95, Rs.1290.87 and Rs.1059.72 respectively.

The total cost of cultivation was found to be highest in conventional method which was Rs. 50926.44 and it is due to higher usage of human labour. The total cost was found lowest in Rs.43.444.07. Similarly, in SRI method and DSR method the cost of cultivation was Rs.48949.92 and Rs.46002.74 respectively. Thus, the hypothesis of cost of cultivation is more in conventional method is more in conventional rice cultivation compared to other systems is accepted.

Yield and returns

The results of the table 8 indicate yield and return structure of paddy under different rice cultivation systems. Across all cultivation systems the yield was found to be highest in SRI method (33.2 q/ac) due to the fact that there are more number of tillers obtained per hill i. e. 30 to 40 tillers thereby increasing the yield.

Table 8: Yield and returns of paddy under different rice cultivation systems**(Rs. /acre)**

Particulars	Conventional			SRI			Aerobic			DSR		
	Qty	Price/ Unit (Rs.)	Total (Rs.)	Qty	Price/ Unit (Rs.)	Total (Rs.)	Qty	Price/ Unit (Rs.)	Total (Rs.)	Qty	Price/ Unit (Rs.)	Total (Rs.)
Main product (qtls)	25.50	1720.00	43860.00	33.20	1730.00	57436.00	23.13	1675.00	38734.38	23.57	1755.00	41359.50
By-product (Tractor load)	2.13		10633.33	2.00		12900.00	2.00		10250.00	2.07		12066.67
Gross returns (Rs.)			54493.33			70336.00			48984.38			53426.17
Net returns (Rs.)			3566.89			21386.08			5540.30			7423.43
Total Fixed cost			12531.66			12230.35			15333.78			12274.89
Total variable cost			38394.78			36719.58			28110.30			33727.85
Cost of cultivation (Rs./acre)			50926.44			48949.92			43444.07			46002.74
Cost of production (Rs./q)			1997.12			1474.40			1878.66			1952.03
Gross returns over VC(Rs./acre)			16098.55			33616.42			20874.08			19698.32
Gross returns over COC(Rs./acre)			3566.89			21386.08			5540.31			7423.43
Gross returns over COP(Rs./acre)			52496.22			68861.60			47105.71			51474.14
Gross returns per VC (Rs./acre)			1.42			1.92			1.74			1.58
Gross returns per COC (Rs./acre)			1.07			1.44			1.13			1.16
Gross returns per quintal (Rs.)			2136.99			2118.55			2118.24			2267.02
Net returns per quintal (Rs.)			139.88			644.16			239.58			315.00
Returns per rupee of expenditure (net returns per COC)			0.07			0.44			0.13			0.16

The average yield in conventional method was 25.5 quintals which is followed by the drum seeded rice (23.57 quintals) and aerobic methods (23.13 quintals). Gross and net returns were highest in case of SRI method (Rs. 70336 and Rs. 21386.08) this is because of higher yield. The gross returns in drum seeded rice cultivation was found to be Rs.53426.17 then in conventional and aerobic rice cultivation method it was found to be Rs. 54493.30 and Rs. 48984.38 respectively. Net return was found to be lowest in case of conventional method which was Rs.3566.89. This was due to higher cost incurred especially for human labour. It was also found that, net return in aerobic and DSR method was Rs.5540.30 and Rs. 7423.43. Gross return per variable cost was found to be highest in SRI method of cultivation i.e. Rs. 1.92 per acre. Gross return per COC was also highest in case of SRI method (Rs. 1.44/ac) followed by DSR (Rs 1.16/ac), aerobic (Rs.1.13/ac) and conventional (Rs. 1.07/ac) method of rice cultivation. Net return per quintal was also highest in case of SRI method (Rs.641.26) followed by the DSR (Rs.314.99), aerobic (Rs.239.58) and conventional method (Rs.139.88). Therefore, the hypothesis of returns realized is more in SRI method of rice cultivation than other methods is accepted.

4.2.2 Efficiency analysis

Table 9: Resource use efficiency in rice cultivation

Sl. No.	Particulars	Economic Efficiency (MVP/MFC)			
		Conventional	SRI	Aerobic	DSR
1.	Seed (kgs)	0.6563**	0.6508**	0.1244	0.9712
2.	FYM (tractor load)	0.9225	0.9257	0.8910*	0.9573
3.	Fertilizer(kgs)	0.2822	1.9345***	3.5129*	0.1799
4.	Human labor (Man days)	0.7101	1.1189	0.9667	0.5221
5.	Machine labor (Hours)	5.7485	0.9955**	0.9802	0.8757**
6.	Irrigation (acre inch)	0.0025***	0.1250	0.9760	0.4576*

***, **, * indicates significance at 1, 5 and 10 per cent level, respectively.

The parameters of rice production function of different rice cultivation systems were estimated using the Cobb-Douglas type of production function, presented in the methodology chapter. The summation of production coefficients for farms of Mandya district was -0.006 for conventional method, -0.49 for SRI method, -0.12 for DSR method indicating decreasing returns to scale prevailed in rice cultivation. Whereas in case of aerobic rice cultivation method the summation of production coefficients is 1.14 indicating increasing returns to scale in rice cultivation.

Using the estimated coefficients obtained through the Cobb-Douglas type of production function and geometric mean levels of inputs and output, the efficiency of the various inputs used in the cultivation of rice under different system were assessed. Economic efficiency is defined as the firm's ability to combine inputs and outputs in the best possible proportions in relation to their cost. The economic efficiency of different rice cultivation systems were estimated using the per acre production function estimates. The marginal physical product (MPP), marginal value product (MVP), and economic efficiency (profitability ratios) were estimated at the geometric mean levels of inputs and outputs. The marginal cost of FYM (Rs. /tonne) and marginal factor cost (MFC) of human labour were taken at the rates prevailing in the study area.

It could be observed from the results on resource use efficiency analysis presented in table 9 that in conventional method of rice cultivation, machine labour was underutilized resource and human labour, seeds, fertilizers and irrigation were overutilized by the farmers practicing conventional system and seed and irrigation were found to be significant at five per cent and one per cent level of probability, respectively. Whereas, FYM was found to be nearly optimally utilized input in this method. In case of SRI method of rice cultivation, seed and machine labour were significant at five per cent level of probability. Also, FYM and machine labour inputs were nearly optimally utilized resources and all other inputs were not optimally utilized. In aerobic rice cultivation method, human labour, machine labour and irrigation were nearly optimally used whereas, seed and fertilizers were overutilized and fertilizer was underutilized. In DSR method, machine labour and irrigation were significant at five and ten per cent level of

probability, respectively. Seed was nearly optimally utilised input, and rest are overutilized in DSR method.

Technical efficiency

The results of the estimates of stochastic frontier and meta frontier model are depicted in table 10. The seeds, human labour, and machine labour were affected the production of rice positively in SRI method. In SRI method, rice production will increase by 0.8 per cent as a result of a one per cent increase in its area. Whereas, rice production will increase by 0.4 per cent as a result of one per cent increase in usage of seeds. Irrigation, area and its square, and machine labour and its square is negatively linked to SRI method of rice cultivation. As one per cent of increase irrigation, area and its square, and machine labour and its square will likely reduce the rice production by 2.6 per cent, 2.5 per cent and 2.8 per cent, respectively.

In case of aerobic method area, machine labour, interaction of area with fertilizer, interaction of area with human labour, interaction term for area with machine labour, interaction term for seeds with machine labour were influenced the rice production positively and found significant. Whereas, area with irrigation, interaction of seeds with itself, interaction of fertilizer with human labour, interaction of human labour with machine labour, and interaction of machine labour with itself negatively affects the rice production in aerobic method of rice cultivation. The rice production is likely to increase by 0.3 per cent as a result of one per cent increase in area and also it will increase by 20.8 per cent as a result of one per cent increase in machine labour which found significant and as one per cent increase in area with irrigation, interaction of seeds with itself, interaction of fertilizer with human labour, interaction of human labour with machine labour, and interaction of machine labour with itself will reduce the rice production by 0.2 per cent, 0.04 per cent, 0.002 per cent, 0.2 per cent and 3.97 per cent, respectively.

Table 10: Parameter estimates from stochastic frontier (SRI, Aerobic, DSR and Pooled) and stochastic meta-frontier (SMF)

Variables	Variable description	SRI	Aerobic	DSR	Pooled	SMF
Intercept		711.76 (0.99)	8.154*** (0.018)	103.35 (1.238)	47.338* (0.06)	26.003*** (0.012)
Area	Area (ha)	0.8972** (0.043)	0.302*** (0.001)	1.695 (4.215)	15.929* (0.65)	0.294 (0.974)
Seeds	Seeds (kg/ha)	0.4416** (0.29)	0.110 (0.441)	0.204 (0.583)	0.031 (0.481)	0.127 (0.312)
Fertilizers	Fertilizers (kg/ha)-229.99	0.436 (0.348)	-0.002 (0.051)	-0.116 (0.103)	0.054 (0.065)	0.064 (0.044)
Human labour	Human labour (mandays)	17.122*** (0.09)	0.376 (0.609)	1.168 (0.789)	4.105** (0.083)	1.610** (0.047)
Machine labour	Machine labour (hrs)	53.539** (0.079)	20.851** (0.041)	-32.585*** (0.002)	16.494*** (0.012)	2.773*** (0.004)
Irrigation	Irrigation (acre inch)	-2.622** (0.035)	-4.75 (0.943)	-1.051 (1.463)	-0.253 (1.352)	-3.956* (0.067)
Area*area	Interaction term for area with itself	-2.538*** (0.063)	1.074* (0.081)	1.813** (0.025)	0.050 (0.431)	0.075 (7.361)
Area*seeds	Interaction term for area with seeds	0.524 (0.885)	-0.042 (0.042)	-0.3175* (0.064)	-0.059 (0.045)	-0.152** (0.042)
Area * fertilizer	Interaction term for area with fertilizer	-0.047 (0.103)	0.018*** (0.010)	0.022*** (0.007)	-0.010 (0.010)	0.001 (6.006)
Area*human labour	Interaction term for area with human labour	0.437 (0.734)	0.152** (0.044)	-0.297* (0.082)	-0.255* (0.060)	0.018 (0.48)
Area*machine labour	Interaction term for area with machine labour	1.457 (0.975)	1.614* (0.075)	-0.138 (0.339)	-0.270 (0.240)	0.438* (0.106)
Area* irrigation	Interaction term for area with irrigation	-0.300 (0.836)	0.297*** (0.070)	0.113 (0.129)	-0.142 (0.85)	-0.118 (0.687)
Seeds*seeds	Interaction term for seeds with itself	-0.187 (0.648)	-0.047* (0.0180)	-0.036 (0.208)	0.020 (0.814)	-0.013 (3.011)
Seeds*fertilizer	Interaction term for seeds with fertilizer	-0.009 (0.019)	-0.001 (0.001)	-0.001 (0.709)	-0.001 (2.001)	-0.0003 (1.0005)
Seeds*human labour	Interaction term for seeds with human labour	-0.056 (0.236)	-0.003 (0.005)	0.006 (0.305)	-0.003 (3.010)	0.006 (2.005)
Seeds*machine labour	Interaction term for seeds with machine labour	-0.291 (4.930)	0.180* (0.064)	0.26428* (0.076)	0.140** (0.050)	0.080** (0.039)

Variables	Variable description	SRI	Aerobic	DSR	Pooled	SMF
Seeds*irrigation	Interaction term for seeds with irrigation	-0.125 (0.314)	0.025 (0.016)	-0.002 (0.522)	-0.012 (3.012)	-0.006 (3.010)
Fertilizer*fertilizer	Interaction term for fertilizer with fertilizer	0.001 (0.894)	-0.001 (0.001)	-0.004 (0.801)	-0.0001 (0.0001)	-0.0001 (2.0001)
Fertilizer*human labour	Interaction term for fertilizer with human labour	-0.009 (2.745)	0.002*** (0.001)	0.003* (0.001)	0.001 (0.001)	0.0007 (0.9005)
Fertilizer*machine labour	Interaction term for fertilizer with machine labour	-0.017 (6.185)	-0.005 (0.010)	0.027*** (0.005)	-0.005 (0.004)	-0.009** (0.053)
Fertilizer*irrigation	Interaction term for fertilizer with irrigation	-0.006 (0.092)	0.007*** (0.002)	-0.001 (0.003)	-0.002 (0.002)	-0.002 (0.001)
Human labour * human labour	Interaction term for human labour with itself	-0.282 (4.179)	-0.012 (0.923)	-0.084*** (0.019)	-0.100** (0.030)	-0.060*** (0.012)
Human labour *machine labour	Interaction term for human labour with machine labour	-0.851 (0.738)	0.220*** (0.041)	0.268* (0.073)	-0.370* (0.076)	-0.085** (0.028)
Human labour*irrigation	Interaction term for human labour with irrigation	-0.153 (1.331)	0.064 (0.407)	0.010 (0.821)	0.067* (0.090)	0.012 (1.014)
Machine labour * machine labour	Interaction term for Machine labour with itself	-2.833** (0.031)	-3.972** (0.044)	1.370 (0.907)	-0.638* (0.083)	0.602** (0.051)
Machine labour*irrigation	Interaction term for Machine labour with irrigation	-0.470 (0.921)	-0.182 (0.110)	0.541** (0.07)	-0.001 (0.051)	-0.215** (0.034)
Irrigation*irrigation	Interaction term for irrigation with irrigation	-1.092 (0.709)	-0.101 (0.130)	-0.021 (0.100)	-0.136** (0.047)	0.319** (0.042)
Sigmasq	SigmaSq	1.285 (0.99)	2.740*** (0.005)	6.380*** (0.008)	3.773* (0.07)	12.669** (0.038)
Gamma		0.94 (0.99)	0.75*** (0.001)	0.77*** (0.00)	0.610 (0.010)	0.88*** (0.0000012)
Log likelihood		58.241	78.922	116.8255	241.609	229.99

***, **, * indicate 1, 5 and 10 per cent level of significance.

Interaction of area with itself, interaction of area with fertilizer, interaction of seeds with machine labour, interaction of fertilizer with human labour, interaction of fertilizer with machine labour, interaction of human labour with machine labour, interaction of machine labour with irrigation positively affects the DSR method of rice production. That means as increase in one per cent of interaction of area with itself, interaction of area with fertilizer, interaction of seeds with machine labour, interaction of fertilizer with human labour, interaction of fertilizer with machine labour, interaction of human labour with machine labour, interaction of machine labour with irrigation will likely to increase the rice production by 1.81 per cent, 0.02 per cent, 0.26 per cent, 0.003 per cent, 0.02 per cent, 0.26 per cent and 0.54 per cent, respectively. Whereas, by one per cent increase in machine labour, interaction term of with seeds, interaction of area with human labour, and interaction of human labour with itself were negatively influenced in DSR method of rice cultivation by influencing to decrease the rice production by 32.58 per cent, 0.31 per cent, 0.29 per cent and 0.08 per cent, respectively.

Similarly, with respect to pooled data, the area, human labour, machine labour and the interaction of seeds with machine labour shows positive significant effect with rice production that means as increase in one per cent area will likely to increase the rice production by 15.92 per cent, the same in case of human labour, as increase in one per cent of human labour will increase the rice production by 4.10 per cent. Whereas it with respect to machine labour, 14.49 per cent of rice production is likely to increase as one per cent increase in machine labour and the Interaction term for seeds with machine labour will also expected to increase the rice production by 0.26 per cent as increase in one per cent of interaction term for seeds with machine labour. The Interaction term for area with human labour, interaction of human labour and itself, interaction of human labour with machine labour, machine labour and interaction of irrigation and itself were negatively associated with rice production. As one per cent increase in interaction of area with human labour, interaction of human labour and itself, interaction of human labour with machine labour, machine labour and interaction with irrigation and itself were likely to reduce the rice production by 0.29 per cent, 0.10 per cent, 0.37 per cent, 0.63 per cent and 0.13 per cent, respectively.

Table 11 summarizes the result of the technical efficiency from stochastic frontier (TE), Meta frontier (TE*) and technology gap ratio (TGR). The results indicate that the mean technical efficiency from the stochastic frontier with respect to group frontiers are equal to 0.94, 0.89, and 0.82 for SRI, aerobic and DSR method of rice production. The mean technical efficiency relative to meta-frontier for SRI, aerobic and drum seeded method are respectively 0.96, 0.91 and 0.89 for SRI, aerobic and DSR farmers. This implies that on average, SRI farms are more technically efficient than those farms operating under different systems of rice production.

Table 11: Estimation of technical efficiency scores and technology gap ratios

Index	SRI	Aerobic	DSR	Pooled
Technical efficiency TE (stochastic frontier)				
Mean	0.948	0.891	0.823	0.887
Min	0.890	0.560	0.572	0.986
Max	0.969	0.921	0.870	0.727
SD	0.238	0.288	0.319	0.077
Technical efficiency * (meta frontier)				
Mean	0.962	0.917	0.890	0.923
Min	0.789	0.004	0.002	0
Max	1	1	1	1
SD	0.132	0.255	0.321	0.311
Technology gap ratios				
Mean	0.935	0.918	0.871	0.91
Min	0.784	0.102	0.575	0.737
Max	1	1	1	1
SD	0.231	0.321	0.231	0.078

Furthermore, the mean technology gap ratio is 0.93, 0.91 and 0.87 for SRI, aerobic and drum seeded farmers, respectively. These results show that if the SRI farmers were technically efficient, they could have increased their production by closing the gap

of 7 per cent while the aerobic farmers could have increased their production by closing the gap of 9 per cent. And drum seeded farmers could have increased their production by closing the gap of 13 per cent. This implies that the DSR farmers are distant to meta frontier than their counterparts. This further indicates that the SRI farmers will reach the maximum potential output for rice production faster than their counterparts if all factors are maintained constant.

Analysis of cost efficiency

The Cobb-Douglas cost function was estimated using the computer version FRONTIER 4.1 and the results of the maximum likelihood estimates of the stochastic cost frontier of rice farmers under conventional rice cultivation is given in table 12. The results revealed that one per cent increase in the seed cost, human labour and machine labour cost will increase the total cost by 1.05, 1.96 and 0.9 per cent, respectively and was found significant. The estimated coefficient of the explanatory variables in the cost inefficiency model shows that all the coefficients have the expected signs except age and experience. With increase in age and experience by one per cent the cost inefficiency increased by 0.239 and 0.215 per cent indicating that the farmers who are old are reluctant to adopt the cost efficient technologies. This is in line with the findings of Singh *et al.* (2020) who reported that age is positively related to cost inefficiency. Similarly with respect to increase in experience, following conventional practices leads to increased cost inefficiency.

Sigma squared (σ^2) on the other hand is 0.221 and statistically significant at one per cent indicating correctness of fit of the model as assumed for the composite error term. The estimated gamma parameter of 0.437 is highly significant at five per cent, indicating that around 44 per cent of the variation in the total cost of production among the sampled farmers is due to differences in their cost efficiency. Moreover, the presence of cost inefficiency was tested by LR (Likelihood Ratio) statistic, it was 14.054 which is lesser than the critical chi square value of 24.049, which implies the assumption of no cost inefficiency was rejected.

Table 12: Maximum likelihood estimates of the stochastic cost frontier of rice farmers (Conventional method)

Variables	Coefficients	t-ratio
Constant	- 9.309	-1.024
Seed cost	1.048*	2.576
Fertilizer cost	-0.082	-0.335
Human labour cost	1.960**	2.127
Machine labour cost	0.914*	2.830
Inefficiency model		
Constant	1.597	0.624
Age	0.239*	2.902
Education	0.144	0.878
Land holding	-0.022**	- 2.074
Family size	-0.280	-0.734
Experience in farming	0.215*	3.741
Membership in organization	-1.006	-0.270
Access to extension services	-0.359	-0.860
Variance parameters		
Sigma squared	0.221*	3.867
Gamma	0.437**	2.292
Log likelihood	19.989	
LR statistic	14.054	

Note: *, ** indicates significance at one and five per cent probability level, respectively

Table 13: Maximum likelihood estimates of the stochastic cost frontier of rice farmers (SRI method)

Variables	Coefficients	t-ratio
Constant	2.452*	3.501
Seed cost	0.054*	5.977
Fertilizer cost	0.130*	13.877
Human labour cost	0.340*	12.923
Machine labour cost	0.373*	9.033
Inefficiency model		
Constant	-0.106	-0.199
Age	0.009	0.158
Education	-0.078	-1.429
Land holding	-0.039	-0.279
Family size	-0.023	-0.828
Experience in farming	- 0.011	-0.427
Membership in organization	- 0.075**	-2.389
Access to extension services	- 0.289*	-2.595
Variance parameters		
Sigma squared	0.636*	3.733
Gamma	0.719*	3.433
Log likelihood	70.878	
LR statistic	20.539	

Note: *, ** indicates significance at one and five per cent probability level, respectively

The inefficiency effects of membership in organization and access to extension services was negative and significant. This means that both the factors are contributing positively to cost efficiency. The farmers obtain required and necessary technical advice and knowledge, thereby produce at efficient costs. Increase in membership in organization and access to extension services by one per cent would lead to increase in cost efficiency by 0.075 and 0.289 per cent, respectively.

The maximum likelihood estimates of the stochastic cost frontier of rice farmers under SRI method of rice cultivation is given in table 13. The cost elasticities of all the input variables used in the cost analysis were positive which implies that an increase in the cost of seed, fertilizer, human labour and machine labour increases total production costs. The coefficients were positive and significant at one per cent. One per cent increase in costs of seed, fertilizer, human labour and machine labour increases the cost by 0.054, 0.130, 0.340 and 0.373 per cent, respectively.

The sigma squared value was 0.636 and significant at one per cent level indicating the goodness of fit. The gamma parameter was estimated to be 0.719 and was significant at one per cent level. This reveals that approximately 72 per cent of the variation in the total cost of production among the sampled farmers is due to differences in their cost efficiency. LR statistic was 20.539 and lesser than the critical chi square value of 24.049, depicting the presence of cost inefficiency.

The result of stochastic cost frontier for aerobic rice cultivation is depicted in Table 14. It was observed that coefficients of all the input variables i.e. cost of seeds, fertilizers, human labour and machine labour were highly significant at one per cent level. With respect to inefficiency effects, education was found negative and significant at one per cent level. Increase in education by one per cent decreases cost inefficiency by 0.31 per cent. This reveals that higher the level of education, higher the cost efficiency of the farms. Aboaba (2020) reported that higher the level of education, the higher the allocative efficiency, which implies that educated farmers are allocatively efficient compared to their counterparts. The Sigma squared estimate (0.031) was also significant at one per cent level indicating the good fit of the model. The gamma value was 0.89 which revealed that 89 per cent of the variation in cost of production is attributed to the variation in costs among the rice farmers and is due to differences in cost efficiency.

Table 14: Maximum likelihood estimates of the stochastic cost frontier of rice farmers (Aerobic method)

Variables	Coefficients	t-ratio
Constant	12.955*	11.533
Seed cost	0.056*	4.510
Fertilizer cost	0.140*	5.540
Human labour cost	0.426*	9.329
Machine labour cost	0.298*	5.213
Inefficiency model		
Constant	-0.115	-0.167
Age	0.074	0.339
Education	-0.310*	-2.77*
Land holding	-0.002	-0.078
Family size	-0.048	-0.689
Experience in farming	0.060	1.940
Membership in organization	-0.039	-1.120
Access to extension services	-0.017	-1.130
Variance parameters		
Sigma squared	0.031*	3.763
Gamma	0.89*	190.080
Log likelihood	68.58	
LR statistic	23.346	

Note: *, ** indicates significance at one and five per cent probability level, respectively

It was observed from the stochastic cost frontier analysis under DSR rice cultivation that the cost of human labour was significant at one per cent whereas seeds and machine labour was significant at five per cent level. The coefficients obtained for the maximum likelihood estimates are given in table 15. Even in the case of DSR method, increase in all the input variables increases the total cost. In the case of cost inefficiency effects, access to extension services and education were significant and one

per cent increase in education and extension services decreases cost inefficiency by 0.20 and 0.08 per cent, respectively. Sigma squared and gamma was observed to be 0.092 and 0.69 and was significant at five per cent level.

Table 15: Maximum likelihood estimates of the stochastic cost frontier of rice farmers (DSR method)

Variables	Coefficients	t-ratio
Constant	7.634*	7.931*
Seed cost	-0.005*	-3.005*
Fertilizer cost	0.109	0.103
Human labour cost	0.169*	3.085*
Machine labour cost	0.022**	2.045**
Inefficiency model		
Constant	0.006	0.007
Age	0.003	0.004
Education	-0.200*	-3.019*
Land holding	-0.024	-0.092
Family size	-0.002	-0.012
Experience in farming	-0.022	-1.302
Membership in organization	-0.036	-0.113
Access to extension services	-0.083*	55.770*
Variance parameters		
Sigma squared	0.092**	1.908
Gamma	0.69**	2.502
Log likelihood	29.104	
LR statistic	7.528	

Note: *, ** indicates significance at one and five per cent probability level, respectively

Efficiency distribution of rice farmers under different rice cultivation systems

The distribution of farmers according to the cost efficiency scores is presented in Table 16. It was observed that mean efficiency score was 0.55, 0.92, 0.94 and 0.88 for

conventional, SRI, aerobic and DSR cultivation, respectively. This indicates that the cost efficiency was highest in aerobic rice cultivation. The cost efficiency obtained is supported by Aboaba (2020) which reported that mean allocative efficiency implies that rice farmers were 94 per cent cost-efficient, that is they were able to maximize their total output by minimizing 94 per cent of their total production cost, which shows that there is room for six per cent improvement.

Table 16: Distribution and summary statistics for cost efficiency scores of farmers under different rice cultivation systems

Cost efficiency scores	Conventional	SRI	Aerobic	DSR
≤0.5	9.00	-	-	-
>0.50 ≤0.70	20.00	4.00	-	7.00
>0.70 ≤0.90	1.00	4.00	2.00	3.00
>0.90	-	22.00	28.00	20.00
Mean	0.55	0.92	0.94	0.88
Minimum	0.12	0.60	0.86	0.66
Maximum	0.60	0.97	0.98	0.95

The lowest cost efficiency was obtained under conventional rice cultivation indicating that around 55 per cent of the farmers were allocatively efficient. The mean efficiency scores obtained for SRI method of cultivation was higher than 83 per cent as reported by Mwatete *et al.* (2015). With respect to DSR rice cultivation, the efficiency scores obtained are in line with results of Maurice *et al.* (2015) which reported allocative efficiency of 0.84 for food crop production among small scale farmers. Thus, there was 45 per cent room for increasing efficiency for conventional farmers and only two per cent for aerobic farmers.

4.3 Water Use: Efficiency and willingness to pay (WTP)

4.3.1 Water use efficiency

The table 17 indicates water use efficiency of paddy across different rice cultivation systems. Irrigation water use was highest in case of conventional method i.e.

38.40 acre inch which was succeeded by drum seeded rice, SRI and Aerobic cultivation methods whose values were 30.18, 25.16 and 18.36 acre inches respectively. Physical water use efficiency (WUE) was highest in case of SRI (1.26 q/ acre inches) than their counter parts. The physical WUE was found to be 0.63 q/acre inches in conventional method which was lowest among all methods. The highest physical WUE was mainly attributed to lower irrigation water used in SRI cultivation (Lal *et al.* 2013). The economic WUE was found highest in case of SRI method (Rs. 850.00/acre inch) as compare to all other cultivation methods. This is followed by the aerobic (Rs. 301.76/acre inch), drum seeded rice (Rs. 245.97/ acre inch) and conventional method (Rs. 92.88/ acre inch). The sustained productivity with lower irrigation water use in crops can enhance returns of the producers because of reduced imputed cost of irrigation water (Balasubramanian and Hill, 2002). Thus, the hypothesis of WUE is least in conventional method of rice cultivation is accepted.

Table 17: Water use efficiency of paddy under different rice cultivation systems

Sl. No.	Particulars	Conventional	SRI	Aerobic	DSR
1.	Irrigation water use (acre inch)	38.40	25.16	18.36	30.18
2.	Main product (q/acre)	25.50	33.20	23.13	23.57
3.	Physical water use efficiency (q/acre inch)	0.63	1.32	1.26	0.75
4.	Net returns (Rs./acre)	3566.89	21386.08	5540.30	7423.43
5.	Economic water use efficiency (Rs./acre inch)	92.88	850.00	301.76	245.97

4.3.2 Willingness to Pay (WTP)

The farmers were presented with double bounded dichotomous CVM format. It was noticed that majority of the farmers in conventional (43 %) and SRI method (60 %) expressed their willingness to pay for both initial and final bid i.e. Rs. 500 and Rs. 750 for assured irrigation and equity in distribution of irrigation water. Around 30 and 13 per cent of the farmers were not willing to pay for use of irrigation water in conventional and SRI method. Twenty per cent of farmers in conventional and SRI method express their

willingness to pay for initial bid (Rs. 500) and fall into category of Yes No category (Table 18). Only seven per cent of farmers fall into the category of No Yes category in conventional and SRI method. Majority of the farmers in DSR and aerobic method of cultivation expressed their non-willingness to pay for the use of irrigation water. This was due to fact that, the farmers in aerobic method were already use less water for rice cultivation. Around 27 and 30 per cent of farmers in Sri Method were fall into No Yes and Yes No category. In DSR method 16 per cent of farmers expressed their willingness to pay final bid and 10 per cent of farmers expressed their willingness to pay for both the bids. Overall the farmers were expressed non-willingness to pay which indicate the presence of free rider problem and failure of institutional arrangements in the study area.

The mean willingness to pay (table 18) was significantly high in case of SRI method followed by the conventional method of rice cultivation systems than their counterparts with the value of Rs. 783 and Rs. 553 respectively. This indicates that farmers under these methods are aware of the impacts of climate change at present and in the future.

Table 18: Number of farmers under each category of bids under different rice cultivation systems

Particulars	Conventional	SRI	Aerobic	DSR
Yes Yes (YY)	13 (43)	18 (60)	5 (16)	3 (10)
Yes No (YN)	6 (20)	6 (20)	9 (30)	2 (7)
No Yes (NY)	2 (7)	2 (7)	8 (27)	5 (16)
No No (NN)	9 (30)	4 (13)	8 (27)	20 (67)
Mean WTP (Rs. /acre/year)	553	783	325	150

Note: Figures in parenthesis indicate per cent to the total

As there is climate change over the years, if there is an institutional arrangement to manage irrigation water as a common good, so that there is fairness in sharing of water; which leads to reduced exploitation of water and also increases water use efficiency. Hence farmer's willingness to pay was estimated across different rice cultivation methods. Since the response of the farmers fall into four category, such as Yes Yes (YY), Yes No (YN), No Yes (NY) and No No (NN). To elucidate factors influencing willingness to pay for use of irrigation water in different cultivation systems multinomial logistic regression was used. (1- YY, 2-YN, 3-NY, 4-NN). YY category was taken as base reference category. Pseudo r^2 was 0.51 indicating 51 per cent of variation in dependent variable was explained by the explanatory variables used in the model.

Factors affecting willingness to pay for irrigation water for farmers (conventional method) is given in table 19. In conventional method, education and gross income were positively significant factors influencing WTP in YN category whereas age has negative influence on WTP in NN category. The results revealed that, if educational attainment increases by one year, the log of odds ratio, probability of YN category to probability of YY, increase by 0.781 indicating that there are less chances to remain in YN category if educational attainment increase by one year. It also means that, the probability of moving to YY category is 0.54 ($1-0.46=0.54$). This indicate role of education in fair use of water and reducing free rider problem in irrigation water use. Similarly, the one rupee increase in gross returns, the log of odds ratio, probability to move to YN category from YY category increase by 0.107 unit , indicating that the probability to remain in YY category was high i.e. 0.68 if gross return increase by one rupee. This results is in line with the result found by Tang *et al* in 2013 i.e. farmers with higher income might command more capital for the economic use of water allotted. If age increase by one year, the log of odds ratio, the probability to move to YY category from NN category was fall by 7.632 indicating that probability to remain in YY falls by 0.7632 unit if age was increased by one year. It also reveals that, probability of farmers to remain in YY was found to be 0.49 if age increase by one year.

Table 19: Factors affecting willingness to pay for irrigation water for farmers (conventional method)

Explanatory variables	YesNo		NoYes		NoNo	
	Co-efficient	P value	Co-efficient	P value	Co-efficient	P value
Age	-0.0479 (0.59)	0.484	-0.790 (0.38)	0.152	-07.632** (0.51)	0.001
Education	0.781* (0.46)	0.002	0.426 (0.65)	0.713	0.426 (0.65)	0.999
Land holding	0.123 (0.88)	0.695	1.835 (0.265)	0.255	1.835 (0.26)	0.996
Gross returns	0.1-07** (0.32)	0.010	0.0001 (1.00)	0.417	0.0002 (1.00)	0.999
Access to extension services	24.800 (0.54)	1.000	38.052 (0.69)	0.999	38.052 (0.980)	0.997
Constant	7.439	0.410	58.799	0.102	101.021	1.000

Note: Chi-square=91.62; Pseudo R²=0.51; Base Category: Yes Yes (YY); Figures in parentheses indicate probability value; * Significant at 5 %; ** Significant at 1%

Table 20: Factors affecting willingness to pay for irrigation water for farmers (SRI method)

Explanatory variables	YesNo		NoYes		NoNo	
	Co-efficient	P value	Co-efficient	P value	Co-efficient	P value
Age	-0.052* (0.49)	0.037	-16.374 (0.742)	1.000	-0.260* (0.771)	0.410
Education	0.4755* (0.208)	0.021	7.22 (0.508)	1.000	0.260 (0.296)	0.936
Land holding	0.631 (0.475)	0.391	23.22 (0.235)	1.000	1.106 (0.322)	0.651
Gross returns	-0.0001 (0.99)	0.258	0.014* (0.486)	0.041	0.0004 (0.990)	0.672
Access to extension services	1.923** (0.146)	0.010	22.3 (0.660)		1.67 (0.312)	0.686
Constant	9.913	0.287	24.81		19.69	

Note: Chi-square=65.61; Pseudo R²=0.59; Base Category: Yes Yes (YY); Figures in parentheses indicate probability value; * Significant at 5 %; ** Significant at 1%

The factors affecting willingness to pay for irrigation water for farmers (SRI method) is given in table 20. Age, Education and Access to extension service were factors significantly influencing factors to WTP in use of irrigation water. Pseudo r^2 was 0.59 indicating 59 per cent of variation in dependent variable is explained by the independent variable considered in the model. The result shown that, if age of respondent was increase by one year, the log of odds ratio, probability of YN category to probability of YY category and probability of NN to probability YY, decrease by 0.052 and 0.260 respectively which indicates there are more chances to remain in YN and NN category if age increase by one year. So there is probability to remain in YY category was 0.46. This is due to the reason that the elder farmers were not willing to pay for fair use of water. Similarly, if education attainment increase by one year, the log of odds ratio, probability of YN to probability of YY increase by 0.4755 indicating less chances to remain in YN category with probability to remain in YY was high i.e. 0.80. Access to extension service was taken as dummy variable that is 1 for access to service 0 otherwise. It was found that if farmers have access to extension service, then the probability to move to YY from YN increase to 1.923 units. It is also inferred that the probability of farmers to remain in YY category was as high as 0.86. This might be due to the fact that, farmers with excess to extension service are well aware of the impact of climate change. Gross return and age were significant factors influencing WTP in NY and NN category respectively. It was drawn from the table that, if gross return increase by one rupee, the probability of moving to YY category from NY, increase by 0.014 indicating that there are less chances of being in YN category if gross return increase by one rupee.

Table 21 depicts the factors affecting willingness to pay for irrigation water for farmers (Aerobic method). In Aerobic rice cultivation, age, education and extension service were important factors influencing WTP in YN category and gross returns in NY category. If increase in age and education by one year, the log of odds ratio, the probability of YN to probability of YY fall by 0.131 and increase by 3.258 units respectively. Similarly farmers having access to extension service increase movement of the probability of YN to probability YY by 4.987. It also means that probability to remain in YY is as high as 0.71 in case of access to extension service, 0.62 in case of education

and 0.53 in case of age. In case of NY category, if gross returns increase by one rupee, the probability of NY to probability of YY increase by 0.203. It also indicates that the probability to remain in YY category was 0.60.

Table 21: Factors affecting willingness to pay for irrigation water for farmers (Aerobic method)

Explanatory variables	YesNo		NoYes		NoNo	
	Co-efficient	P value	Co-efficient	P value	Co-efficient	P value
Age	-0.131** (0.477)	0.017	-0.109 (0.896)	0.511	-0.015 (0.985)	0.923
Education	3.258* (0.380)	0.031	3.591 (0.027)	0.190	3.265 (0.038)	0.232
Land holding	1.729 (0.177)	0.206	1.519 (0.218)	0.263	1.507 (0.221)	0.269
Gross returns	0.0003 (1.00)	0.423	0.203* (0.400)	0.042	0.0003 (1.00)	0.417
Access to extension services	4.987** (0.296)	0.002	6.862 (0.856)	0.260	6.584 (0.874)	0.281
Constant	3.084	0.827	-1.989	0.891	5.087	0.731

Note: Chi-square=59.62; Pseudo R²=0.44; Base Category: Yes Yes (YY); Figures in parentheses indicate probability value; * Significant at 5 %; ** Significant at 1%

The results shown in table 22 indicate factors affecting willingness to pay for irrigation water for farmers following DSR method. It was found that, if education attainment increases by one year, probability of YN to probability YY increase by 0.900 indicating less chance to remain in YN category if education increases by one year. In NN category age and land holding were important factor significantly affecting WTP of farmers. As interpreted above, if age increase by one year the probability to move to YY category from NN category decrease by 0.503 units. It also indicate that the probability to remain in YY category was 0.60. Similarly, if land holding increase by one acre, the log of odds ratio, the probability of NN to probability YY increase by 0.771 and the probability to remain in YY category is as high as 0.84. This is because of the fact that,

increase in land holding of the respondents will increase the need for water use in crop production.

Table 22: Factors affecting willingness to pay for irrigation water for farmers (DSR method)

Explanatory variables	YesNo		NoYes		NoNo	
	Co-efficient	P value	Co-efficient	P value	Co-efficient	P value
Age	-0.127 (0.335)	0.310	-0.024 (0.976)	0.772	-0.503** (0.400)	0.006
Education	0.900** (0.459)	0.014	0.680 (0.973)	0.391	0.391 (0.478)	0.561
Land holding	-0.691 (0.501)	0.634	0.00009 (0.600)	1.000	0.771* (0.161)	0.035
Gross returns	0.0001 (1.00)	0.652	0.0001 (1.00)	0.342	0.00002 (0.30)	0.832
Access to extension services	16.452 (0.562)	0.994	0.141 (0.08)	0.946	-1.223 (0.294)	0.478
Constant	-33.219	0.989	-8.855	0.408	-1.929	0.821

Note: Chi-square=72.61; Pseudo R²=0.66; Base Category: Yes Yes (YY); Figures in parentheses indicate probability value; * Significant at 5 %; ** Significant at 1%

Farmer's actual willingness to pay for irrigation water was estimated using the tobit model and is presented in table 23. Actual amount the farmers were willing to pay was taken as latent variable for the tobit model. Actual willingness to pay was zero for NN category which makes it suitable for use the tobit model. Zero willingness indicates that the farmers may think that the water is free gift of nature or cannot afford to pay for irrigation water (Divya *et al.*, 2015).

The tobit equation obtained was as follows,

$$WTP (Rs.) = 252.50 - 2.22X_1 + 29.70X_2 - 38.98X_3 + 0.043X_4 + 51.79 D_1$$

Education and access to extension service had significant effect on the farmers' actual willingness to pay. To check fit of the model, pseudo r^2 was calculated which was 0.47 indicate that 47 per cent of variation in dependent variable explained by independent variable considered in the model. If the year of schooling increases by one year then actual WTP increases by Rs. 29.70 per acre. Similarly, if a farmer had access to extension service then actual WTP increases by Rs. 51.79.

Table 23: Functional analysis for farmers' actual willingness to pay for irrigation water

Sl. No.	Particulars	Coef	P> t
1.	Constant	252.50	0.676
2.	Age	-2.22	0.969
3.	Education	29.70**	0.013
4.	Landholding	38.98	0.082
5.	Gross returns	0.043	0.609
6.	Access to extension services	51.79***	0.001
7.	Sigma	126.36	
8.	Pseudo R^2	0.47	

‘***’, ‘*’ indicates significance at 1 and 5 per cent level

Thus, understanding WTP of farmers will help the authorities in fixing the charges for irrigation water. This is because, as there is climate change over the years there will be institutional arrangement to monitor and regulate the use of water so as to produce rice under with climate smart practices. The climate smart practices are the only solutions to withstand the effects of climate change particularly the water scarcity. Thus assessing WTP will indicate the range within which farmers are willing to pay.

4.4 Externalities in rice cultivation

4.4.1 Partial budgeting

Table 24: Externality in rice cultivation (SRI) using partial budgeting of rice farms

Sl. No.	Debit	Amount (Rs.)	Sl. No.	Credit	Amount (Rs.)
a.	Increase in costs		a.	Decrease in costs	
	i. Fertilizers	79		i. Seed	176
	ii. PPC	268		ii. FYM	1296
	iii. Machine labour	1019		iii. Micronutrients	358
				iv. Human labour	227
				v. Irrigation cost	702
	Total	1366		Total	2759
b.	Decrease in returns	-	b.	Increase in returns	15843
	Total debits	1366		Total credits	18602
		Net gain	17236		

The partial budgeting technique was employed to estimate the externality costs involved in cultivation of rice under different cultivation systems. It was observed that there was an additional gain of Rs. 17236 per acre by growing rice under SRI method of cultivation when compared to conventional system of rice cultivation (Table 24). It was found that the SRI method of cultivation experienced decrease in cost of seeds, FYM, micronutrients, human labour and irrigation cost (totalling it to Rs. 2759/ ac), while incurred increase in cost of fertilizers, PPCs and machine labour (totalling it to Rs. 1366 /ac). Moreover, SRI method of rice cultivation had increase in returns worth Rs. 15843 per ac due to higher yield.

Aerobic method of cultivating rice also witnessed additional gain of Rs. 2729 per acre over the conventional method of rice cultivation (Table 25). Also, there was decrease in returns due to decrease in yield (Rs. 5509) from aerobic method of rice cultivation. Similarly, drum seeded method of rice cultivation noted decrease in returns of Rs. 1232 (Table 26), however, there was a net gain of Rs. 2964 per acre for drum seeded rice cultivation over the conventional method.

Table 25: Externality in rice cultivation (Aerobic) using partial budgeting of rice farms

Sl. No.	Debit	Amount (Rs.)	Sl. No.	Credit	Amount (Rs.)
a.	Increase in costs		a.	Decrease in costs	
	i. PPC	398		i. Seed	242
				ii. FYM	359
				iii. Fertilizers	253
				iv. Micronutrients	358
				v. Irrigation cost	350
				vi. Human labour	6272
				vii. Machine labour	802
	Total	398		Total	8636
b.	Decrease in returns	5509	b.	Increase in returns	-
	Total debits	5907		Total credits	8636
		Net gain			2729

Table 26: Externality in rice cultivation (DSR) using partial budgeting of rice farms

Sl. No.	Debit	Amount (Rs.)	Sl. No.	Credit	Amount (Rs.)
a.	Increase in costs		a.	Decrease in costs	
	i. Fertilizers	54		i. Seed	169
	ii. PPC	1321		ii. FYM	630
	iii. Machine labour	1811		iii. Micronutrients	538
				iv. Irrigation cost	140
				v. Human labour	5740
	Total	3186		Total	7217
b.	Decrease in returns	1067	b.	Increase in returns	-
	Total debits	4253		Total credits	7217
		Net gain	2964		

Rice cultivation systems are associated with modification of soil ecosystems which has unintentional and inevitable effects like emission of greenhouse gas emissions, environmental damage cost and unpaid irrigation subsidy. Moreover, positive externalities including ecosystem services like flood mitigation, groundwater recharge and micronutrient provisioning services are also observed. Nearly 100 per cent in each of farmers practicing conventional system of rice cultivation and DSR have the perception that conventional system and DSR, respectively would recharge ground water. Very few farmers practicing DSR cultivation (3.33 %) had the perception that the method would help in flood mitigation. However, 67 and 73 per cent of farmers practicing DSR and conventional method, respectively perceived that the respective methods would promote food security (Table 27).

Table 27: Farmers' perception on externalities from rice cultivation

Sl. No.	Positive externalities	Conventional	SRI	Aerobic	DSR	Overall
1.	Ground water recharge	30 (100.00)	28 (93.33)	25 (83.33)	30 (100.00)	113 (94.17)
2.	Flood mitigation	2 (6.66)	5 (16.66)	7 (23.33)	1 (3.33)	15 (12.50)
3.	Soil erosion prevention	12 (40.00)	17 (56.66)	18 (60.00)	10 (33.33)	57 (47.50)
4.	Recreational or aesthetic benefits	20 (66.66)	19 (63.33)	22 (73.33)	20 (66.66)	81 (67.50)
5.	Food security	22 (73.33)	24 (80.00)	25 (83.33)	20 (66.66)	91 (75.83)
	Negative externalities					
1.	Water pollution	15 (50.00)	24 (80.00)	28 (93.33)	29 (96.66)	96 (80.00)
2.	Higher water consumption	30 (100.00)	21 (70.00)	20 (66.66)	30 (100.00)	101 (84.16)
3.	GHG's emission	0	0	0	0	0
4.	Decrease in soil Health	21 (70.00)	25 (83.33)	27 (90.00)	30 (100.00)	103 (85.83)
5.	Increase in soil salinity	20 (66.66)	23 (76.66)	25 (83.33)	26 (86.66)	94 (78.33)

Most importantly, nearly more than 90 per cent of aerobic and DSR rice farmers along with more than 50 per cent of conventional and SRI farmers perceive that the respective methods used for rice cultivation contribute to water pollution. However, none of the farmers perceived that the rice cultivation caused greenhouse gas emissions in the environment. But, 100 per cent of DSR farmers perceived that DSR method would deteriorate soil health. Soil salinity due to paddy cultivation was perceived by nearly 83 per cent of farmers practicing aerobic rice cultivation.

Economic valuation of externalities in different rice cultivation system

The study has estimated economic value of these externalities in different rice cultivation systems and is presented in table 28. It was found that aerobic system of rice cultivation had the most flood mitigating capacity of 138.40 m³ per acre valuating to Rs. 4248 per ac. SRI method of cultivation was also found to mitigate floods to an extent of 118 m³ whose economic value is accounted to Rs. 3621 per acre of rice cultivation.

Groundwater recharge was found to be highest in SRI system of rice cultivation followed by conventional method and aerobic method of rice cultivation. Economic value of groundwater recharge in SRI was Rs. 10161 per acre for 18816 m³ of groundwater recharge per acre of rice cultivation. DSR system of rice cultivation had the least ground water recharge capacity. Micronutrient provisioning services include provision of iron and zinc micronutrients. SRI method of rice cultivation was found to possess highest iron content of 90636 mg per acre whose economic value was Rs. 8973 per acre. Similarly, zinc was found in highest amount (5312 mg/ac) in rice grown by SRI method whose economic value was Rs. 7437 per acre.

The negative externalities were also estimated and the study found that conventional method of rice cultivation emitted higher GHGs which was quantified as 1620 kg acre of greenhouse gases that accounted for Rs. 781 per acre. The greenhouse gas emissions were found in aerobic method of rice cultivation (180 kg/ac) that amounted for just Rs. 87 per acre. The conventional system was also found to cause economic damage worth Rs.1088 per acre, which was highest among all the rice cultivation systems. Thus, the hypothesis of negative externality associated with conventional method of rice cultivation is more than others systems is accepted.

Irrigation subsidy was calculated to be Rs. 619 per ac, that was borne by the government for conventional system of rice cultivation. Similarly, irrigation subsidy borne by government in case SRI, aerobic and DSR was Rs. 392, Rs. 270 and Rs. 479 per acre, respectively.

Table 28: Economic valuation of externalities in different rice cultivation system

Sl. No.	Particulars	Conventional		SRI		Aerobic		DSR	
		Physical magnitude	Economic value(₹/ac)	Physical magnitude	Economic value(₹/ac)	Physical magnitude	Economic value(₹/ac)	Physical magnitude	Economic value(₹/ac)
Ecosystem services									
1.	Flood mitigation (m³/ac)	16.30	503.00	118.00	3621.42	138.00	4248.00	75.60	2320.00
2.	Groundwater recharge (m³/ac)	1612.00	8709.00	18816.00	10161.00	7920.00	4277.00	3816.00	2061.00
3.	Micronutrient provisioning								
	a. Iron (mg/ac)	69615.00	6892.00	90636.00	8973.00	63145.00	6251	64346.00	6370.00
	b. Zinc (mg/ac)	40800.00	5712.00	53120.00	7437.00	37008.00	5181	37712.00	5280.00
	Total	112043.30	21816.00	162690.00	30192.42	108211.00	19957.00	105949.60	16031.00
Government cost									
4.	Irrigation subsidy (ac-inch)	38.00	619.24	25.00	392.00	18.00	270	30.00	479.00
Environment cost									
5.	Greenhouse gas emission (kg/ac)	1620.00	780.68	378.00	182.16	180.00	87	660.00	318.00
6.	Environment Damage Cost (EDC) (kg)	150.00	1087.50	120.00	873.60	80.00	582	90.00	655.00
	Total	1808.00	2487.42	523	1447.76	278.00	939.00	780.00	1452.00

4.5 Traits preferences of producers and consumers

The traits preferred by the rice growers were analysed using rank based quotients and presented in table 29. It is drawn from table that high yield, resistance to pest and disease and market oriented reasons were the most preferred characters by all the producers in general with RBQ values 97.04, 85.28 and 71.48 respectively. Resistance to pest and diseases was the second most preferred character in the case of conventional, aerobic and DSR methods with RBQ values of 88.15, 89.63 and 90.00 respectively whereas it was preferred third in case of SRI method. In SRI method, market oriented reasons was the second most preferred trait with RBQ value of 88.89 whereas it is third most preferred trait in case of aerobic and DSR methods with value 65.93 and 67.78 respectively. Lower grain losses during harvest and high straw ratios were the least preferred traits by the all farmers practicing different method of cultivation practices. Therefore, the hypothesis of high yield and good grain quality are the major trait preferred by the farmers is rejected.

Assessment of trait preferences of producers is a very important input to rice breeders because those varieties have to be developed and adopted which will not only fulfil the needs of rice production in the country, provide expected yields and also give remunerative returns to the farmers but also adapt to the changing climate and mitigate the effects of climate change.

The table 30 indicates socio-economic profile of consumers in the study area. It was found that average age of consumers was 40 years with completion 15 years of formal schooling that indicate majority of respondents completed graduation. It was noticed that majority of respondents fall into the medium size of family category (4 to 5). So, average size of family was 4.5. The annual income of the consumers was Rs424917 with monthly income of Rs. 35410 and expenditure of Rs. 22104.17/month. Out of their total expenditure, around 30 per cent they have spent on food items and 14 per cent on rice. The result also shows that, average consumption of rice per month was around 24.79 Kg per month.

Table 29: Rank based quotient for the traits preferred by rice producers

Traits	Conventional		SRI		Aerobic		DSR		Overall	
	RBQ	Rank	RBQ	Rank	RBQ	Rank	RBQ	Rank	RBQ	Rank
High yielding	97.78	1	93.33	1	99.26	1	97.78	1	97.04	1
Resistance to P & D	88.15	2	74.00	3	89.63	2	90.00	2	85.28	2
Market oriented reasons	63.33	4	88.89	2	65.93	3	67.78	3	71.48	3
Good grain quality	55.19	5	73.33	4	60.74	5	70.74	4	65.00	4
Short duration	65.56	3	44.44	6	61.48	4	45.19	5	54.17	5
late sowing	51.11	6	43.33	7	49.63	6	43.70	6	46.94	6
Grain losses during harvest (lower)	22.59	8	51.11	5	34.07	7	24.07	8	32.96	7
Resistance to abiotic stress	42.96	7	17.78	9	27.41	8	41.48	7	32.41	8
Higher straw ratio	12.22	9	18.89	8	11.85	9	15.56	9	14.63	9

Table 30: Socio-economic profile of the sample consumers (n=80)

Sl. No.	Particulars	Value
1.	Age	40.00
2.	Education (years of formal education)	15.00
3.	Family size	4.50
4.	Income (Rs. /year) (Rs. /month)	424917 35410
5.	Total expenditure (Rs. /month)	22104.17
6.	Expenditure on food (Rs. /month)	6799.79
7.	Expenditure on rice (Rs. / month)	3235.42
8.	Quantity of purchase (kg. /month)	25.21
9.	Frequency of purchase (No. /month)	1.00
10.	Rice consumption (kg. /month)	24.79

The table 31 shows the traits or attributes preferences by the consumers. The attribute or trait levels preferred by majority of the consumers were appearance, texture, cooking quality and nutritional benefits. Around 90 per cent of consumers expressed appearance as the major trait, followed by texture (87.50 %) and cooking quality (85 %). Further, these seven attributes under appearance such as size, shape, colour and kind of polishing along with texture cooking quality and nutritional benefits were subjected to conjoint analysis.

Table 31: Trait or attributes preferences of rice consumers

Sl. No.	Traits or Attributes	Rank (n=90)
1.	Appearance (Size, shape, colour and Kind of polishing)	1 (90.00)
2.	Texture	2 (87.50)
3.	Taste	5 (57.50)
4.	Aroma	6 (60.00)
5.	Nutritional benefits	4 (83.75)
6.	Cooking quality	3 (85.00)
7.	Keeping quality	7 (20.00)

Pattern of traits or attributes of rice consumer's preference

The important attributes of rice influencing the consumer preference were size, shape, colour, cooking quality, texture, nutritional content and kind of polish. For each consumer, the part-worth estimates were calculated using the conjoint analysis.

Table 32: Correlation between consumer preferences traits or attributes

Correlations	Values	Significance
Pearson's rank correlation	0.875**	<0.01
Kendal's rank correlation	0.827**	<0.01

Note: ** Significant at the one per cent level of probability

The additive model considered for the analysis was found to be good fit. The Pearson's rank correlation coefficient (0.875) was found to be significant at one per cent probability level. Similarly, Kendall's correlation coefficient (0.827) was also significant at one per cent probability level. These findings indicated the suitability of the additive model to the data set (Table 32).

Consumer's preference for rice traits or attributes

The relative importance of the part worth function was compared across different attributes within segments in order to arrive at the relative importance of each attribute. Results on average part-worth and relative importance of the attributes are presented in table 33.

Among all the attributes and attribute levels of the rice, size was found to be the most significant attribute for consumers, accounting for 21.42 per cent of relative importance with small and medium size having utility scores of -6.979 and 6.979 respectively. After size, the colour of the grain was another important characteristic that significantly influenced the consumer's preference, with a relative importance of 18.34 per cent. Among colour white colour was preferred the most with a utility score of -5.976, red and brown colour were having utility scores of 2.667 and 3.309 respectively. The shape of the grain was the next preferred attribute with a relative importance of 17.16

per cent with medium, fine and bold shape having utility scores of -5.593, -0.431 and 5.162 respectively. The texture of the grain was the fourth preferred attribute with a relative importance of 15.84 per cent and the consumers prefer non-sticky rice with a utility score of -5.161 whereas sticky rice had a utility score of 5.161. Polish to the rice came in fifth place, accounting for 14.36 per cent relative importance, with polished, medium and unpolished having a utility score of -4.678, 2.302 and 2.376, respectively. Cooking quality and nutritional content had the least preference among the consumers with a relative importance of 7.46 and 6.75 per cent respectively wherein, volume expansion and short time for cooking rice were having a utility score of -2.432 and 2.432 respectively and the attributes which showed the nutritional quality of rice which is rich in iron and fibre had utility scores of -2.198 and 2.198 respectively as these attributes were less visible among the consumers. Thus, the hypothesis of consumers chose appearance and grain size as the major trait to make consumption decision is accepted.

Table 33: Results of conjoint analysis of consumer’s preference for rice produced in the study area

Sl. No.	Attributes/ traits	Attribute levels	Utility score	Relative importance
1.	Size	a. Small b. Medium	-6.979 6.979	21.42
2.	Color	a. White b. Brown Red	-5.976 3.309 2.667	18.34
3.	Shape	a. Bold (Coarse grain) b. Medium (Fine grain) c. Slender (Very fine grain)	5.162 -5.593 -0.431	17.16
4.	Texture	a. Sticky c. Non-sticky	5.161 -5.161	15.84
5.	Polish	a. Polished b. Medium polished Unpolished	-4.678 2.376 2.302	14.36
6.	Cooking	a. Short time b. Volume expansion	2.432 -2.432	7.46
		b.		
7.	Nutritional Contents	a. Fibre b. Iron	2.198 -2.198	6.75
	Total		32.586	100.00

Every variety adopted under each of the rice cultivation system will be useful to farmers only when the varieties produced through climate smart practices will meet the needs of the consumer. Thus, the assessment of trait preferences of consumers will also aid in rice breeding.

4.6 Adaptation and mitigation strategies

Table 34: Farmers' perception on change in climatic conditions due to climate change

Sl. No.	Climatic conditions	Increase (%)	Decrease (%)	Remains the same (%)
A.	Conventional			
i.	Temperature	30 (100.00)		
ii.	Frequency of rainfall		25 (83.33)	5 (16.67)
iii.	Intensity of rainfall	21 (70.00)	6 (20.00)	3 (10.00)
iv.	Availability of groundwater	23 (76.67)	7 (23.33)	
v.	Availability of surface water	27 (90.00)		3 (10.00)
vi.	Severity of heat wave	30 (100)		
viii.	Severity of cold wave	1 (3.33)	29 96.67	
B.	SRI			
i.	Temperature	30 (100.00)		
ii.	Frequency of rainfall	2 (6.67)	24 (80.00)	4 (13.33)
iii.	Intensity of rainfall	21 (70.00)	8 (26.67)	1 (3.33)
iv.	Availability of groundwater	24 (80.00)	6 (20.00)	
v.	Availability of surface water	28 (93.33)		2 (6.67)
vi.	Severity of heat wave	30 (100.00)		
viii.	Severity of cold wave	3 (10.00)	27 (90.00)	

Sl. No.	Climatic conditions	Increase (%)	Decrease (%)	Remains the same (%)
C.	Aerobic			
i.	Temperature	30 (100.00)		
ii.	Frequency of rainfall		30 (100.00)	
iii.	Intensity of rainfall	22 (73.33)		8 (26.67)
iv.	Availability of groundwater	18 (60.00)	12 (40.00)	
v.	Availability of surface water	22 (73.33)	7 (23.33)	1 (3.34)
vi.	Severity of heat wave	30 (100.00)		
viii.	Severity of cold wave	2 (6.66)	26 (86.67)	2 (6.66)
D.	DSR			
i.	Temperature	30 (100.00)		
ii.	Frequency of rainfall		28 (93.33)	2 (6.66)
iii.	Intensity of rainfall	24 (80.00)		6 (20.00)
iv.	Availability of groundwater	30 (100.00)		
v.	Availability of surface water	30 (100.00)		
vi.	Severity of heat wave	30 (100.00)		
viii.	Severity of cold wave	2 (6.66)	28 (93.33)	
	Overall			
i.	Temperature	120 (100.00)		
ii.	Frequency of rainfall	2 (1.66)	107 (89.16)	11 (9.16)
iii.	Intensity of rainfall	88 (73.33)	14 (12.67)	18 (15.00)
iv.	Availability of groundwater	95 (79.16)	25 (20.83)	
v.	Availability of surface water	107 (89.16)	7 (5.83)	6 (5.00)
vi.	Severity of heat wave	120 (100.00)		
viii.	Severity of cold wave	8 (6.67)	110 (91.67)	2 (1.66)

Based on the farm field survey conducted the above table summarizes the farmers perception regarding change in climate variables from past 10 years. It is clear from survey that farmers have noticed substantial change in climate variability over the course of their cultivation. It is revealed from the discussion with farm household that they have been experiencing unprecedently adverse weather conditions over recent decade. All the respondents have observed there is considerable increase in temperature over the years. The results revealed that around 89.16 per cent and 73.33 per cent of respondents noticed decrease in frequency and increase in intensity of rainfall respectively. Due to the untimely, unpredictable weather and rainfall conditions farmers have experienced negative impact on the full range of agricultural activities (Table 34).

The study also identifies that farmers perceive there was increase in availability of ground water (79.16 %) and surface water (89.16 %). Majority the respondents have opined that increase in severity of heat wave (100 %) and decrease in severity of cold wave (91.67 %) over the years due to climate change.

To rank farmers perception about effects of climate change garret ranking technique was used and is depicted in table 35. The study reveals that, untimely rains, irregular weather patterns and fluctuation in temperature were ranked first by the farmers with garret score of 67.88, 66.42 and 53.14 respectively and the same is followed by the farmers in case if conventional, SRI and DRI methods of rice cultivation. The farmers practicing aerobic method perceived that irregular weather pattern, untimely rains and fluctuations in temperature were ranked first second and third with garret score of 68.57, 66.33 and 51.80 respectively. The farmers also perceived increase in pest and disease and change in soil health were ranked least by the farmers. From the above it was found that farmers are aware of the changing climatic condition and also are aware of the effects of climate change. Thus, this would help in creating awareness among farmers with respect to adoption of suitable climate smart practices under changing climate conditions.

Table 35: Ranking of climate change effects as perceived by farmers using Garrett ranking technique

Sl. No.	Particulars	Conventional		SRI		Aerobic		DSR		Total	
		Scores	Rank	Scores	Rank	Scores	Rank	Scores	Rank	Scores	Rank
1.	Untimely rains	68.50	I	69.60	I	66.33	II	67.10	I	67.88	I
2.	Irregular weather pattern	65.20	II	65.30	II	68.57	I	66.60	II	66.42	II
3.	Fluctuation in temperature	54.33	III	53.13	III	51.80	III	53.30	III	53.14	III
4.	Increase in pests and diseases	37.50	IV	36.50	IV	37.83	IV	36.67	IV	37.13	IV
5.	Changes in soil health	27.50	V	28.50	V	29.50	V	29.00	V	28.63	V

Table 36: Adaptation and mitigation strategies followed by farmers in the study area

Sl. No.	Strategies	Conventional	SRI	Aerobic	DSR	Overall
A.	Adaptation strategies					
1.	Selection of appropriate variety	20 (66.67)	10 (33.33)	12 (40.00)	10 (33.33)	52 (43.34)
2.	Optimum seed rate	10 (33.33)	15 (50.00)	5 (16.67)	10 (33.33)	40 (33.33)
3.	Adjusting the no. of seedling per hill	0	20 (66.67)	10 (33.33)	13 (43.33)	43 (35.83)
4.	Changing planting dates	0	0	0	0	0
5.	Planting of aged seedlings	0	0	0	0	0
6.	Crop diversification	2 (6.67)	5 (16.67)	7 (23.33)	3 (10.00)	17 (14.17)
7.	Increasing space between rows and plants	0	20 (66.67)	10 (33.33)	0	30 (25.00)
8.	Adopting rain harvesting methods	4 (13.33)	5 (16.67)	7 (23.33)	0	16 (13.33)
9.	Changing harvesting time	0	0	0	0	0
B.	Mitigation strategies					
1.	Potassium application	28 (93.34)	30 (100.00)	30 (100.00)	27 (90.00)	115 (95.83)
2.	Use of organic manure	25 (83.34)	28 (93.34)	27 (90.00)	29 (96.67)	109 (90.83)
3.	Ecological pest management	0	0	0	0	0
4.	Intercultivation	0	0	0	0	0
5.	Agro-forestry (Ex:Planting along bunds)	28 (93.34)	30 (100.00)	30 (100.00)	29 (96.67)	117 (97.50)
C.	Both adaptation and mitigation strategies					
1.	Following integrated farming system	7 (23.33)	8 (26.67)	10 (33.33)	9 (30.00)	34 (28.34)
2.	Changing cropping pattern	0	0	0	0	0
3.	Alternate wetting and drying	0	8 (26.67)	20 (66.67)	0	28 (23.34)
4.	Minimum tillage	0	0	0	0	0

The results of table 36 shows the adaptation and mitigation strategies followed by the farmers in the study area to overcome the effects of climate change. The adaptation strategies followed by conventional farmers were selection of appropriate variety (66.67 %), optimum seed rate (33.33 %) and adopting rain harvesting methods (13.33 %). The same strategies were followed by the farmers practicing DSR method. In SRI and aerobic method strategies adopted by the majority of farmers were increasing space between rows and plants, adjusting the no of seedling per hill, selection of variety suited for the particular method and optimum seed rate. The study reveals that, potassium application, use of organic manure and Agro-forestry were the mitigation strategies followed by majority of farmers across different cultivation methods. The adaptation and mitigation strategies followed by the most of the farmers were alternate wetting and drying and potassium application to compensate impact of climate change.

SUMMARY

V SUMMARY

In India, rice is grown in warm temperate, subtropical, and tropical regions. The production, accessibility, and availability of food are under constant strain in many nations due to the growing global population, climate change, and depleting natural resources. According to reports, Asia's major rice-producing nations are adversely impacted by factors like rising temperatures, variable rainfall, intermittent access to water, and a variety of biotic and abiotic pressures.

Rice cultivation is both an important sequester of carbon dioxide from the atmosphere and an important source of greenhouse gases (*e.g.* methane and nitrite oxide) emission. In 2004, for example, rice sequestered about 1.74 billion tonnes of CO₂ from the atmosphere to produce about 1.16 billion tonnes of biomass. Flooded rice fields emit methane (CH₄) which is second in importance next to carbon-dioxide as a greenhouse gas. Under anaerobic condition of submerged soils of flooded rice fields, methane is produced and much of it escapes from soil into atmosphere via gas spaces in the rice roots and stems, and the remainder CH₄ bubbles up from the soil and/or diffuses slowly through the soil and overlying flood water.

Despite its vital role, the rice cultivation system has become one of the major sources for greenhouse gas emission from agriculture and also a cause for higher water consumption. The different rice cultivation systems like aerobic, SRI (System of Rice Intensification), dry seeded rice cultivation, alternate wetting and drying etc. help in yielding higher returns and reducing costs. Adopting a system which increases yield, reduces water consumption, reduces costs etc. will aid in sustainable rice production with increased efficiency.

In this regard, an attempt was made to study the economics of climate smart rice cultivation systems in Southern Karnataka with following objectives:

1. To assess the economics of different rice cultivation systems.
2. To assess physical and economic water use efficiency.

3. To identify and quantify the externalities associated with different systems of rice cultivation.
4. To assess the trait preferences of rice producers and consumers.
5. To document adaptive and mitigation strategies adopted by farmers.

Methodology

The study was carried out in rice growing Mandya district in Southern Karnataka. Purposive sampling technique was employed for selection of area in Southern Karnataka. Simple random and Snowball sampling technique was employed for the selection of sample respondents.

Primary data on socio-economic characters of the farm family, cost incurred, yield and price realized from rice cultivation, externalities associated with different systems, producer and consumers trait preferences and other required information were collected with the help of pre-structured, well tested schedule through personal interview method. Primary data was collected from 120 farmers comprising of 30 farmers each in conventional/wetland, aerobic, System of Rice Irrigation (SRI) and Drum Seeding Method (DSM) of rice cultivation systems and 80 consumers. The data pertains to the agricultural production year 2020-2021.

Major findings of the study

1. The primary survey indicated that average age of the of farmer under conventional rice cultivation was 53 years and with respect to SRI, aerobic and DSR farmers, the average age was 48, 47 and 43 years, respectively.
2. The conventional farmers had around 8 years of formal education and SRI, aerobic and DSR farmers had 8, 10 and 10 years of formal education, respectively.
3. The findings also revealed that more than 70 per cent of the farmers under SRI, aerobic and DSR had access to extension services but it was only 20 per cent for farmers under conventional method.

4. The results of economics of rice cultivation under different cultivation systems showed that farmer spent total cost of Rs. 50926.44/acre in conventional method which was highest among all cultivation systems. Similarly, in aerobic method, SRI method and DSR method the cost of cultivation was Rs. 43.444.07, Rs. 48949.92 and Rs. 46002.74/acre, respectively.
5. The variable cost accounts significant share i.e. 70 to 75 per cent of total cost of cultivation. It was also found that variable cost was highest in conventional method Rs. 38394.78/acre which was followed by SRI (Rs. 36719.58/ac), DSR (Rs. 33727.85/ac) and aerobic method (Rs.28110.30/ac), and human labour cost was the major cost in total cost in general and variable cost in specific.
6. Across all cultivation systems the yield was found to be highest in SRI method (33.2 q/ac) followed by conventional method (25.5 q/ac), drum seeded rice (23.56 q/ac) and aerobic methods (23.12 q/ac). Gross and net returns were highest in case of SRI method (Rs. 70336 and Rs. 21386/ac) than their counter parts.
7. The resource use efficiency revealed that, inputs such as seed and irrigation were overutilised in conventional, in case of SRI method seed and machine labour were overutilised and fertiliser was underutilised and for aerobic method FYM was nearly optimally utilised and fertilizer was underutilised whereas machine labour and irrigation were the overutilised inputs in DSR method. In overall, inputs were nearly optimally utilised in aerobic method compared to the other.
8. The results of stochastic meta frontier analysis for measuring technical efficiency revealed that, mean technical efficiency was 0.54, 0.42 and 0.32 for SRI, aerobic and DSR method of rice cultivation.
9. The results of cost efficiency analysis indicate that mean efficiency score was 0.55, 0.92, 0.94 and 0.88 for conventional, SRI, aerobic and DSR cultivation, respectively. The lowest cost efficiency was obtained under conventional rice cultivation indicating that around 55 per cent of the farmers were allocatively efficient. Thus, there was 45 per cent scope for increasing efficiency for conventional farmers and only two per cent for aerobic farmers.

10. The analysis of WUE indicates that, irrigation water use was highest in case of conventional method i.e. 38.40 acre inch which was succeeded by drum seeded rice, SRI and Aerobic cultivation methods whose values were 30.18, 25.16 and 18.36 acre inches respectively.
11. The physical water use efficiency (WUE) was highest in case of SRI (1.32 q/acre inches) followed by aerobics (1.26 q/acre inches), drum seeded rice cultivation method (0.75 q/ acre inches) and conventional (10.63 q/acre inches). The economic WUE was found highest in case of SRI method (Rs. 849.17/acre inch) as compare to all other cultivation methods.
12. The mean willingness to pay (WTP) for assured and fairness in sharing of water was significantly high in case SRI followed by the conventional method of rice cultivation systems than their counterparts with the value of Rs. 783 and Rs. 553 respectively.
13. To find the extent of farmers' willingness to pay for assured irrigation and fairness in sharing of irrigation water was analysed using tobit model. The results reveal that, Education and access to extension service had significant effect on the farmers' actual willingness to pay.
14. The results of the partial budgeting technique to measure the externality cost in rice cultivation indicate net gain of Rs.17236/ac in SRI method, Rs.2729/ac for aerobic and Rs.2964/ac for DSR method.
15. The finding of the farmers perception on externalities from rice cultivation reveal that, around 94 per cent of the farmers perceive recharge of ground water as positive externality and 96 per cent of the farmers perceive water pollution as negative externality. It was interesting to note that, none of the farmers are aware of GHG emissions from rice cultivation.
16. The identifies positive externalities were flood mitigation , ground water recharge and micronutrient provisioning and negative externalities were GHG emission and environment damage cost considered as environment cost and irrigation subsidy considered as government cost.

17. The economic value of externalities in rice cultivation revealed flood mitigation (Rs.4248.00/ac) was highest in aerobic method and ground water recharge (Rs.8709.00/ac) was highest in conventional method.
18. The GHGs emissions from conventional method was quantified at Rs. 1620/ac and valued for Rs.781/ac and it was found to be higher than other methods. Environment damage cost was highest in conventional method and was quantified as Rs.1087.50.
19. High yielding and resistance to pest and diseases were the most preferred traits by rice producers.
20. From primary survey of consumers it was observed that, average age of consumers was 40 years and majority of respondents completed graduation level. The monthly income of the consumers was Rs.35410 with monthly expenditure of Rs. 22104.17.
21. Major traits preferred by consumers were appearance, texture and taste. Among them size, shape, colour, texture, polish, cooking quality and nutritional content were the most preferred traits.
22. The results of conjoint analysis revealed that, the relative importance of traits or attributes was highest for size, colour and shape.
23. The farmers perception on change in climatic conditions revealed that increasing temperature, decrease in frequency of rainfall, increase in severity of heat wave and increase in availability of surface water were the major changes.
24. The study found that, untimely rains, irregular weather patterns and fluctuation in temperature were ranked first by the farmers with garret score of 67.88, 66.42 and 53.14 respectively.
25. The study identifies selection of appropriate variety, adjusting the number of seedling per hill and using optimum seed rate as the major the adaptation strategies. The major mitigation strategies identified were potassium application, use of organic manure and Agro-forestry.
26. It was observed from the study that, the farmer followed adaptation and mitigation strategies without their conscience and did not adopt any of the practices to

overcome effects of climate change as they were not aware major impact that is GHGs emission.

Policy recommendations

1. It is recommended to practice aerobic and SRI method for the rice cultivation on a larger scale to overcome GHGs emission and also to make efficient use of water.
2. There is need to create more awareness about effects of climate change in general and Greenhouse gases emission in particular.
3. Institutions should recommend relevant adaptation and mitigation strategies to farmers in order to overcome and mitigate the effects of climate change.
4. There is a need for an institutional arrangement to monitor the use and efficiency of surface or canal water.

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APPENDICES

APPENDIX



UNIVERSITY OF AGRICULTURAL SCIENCES, DEPARTMENT OF AGRICULTURAL ECONOMICS, GKVK, BENGALURU.

Research Title: Climate smart rice cultivation in southern Karnataka: An economic analysis

SCHEDULE

A. FARMERS

Name of investigator: Bindu, H. A.

Date:

Conventional/Aerobic/SRI/DSR Rice cultivation

I. General information

- | | | | |
|----------------|-------------|------------------|----------|
| 1. Name | : | 6. Mobile No. | : |
| 2. Village | : | 7. Education | : |
| 3. Taluk | : | 8. Experience in | : |
| 4. Age (Years) | : | farming (Years) | : |
| 5. Occupation | : Main: | 9. Membership in | : Yes/No |
| | Income: | organisation | |
| | Subsidiary: | | |
| | Income: | | |

II. Family information: Joint/Nuclear

Sl. No.	Gender	Number	On farm	Off farm		Non-farm	
				No.	Income	No.	Income
1.	Adult male						
2.	Adult female						
3.	Children						
4.	Old age						
5.	Total						

III. Land holding

Sl. No.	Ownership	Rainfed area (acres)	Irrigated		Total
			Area (acres)	Source	
1.	Owned				
2.	Leased in				
3.	Leased out				
4.	Fallow land				
	Total				

Market value of land: Irrigated (Rs./acre):

Rainfed (Rs./acre):

IV. Cropping pattern (2021-22)

Sl. No.	Kharif		Rabi		Summer	
	Crop	Area (acres)	Crop	Area (acres)	Crop	Area (acre)
Rain fed						
1.						
2.						
3.						
Irrigated						
1.						
2.						
3.						
Perennial crops						
1.						
2.						

V. Farm machinery/ Equipment's/Assets

Sl. No.	Particulars	No's	Year of purchase	Purchase value (Rs.)	Present value (Rs.)	Average life (Yrs)	Annual repairs (Rs.)
1.	Farm building						
	a. Cowshed						
	b. Godown						

	c. Pump house						
2.	Bullock cart						
3.	Seed drill/ Drum seeder						
4.	Wooden / M.B. Plough						
5.	Power tiller						
6.	Tractor and accessories						
7.	Irrigation pump (IP Set)						
8.	Electric motor						
9.	Tube well / Open Well						
10.	Intercultural implements						
11.	Paddy thresher						
12.	Sprayer						
13.	Puddler						
14.	Bund former						
15.	Leveler						
16.	Others						

VI. Livestock inventory

Sl. No.	Animals	No's	Purchase value (Rs.)	Present value (Rs.)	Cost/ year (Rs.)	Returns/ year (Rs.)
1.	Bullocks					
2.	Local Cows					
3.	Cross Bred Cows					
4.	Calves					
5.	Buffalo					
6.	Sheep					
7.	Goat					
8.	Poultry					
9.	Others					

VII. Household assets:

Sl. No.	Particulars	No's	Year of purchase	Purchase value(Rs.)
1.	House			
2.	Television			
3.	Mobile			
4.	Refrigerator			
5.	2 Wheelers			
6.	4 Wheelers			
7.	Others			

VIII. Family expenditure:

Sl. No.	Particulars	Amount(Rs./ month)
1.	Consumption expenditure	
2.	Total expenditure	

IX. Wage rate (Rs):

Male Labour: _____/day,

Female Labour: _____/day

Bullock labour (pair): _____/ day.

Machine labour: _____/hour

X. Cost of cultivation

Variety	:	Area:
Duration	:	Seed replacement : Yes/ No

A. Labour use pattern:

Sl. No.	Name of the operation	Frequency	Family		Hired		Bullock pair days	Machine hours
			M	W	M	W		
1.	Land Preparation							
	Nursery preparation							
	Ploughing							
	Bund trimming							
	Levelling and puddling							

2.	Seed treatment							
3.	Sowing/Transplanting							
4.	Manure Application							
5.	Fertilizer application							
6.	Weeding							
	a. Manual							
	b. Mechanical							
	c. Chemical							
7.	Plant protection							
8.	Irrigation							
9.	Harvesting							
10.	Threshing							
11.	Cleaning / Bagging							
12.	Others							

B. Input cost

Sl. No.	Input	Units	Quantity	Price (Rs.)
1.	Seeds			
2.	FYM			
3.	Seed treatment			
4.	Fertilizers a) b) c) d)			
5.	PP chemicals a) b) c)			
6.	Weedicides a) b)			
7.	Irrigation			
8.	Electricity charges			
9.	Land revenue			
10.	Land rent or rental value of owned land			

11.	Maintenance of machinery			
12.	Others (if any)			

D. Yield and returns:

Sl. No.	Particulars	Unit	Yield	Price (Rs.)	Quantity			
					Sold	Self-consumption	Seed purpose	Payment in kind
1.	Paddy grains	Quintals						
2.	Paddy straw	tonnes						

XI. Marketing

Sl. No.	Particulars	Amount (Rs.)
1.	Bagging, loading and unloading costs	
2.	Cleaning/grading cost	
3.	Transportation cost	
4.	Commission charge/brokerage/market cess/tax	
5.	Storage cost	
6.	Grain losses (kgs/qtls)	
7.	Other charges (if any)	

XII. Details on irrigation

A. Surface Water Irrigation.

a) Water release to the field

Season	Crops grown	Area irrigated (acre)	No. of irrigation	Duration (Hours)	Total hours of irrigation	Depth of irrigation (cm/inch)
Kharif						
Rabi						
Summer						

b) **Water Rate Charged (Rs./acre):** _____

B. Details on Groundwater irrigation (Borewell)

Sl. No.	Particulars	Units	Investment/cost [Rs.]
1.	Year of drilling and Installation.	Year	
2.	Drilling Depth.	Mtr/ft	Cost of Drilling:
3.	Diameter of well	inches	
4.	Casing length	Mtr/fts	
5.	Length of pipes (Suction and delivery)	Mtr/fts	
6.	Pump capacity	HP	
7.	Pump cost	Rs.	
8.	Pump Placement depth	Fts	
9.	Pump house	-	
10.	Electrical Installation Cost	-	
11.	Other Costs (Specify)		

C. Season-wise water yield and utilization under groundwater irrigation

Initial yield _____

Current yield: _____

Season	Crops grown	Area irrigated (acre)	No. of irrigation	Duration (Hours)	Total hours of irrigation	Depth of irrigation (cm/inch)
Kharif						
Rabi						
Summer						

D. Energy Costs:

Sl. No.	Particulars	Details
1.	Method of Irrigation	
2.	Pump (HP)	
3.	Hours of Electricity Supply	
4.	No. of Units Consumed	
5.	Rate/Price (per unit)	
6.	Expenditure on diesel (in case of diesel pumps)	

XIII. Farmers perception on externalities from paddy cultivation

Sl. No.	Positive	Rank	Negative	Rank
1.	Ground water recharge		Water pollution	
2.	Flood mitigation		Higher water consumption	
3.	Soil erosion prevention		GHG's emission	
4.	Biological control of pests		Decrease in soil fertility	
5.	Recreational or aesthetic benefits		Increase in soil salinity	
6.	Others		Others	

XIV. Rank the following varietal characteristics preferred in paddy

Sl. No.	Characteristics	Rank
1.	Good grain quality (appearance, cooking quality, texture and fragrance)	
2.	High yielding	
3.	Resistance to diseases and pests	
4.	Resistance to abiotic stress (temperature, iron toxicity)	
5.	Short duration	
6.	Late sowing	
7.	Market oriented reasons (high price, high demand)	
8.	Grain losses during harvest (low)	
9.	Higher straw ratio	
10.	Others (if any)	

XV. Climate change

i. Did you observe climate change in last 10 years?

- a. No changes b. Some what c. Very much

ii. Are you concerned about climate change?

- a. No changes b. Some what c. Very much

iii. Climate change effects as perceived by farmers

Sl. No.	Climate change effects	Rank
1.	Untimely rains	
2.	Irregular weather pattern	
3.	Fluctuation in temperature	
4.	Changes in soil health	
5.	Increase in pests and diseases	
6.	Others	

iv. Farmer perception on change in climatic parameters due to climate change

1. Availability of ground water

- a. Increased b. Decreased c. Remained same d. Don't Know

2. Availability of surface water

- a. Increased b. Decreased c. Remained same d. Don't Know

3. Severity of heat wave

- a. Increased b. Decreased c. Remained same d. Don't Know

4. Severity of cold wave

- a. Increased b. Decreased c. Remained same d. Don't Know

5. Frequency and intensity of rainfall

- a. Increased b. Decreased c. Remained same d. Don't Know

6. Temperature

- a. Increased b. Decreased c. Remained same d. Don't Know

- v. Do you receive/obtain information regarding climate variables such as temperature, rainfall etc.? Yes/No

XVI. Which of the following adaptation and mitigation strategies have you adopted? Please indicate

Sl. No.	Strategies		Yes/No
A.	Adaptation strategies		
	1.	Selection of appropriate variety	
	2.	Optimum seed rate	
	3.	Adjusting the no. of seedling per hill	
	4.	Changing planting dates	
	5.	Planting of aged seedlings	
	6.	Crop diversification	
	7.	Increasing space between rows and plants	
	8.	Adopting rain harvesting methods	
	9.	Changing harvesting time	
B.	Mitigation strategies		
	1.	Balanced fertilizer usage	
	2.	Potassium application	
	3.	Use of organic manure	
	4.	Ecological pest management	
	5.	Intercultivation	
	6.	Agro-forestry (Ex:Planting along bunds)	
C.	Both adaptation and mitigation strategies		
	1.	Following integrated farming system	
	2.	Changing cropping pattern	
	3.	Alternate wetting and drying	
	4.	Minimum tillage	
	Others (if any)		

XVII. Willingness to pay for irrigation water

There is climate change over the years, if there is an institutional arrangement to manage irrigation water as a common good, so that there is fairness in sharing of water; which leads to reduced exploitation of water and also increases water use efficiency. What is your willing to pay for irrigation water?. The initial bid amount is Rs. 500.

- a. Are you willing to pay Rs.500 per acre? Yes / No
- b. If yes, are you willing to pay Rs. 750 per acre? Yes / No
- c. If no, are you willing to pay Rs. 250 per acre?? Yes / No
- d. How much you are actually willing to pay per acre?

B. CONSUMERS

I General information

- | | | | |
|------------------------|-----------------|----------------------|---|
| 1. Name | : | 6. Mobile No | : |
| 2. Place | : | 7. Education | : |
| 3. Age (Years) | : | 8. Occupation | : |
| 4. Type of family | : Nuclear/Joint | 9. Family size (No.) | : |
| 5. Annual income (Rs.) | : | | : |

II Expenditure details

- a. Total expenditure (Rs. /month) :
- b. Expenditure on food (Rs. /month) :
- c. Expenditure on rice (Rs. /month) :
- d. Quantity of purchase (kg):
- e. Frequency of purchase (kg):
- f. Decision maker:
- g. Rice consumption (per month):

III Select the characteristics preferred in rice purchase and consumption

1. Appearance

- i) Size:** A. Short B. Medium C. Long
- ii) Shape:** A. Bold B. Medium C. Slender
(Coarse grains) (Fine grains) (Very fine grains)
- iii) Colour:** A. White B. Brown C. Red
- iv) Polish:** A. Polished B. Medium polished C. Unpolished

- 2. Aroma:** A. Aromatic B. Non-aromatic

- 3. Cooking quality:** A. No excess water B. Short time C. Volume expansion

- 4. Taste:** A. Good taste B. Tasteful C. Delicious

- 5. Texture:** A. Sticky B. Non-sticky

6. Keeping quality

- A. Good B. Poor

7. Nutritional contents

- A. High fibre B. High iron

III Rank the following characteristics of rice preferred for consumption

Sl. No.	Quality characteristics	Rank
1.	Taste	
2.	Texture	
3.	Aroma	
4.	Appearance (size, shape, colour and kind of polishing)	
5.	Nutritional benefits	
6.	Cooking quality	
7.	Keeping quality	

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Efficiency of rice farms under different cultivation systems: A stochastic frontier cost approach

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Abstract

The paper has examined the efficiency of growing rice under different cultivation systems in Mandya district of Karnataka, using the data collected from 30 farmers under each of the cultivation systems namely, conventional, SRI (System of Rice Intensification), aerobic and DSR (Drum Seeded Rice) method. In total, the sample size was 120 rice growing farmers. The data was analysed using stochastic frontier cost function to estimate the cost efficiency of the farmers and to examine the factors influencing cost inefficiency. The results revealed that cost of seeds, fertilizers, human labour and machine labour had significant influence on cost of production. The variables such as age (0.239), landholding (0.022) and experience (0.215) in farming influenced cost inefficiency in conventional rice cultivation. Membership in organization (-0.075) and access to extension services (-0.289) were significant in explaining cost efficiency in SRI method. Education (-0.310) was the major factor which significantly contributed to the cost efficiency of aerobic farmers. Whereas, in DSR method age (-0.200) and access to extension services (0.083) were the significant factors. The mean cost or allocative efficiency score in aerobic was 0.94, which was highest among all the systems followed by SRI, DSR and conventional method with scores of 0.92, 0.88 and 0.55, respectively.

Key words: cultivation system, cost efficiency, stochastic frontier

Introduction

Rice is a staple food of people in most of the countries of the world and is a very important and essential part of the food system in many countries. India is the second largest producer of rice in the world after China. In India, rice is grown on an area of 45,769 thousand hectares with production of about 124 million tonnes

(www.indiastat.com). It is the food cereal which made countries to overcome the problems of hunger and starvation and has certainly played a major role in taking out the people out of food insecurity. Despite its vital role, the rice cultivation system has become one of the major sources for greenhouse gas emission from agriculture and also a cause for higher water consumption. The different rice cultivation systems like aerobic, SRI (System of Rice Intensification), dry seeded rice cultivation, alternate wetting and drying etc. help in yielding higher returns and reducing costs. Adopting a system which increases yield, reduces water consumption, reduces costs etc. will aid in sustainable rice production with increased efficiency.

Efficiency means producing maximum output from given level of inputs with respect to production is concerned. Cost or allocative efficiency is producing output at minimum possible costs and with given input prices. Measuring efficiency will help in knowing what amount of resources can be saved by following a particular system of cultivation, which is reflected in the reduced costs. Efficiency can be measured for an individual farm or a group of farms or farms practicing different methods of cultivation. A better understanding and measurement of efficiency in agriculture is required in the context of lower availability of key resources and production factors, such as land or water in adequate quantity and quality (Singh *et al.*, 2020). Factors that influence the farming system efficiency can be distinguished as controlled (farmer's managerial skill) and uncontrolled factors (natural factors, price, and agriculture institution). The integration of all of the variables together, will create the level of efficiency that can be achieved (Hidayah *et al.*, 2013). Farm level inefficiency is likely to be affected by exogenous factors, i.e. factors that are neither inputs nor outputs of the production process, but nonetheless affect the farm performance (Bhattacharyya, 2016). So, it is important to study the variables which influence inefficiency.

Cultivation system like SRI method is considerably more profitable than traditional method due to low input expenditure. The total cost of cultivation was higher in traditional method (Rs. 14014.54/ac) than SRI method i.e. Rs. 12154.63/ac (Agarwal *et al.*, 2018). Thus, cost efficiency analysis will reveal the method of cultivation to be practised. Vinay *et al.* (2016) analysed the impact of direct seeded rice (DSR) on

economics of paddy crop in Haryana. The net return was higher in DSR (Rs. 60105/ha) as compared to transplanted rice (Rs. 57532.5/ha) and BC ratio was 2.13 in DSR while it was only 1.94 in transplanted rice. This indicates the decreased costs due to increase in efficiency. Moreover, efficiency analysis is also an important input to the policy makers. The aerobic rice cultivating farms were more technically and economically efficient compared to conventional rice cultivating farms. Effective policies to promote and create awareness about aerobic rice can boost the rice production and productivity sustainably. The focus should be given to optimal allocation of resources which enhances the farm productivity and returns (Kumar *et al.*, 2021). This highlights the requisite of cost efficiency analysis.

In this regard, the study made an attempt to estimate the cost efficiency of different rice cultivation systems and identify the system which is cost or allocatively most efficient. It also examined the influence of socio-economic characteristics on cost inefficiency under different rice cultivation system.

Study area and selection of farmers

The study was carried out in Mandya district of Karnataka, which is one of the major producers of rice in Southern Karnataka. Purposive sampling was used to sample the farmers for the study. The primary data was collected from 120 farmers consisting of 30 farmers from each cultivation system namely, conventional rice cultivation, SRI (System of Rice Intensification), aerobic and DSR (Drum Seeded Rice) method. At first the villages practicing these cultivation systems were selected and then the farmers were selected randomly. The data was collected from the respondents through personal interview method using pre-tested, well-structured schedule to achieve the objectives of the study. The required information regarding age, education, land holdings, costs incurred, input usage etc. in rice cultivation was collected for the agricultural year 2021-22.

Analytical tools used

Efficiency analysis

Efficiency analysis orders decision-making units such as firm or a farm, by comparing all resources engaged in production and the costs incurred to produce a given set of outputs and building a frontier based on the input costs. The Cobb-Douglas

Stochastic Frontier Cost (SFC) approach was used for assessing the cost efficiency of rice farmers under different rice cultivation system, following the Coelli (1996) model as follows:

$$\ln C_i = \alpha_0 + \sum_{j=1}^4 \alpha_j \ln X_{ji} + (v_i + u_i)$$

where, \ln denotes natural logarithm. C_i is the total production cost of the farm i measured in rupees per acre, X_{1i} is the cost of seeds (Rs./acre), X_{2i} is the cost of fertilizers used (Rs./acre), X_{3i} is human labour cost and X_{4i} is the machine labour cost. v_i is a symmetric, identically and independently distributed $N(0, \sigma_v^2)$ error term. It represents random variation in production due to random exogenous factors, such as measurement errors and statistical noise. u_i is a non-negative error term. It reflects cost inefficiency relative to the stochastic frontier.

The computer programme FRONTIER Version 4.1 was used to estimate the model and to obtain the maximum likelihood estimates of the SFP function. The calculation of MLE requires (Coelli, 1996). $\sigma^2 = \sigma_v^2 + \sigma_u^2$. This indicates total variance is due to variance in error term (v) and non-negative random variable (u), wherein v and u assumed to be independent of each other. The error term v_i represents the influence of factors outside the control of the farmer, while u_i represents the cost inefficiency factors because of poor management practices which are under control of the farmer. This variance parameter in model is represented by Gamma value, calculated using the following equation:

$$\gamma = \frac{\sigma_u^2}{\sigma_v^2 + \sigma_u^2}$$

Factors affecting the cost inefficiency

In order to assess the factors associated with cost inefficiency, the cost efficiency scores were used. It was analysed taking the degree of cost efficiency scores as dependent variable. The empirical specification of the cost inefficiency model is given by (Bettese and Coelli, 1995).

$$u_i = \delta_0 + \sum_{m=1}^7 (\delta_m Z_m)$$

Where Z_{mi} are socio-economic characteristics, Z_{1i} is age of the farmer. Z_{2i} is education (0=Illiterate, 1=primary, 2=secondary, 3=college, 4=graduation), Z_{3i} is landholding of the

farmer, Z_{4i} is the size of the family, Z_{5i} is the experience in farming, Z_{6i} is a binary variable equal to one if the farmer has membership in any organization and zero otherwise and Z_{7i} is binary variable equal to one if the farmer has access to extension services and to zero otherwise.

Results and discussion

a. Socio-economic characteristics of rice farmers

The socio-economic characteristics of the farmers is given in Table 1. The results indicated that average age of the farmers under conventional rice cultivation was 53 years and with respect to SRI, aerobic and DSR farmers, the average age was 48, 47 and 43 years, respectively. The average landholding was more than 3 acres for SRI, aerobic and DSR farmers but was more than 4 acres for farmers under conventional rice cultivation. The conventional farmers had around 8 years of formal education and SRI, aerobic and DSR farmers had 8, 10 and 10 years of formal education, respectively. The farmers under all the cultivation system had more than 20 years of experience in farming. It was also found that majority of the farmers belonged to the family size of five across all the systems.

It was noticed that around 43 per cent of the farmers under conventional rice cultivation had membership in organizations and 70, 63 and 67 per cent of the farmers under SRI, aerobic and DSR cultivation had membership in organizations, respectively. It was also noted that more than 70 per cent of the farmers under SRI, aerobic and DSR had access to extension services but it was only 20 per cent for farmers under conventional method.

Table 1: Socio-economic characteristics of rice farmers under different rice cultivation system

Variables	Conventional (n=30)	SRI (n=30)	Aerobic (n=30)	DSR (n=30)
Age (years)	53.00	48.00	47.00	43.00
Education level (years of formal education)	8.00	8.00	10.00	10.00
Landholding (acres)	4.83	3.08	3.33	3.40
Experience (years)	25.00	22.00	20.00	20.00
Family size (No.)	5.00	5.00	5.00	5.00
Membership (No.)	13.00 (43)	21.00 (70)	19.00 (63)	20.00 (67)
Access to extension services (No.)	6.00 (20)	25.00 (83)	23.00 (77)	27.00 (93)

Note: Figures in parentheses indicate percentage to total

b. Analysis of cost efficiency

The Cobb-Douglas cost function was estimated using the computer version FRONTIER 4.1 and the results of the maximum likelihood estimates of the stochastic cost frontier of rice farmers under conventional rice cultivation is given in Table 2. The results revealed that one per cent increase in the seed cost, human labour and machine labour cost will increase the total cost by 1.05, 1.96 and 0.9 per cent, respectively and was found significant. The estimated coefficient of the explanatory variables in the cost inefficiency model shows that all the coefficients have the expected signs except age and experience. With increase in age and experience by one per cent the cost inefficiency increased by 0.239 and 0.215 per cent indicating that the farmers who are old are reluctant to adopt the cost efficient technologies. This is in line with the findings of Singh *et al.* (2020) who reported that age is positively related to cost inefficiency. Similarly with respect to increase in experience, following conventional practices leads to increased cost inefficiency.

Sigma squared (σ^2) on the other hand is 0.221 and statistically significant at one per cent indicating correctness of fit of the model as assumed for the composite error term. The estimated gamma parameter of 0.437 is highly significant at five per cent, indicating that around 44 per cent of the variation in the total cost of production among the sampled farmers is due to differences in their cost efficiency. Moreover, the presence of cost inefficiency was tested by LR (Likelihood Ratio) statistic, it was 14.054 which is lesser than the critical chi square value of 24.049, which implies the assumption of no cost inefficiency was rejected.

The maximum likelihood estimates of the stochastic cost frontier of rice farmers under SRI method of rice cultivation is given in Table 3. The cost elasticities of all the input variables used in the cost analysis were positive which implies that an increase in the cost of seed, fertilizer, human labour and machine labour increases total production costs. The coefficients were positive and significant at one per cent. One per cent increase in costs of seed, fertilizer, human labour and machine labour increases the cost by 0.054, 0.130, 0.340 and 0.373 per cent, respectively.

The inefficiency effects of membership in organization and access to extension services was negative and significant. This means that both the factors are contributing positively to cost efficiency. The farmers obtain required and necessary technical advice and knowledge, thereby produce at efficient costs. Increase in membership in organization and access to extension services by one per cent would lead to increase in cost efficiency by 0.075 and 0.289 per cent, respectively.

Table 2: Maximum likelihood estimates of the stochastic cost frontier of rice farmers (Conventional method)

Variables	Coefficients	t-ratio
Constant	- 9.309	-1.024
Seed cost	1.048*	- 2.576
Fertilizer cost	-0.082	-0.335
Human labour cost	1.960**	2.127
Machine labour cost	0.914*	2.830
Inefficiency model		
Constant	1.597	0.624
Age	0.239*	2.902
Education	0.144	-0.878
Land holding	-0.022**	- 2.074
Family size	-0.280	-0.734
Experience in farming	0.215*	-3.741
Membership in organization	-1.006	0.270
Access to extension services	-0.359	0.860
Variance parameters		
Sigma squared	0.221*	3.867
Gamma	0.437**	2.292
Log likelihood	19.989	
LR statistic	14.054	

Note: *, ** indicates significance at one and five per cent probability level, respectively

The sigma squared value was 0.636 and significant at one per cent level indicating the goodness of fit. The gamma parameter was estimated to be 0.719 and was significant at one per cent level. This reveals that approximately 22 per cent of the variation in the total cost of production among the sampled farmers is due to differences in their cost efficiency. LR statistic was 20.539 and lesser than the critical chi square value of 24.049, depicting the presence of cost inefficiency.

Table 3: Maximum likelihood estimates of the stochastic cost frontier of rice farmers (SRI method)

Variables	Coefficients	t-ratio
Constant	2.452*	3.501
Seed cost	0.054*	5.977
Fertilizer cost	0.130*	13.877
Human labour cost	0.340*	12.923
Machine labour cost	0.373*	9.033
Inefficiency model		
Constant	-0.106	-0.199
Age	0.009	-0.158
Education	0.078	1.429
Land holding	-0.039	-0.279
Family size	0.023	0.828
Experience in farming	- 0.011	-0.427
Membership in organization	-0.075**	2.389
Access to extension services	-0.289*	-2.595
Variance parameters		
Sigma squared	0.636*	3.733
Gamma	0.719*	3.433
Log likelihood	70.878	
LR statistic	20.539	

Note: *, ** indicates significance at one and five per cent probability level, respectively

The result of stochastic cost frontier for aerobic rice cultivation is depicted in Table 4. It was observed that coefficients of all the input variables i.e. cost of seeds, fertilizers, human labour and machine labour were highly significant at one per cent level. With respect to inefficiency effects, education was found negative and significant at one per cent level. Increase in education by one per cent decreases cost inefficiency by 0.37 per cent. This reveals that higher the level of education, higher the cost efficiency of the farms. Aboaba (2020) reported that higher the level of education, the higher the allocative efficiency, which implies that educated farmers are allocatively efficient

compared to their counterparts. The Sigma squared estimate (0.031) was also significant at one per cent level indicating the good fit of the model. The gamma value was 0.89 which revealed that 89 per cent of the variation in cost of production is attributed to the variation in costs among the rice farmers and is due to differences in cost efficiency.

Table 4: Maximum likelihood estimates of the stochastic cost frontier of rice farmers (Aerobic method)

Variables	Coefficients	t-ratio
Constant	12.955*	11.533
Seed cost	0.056*	-4.510
Fertilizer cost	0.140*	-5.540
Human labour cost	0.426*	9.329
Machine labour cost	0.598*	-5.213
Inefficiency model		
Constant	-0.115	-0.167
Age	0.074	0.339
Education	-0.310*	-2.77
Land holding	0.002	0.078
Family size	-0.048	-0.689
Experience in farming	0.060	1.980
Membership in organization	-0.039	-1.120
Access to extension services	-0.017	1.130
Variance parameters		
Sigma squared	0.031*	3.763
Gamma	0.89*	190.080
Log likelihood	68.58	
LR statistic	23.346	

Note: *, ** indicates significance at one and five per cent probability level, respectively

It was observed from the stochastic cost frontier analysis under DSR rice cultivation that the cost of human labour was significant at one per cent whereas seeds and machine labour was significant at five per cent level. The coefficients obtained for

the maximum likelihood estimates are given in Table 5. Even in the case of DSR method, increase in all the input variables increases the total cost. In the case of cost inefficiency effects, access to extension services and education were significant and one per cent increase in education and extension services decreases cost inefficiency by 0.20 and 0.08 per cent, respectively. Sigma squared and gamma was observed to be 0.092 and 0.69 and was significant at five per cent level.

Table 5: Maximum likelihood estimates of the stochastic cost frontier of rice farmers (DSR method)

Variables	Coefficients	t-ratio
Constant	7.634*	7.931
Seed cost	-0.005*	-3.005
Fertilizer cost	0.109	0.103
Human labour cost	0.169*	3.085
Machine labour cost	0.022**	2.045
Inefficiency model		
Constant	0.006	0.007
Age	-0.003	-0.004
Education	-0.200*	-3.019
Land holding	0.024	0.092
Family size	-0.002	-0.012
Experience in farming	-0.022	1.302
Membership in organization	-0.036	0.113
Access to extension services	-0.083*	55.770
Variance parameters		
Sigma squared	0.092**	1.908
Gamma	0.69**	2.502
Log likelihood	29.104	
LR statistic	7.528	

Note: *, ** indicates significance at one and five per cent probability level, respectively

c. Efficiency distribution of rice farmers under different rice cultivation systems

The distribution of farmers according to the cost efficiency scores is presented in Table 6. It was observed that mean efficiency score was 0.55, 0.92, 0.94 and 0.88 for conventional, SRI, aerobic and DSR cultivation, respectively. This indicates that the cost efficiency was highest in aerobic rice cultivation. The cost efficiency obtained is supported by Aboaba (2020) which reported that mean allocative efficiency implies that rice farmers were 94 per cent cost-efficient, that is they were able to maximize their total output by minimizing 94 per cent of their total production cost, which shows that there is room for six per cent improvement.

The lowest cost efficiency was obtained under conventional rice cultivation indicating that around 55 per cent of the farmers were allocatively efficient. The mean efficiency scores obtained for SRI method of cultivation was higher than 83 per cent as reported by Mwatete *et al.* (2015). With respect to DSR rice cultivation, the efficiency scores obtained are in line with results of Maurice *et al.* (2015) which reported allocative efficiency of 0.84 for food crop production among small scale farmers. Thus, there was 45 per cent room for increasing efficiency for conventional farmers and only two per cent for aerobic farmers.

Table 6: Distribution and summary statistics for cost efficiency scores of farmers under different rice cultivation systems

Cost efficiency scores	Conventional	SRI	Aerobic	DSR
≤0.5	9.00	-	-	-
>0.50 ≤0.70	20.00	4.00	-	7.00
>0.70 ≤0.90	1.00	4.00	2.00	3.00
>0.90	-	22.00	28.00	20.00
Mean	0.55	0.92	0.94	0.88
Minimum	0.12	0.60	0.86	0.66
Maximum	0.60	0.97	0.98	0.95

Conclusion

The adoption of a rice cultivation system which decreases cost inefficiency is the important aspect in the present context because with rice being a major staple food it has to be seen that there is sufficient and sustainable rice production in the country which can be produced at minimum costs. The results from the maximum likelihood estimates revealed that cost of seeds, fertilizers, human labour and machine labour were the various input variables influencing cost of production. The variables such as age, landholding and experience in farming significantly influenced cost inefficiency in conventional rice cultivation. Membership in organization and access to extension services were significant in explaining cost inefficiency of SRI method of cultivation. The major factor for aerobic farmers was education which contributed significantly to cost efficiency. With respect to DSR method, age and access to extension services were the significant factors. Moreover, it was observed that the most cost efficient system was aerobic rice cultivation followed by SRI method and the system which had more scope for allocative efficiency was conventional method. Therefore, adopting aerobic rice cultivation or SRI method on a larger scale in the study area would help in increasing efficiency and sustainable management of resources.

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Comparative economics of climate smart rice cultivation systems in Mandya district of Karnataka

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Abstract

Rice is an important cereal crop and is the staple food in most of the countries of the world. There is always growing population and increasing demand for food on one hand and on the other there is increasing changes in the climate which is affecting the productivity of the crop and also rice cultivation is effecting the environment. The study is an attempt to assess the economics of climate smart practices such as SRI (System of Rice Intensification), aerobic cultivation, dry seeded rice farming which will aid in sustainable rice production. The total cost of cultivation was found to be highest in conventional method which was Rs. 50926.44 per acre and was lowest in aerobic method (Rs.43.444.07/ha). Similarly, in SRI method and DSR method the cost of cultivation was Rs.48949.92 and Rs.46002.74 per acre, respectively. Across all cultivation systems the yield was found to be highest in SRI method (33.2 quintals) and gross and net returns were also highest in case of SRI method (Rs. 70336 and Rs. 21386.08).

Key words: System of Rice Intensification, aerobic method, costs and returns.

1. Introduction

The Indian economy has always been based on agriculture. It has to support almost 17 per cent of world population from 2.3 per cent of world geographical area and 4.2 per cent of world's water resources. The world has recognised Indian agriculture's

accomplishment as food grain production rose from 50.8 million tonnes during 1950-51 to 316.06 million tonnes in 2021 (Anonymous, 2021-22), out of which 127.93 million tonnes is contributed by rice alone. Rice continues to hold the key component of sustainable production of food in the country. India has occupied the first place in area and second place in production of rice after China, contributing 28.53 per cent of the world's area and 14.61 per cent of world's production with 44.19 million hectares and 104.4 million hectare. (INDIASTAT, 2016). In the year 2020-21, India produced 124.37 million tonnes of rice and covered area of 45.77 million hectares with productivity of 2717 kg per hectares.

With respect to Indian scenario is concerned, the major states with highest area under rice cultivation are Uttar Pradesh (5678 '000 ha), West Bengal (5585.63 '000 ha), Odisha (4038.24 '000 ha). In terms of production, the major rice producing states are West Bengal (16524.44 '000 tonnes), Uttar Pradesh (15520.02 '000 tonnes), Punjab (12783.65 '000 tonnes) and Chandigarh has the highest productivity with 55q/ha followed by Punjab (43.66 q/ha), Andhra Pradesh (33.93 q/ha).

The production, accessibility, and availability of food are under constant strain in many nations due to the growing global population, climate change, and depleting natural resources. Rice production is adversely impacted by factors like rising temperatures, variable rainfall, intermittent access to water and a variety of biotic and abiotic pressures that reduce output. The goal is to increase productivity and strengthen food security on a sustainable basis, improving human wellbeing in the process. Rice cultivation is both an important sequester of carbon dioxide from the atmosphere and an important source of greenhouse gases (*e.g.* methane and nitrite oxide) emission. In 2004, for example, rice sequestered about 1.74 billion tonnes of CO₂ from the atmosphere to produce about 1.16 billion tonnes of biomass.

Climate change poses a serious and growing threat to global food security. Climate change's effects include rising temperatures, an increase in extreme weather occurrences, water shortages, and other things. Rising sea levels, ocean acidification, land degradation, ecosystem disruption, and biodiversity loss could seriously jeopardise

agriculture's ability to feed the most vulnerable, impeding the eradication of hunger, malnutrition, and poverty.

Thus in order to overcome the impacts of climate change there is a need to adopt climate smart agricultural practices for rice cultivation. Climate smart agriculture is the practice of adopting agricultural practices which help in increasing productivity and income, adapting to the effects of climate change and also in reducing the emission of GHGs in to the atmosphere.

The study is an attempt to assess the different climate smart practices such as system of rice intensification (SRI), aerobic and drum seeded rice (DSR) cultivation systems. The SRI method is aimed at increasing the yield of rice. Aerobic method is a practice where rice is grown aerobically when it is directly sown on non-puddle aerobic soil with more irrigation and fertiliser while using optimal high yielding rice types. And DSR is a technique of rice cultivation where farmers directly sow the paddy seeds in the field without transplanting process.

2. Materials and methods

The study was carried out in Mandya district of Karnataka. Simple random and snowball sampling technique was employed for the selection of sample respondents under each of the cultivation system i.e. conventional, System of Rice Intensification (SRI), aerobic and drum seeded rice (DSR) method. Thirty farmers under each of the cultivation system were selected for the study. A total of 120 farmers were selected for the study.

Descriptive statistics

Frequency, percentage and arithmetic mean were worked out for the purpose of comparison among different cultivation systems

$$A = (x_1 + x_2 + x_3 + \dots + x_n) / n$$

Where,

A = Arithmetic mean

$x_1 + x_2 + x_3 + \dots + x_n$ are the value of individual items

n = number of individuals

Cost of Cultivation

The cost of cultivation (Rs./ha) was calculated on per acre basis for every cultivation system by taking into account the inputs, labour and operational cost etc. Cost of cultivation included total variable cost and total fixed cost.

Variable Cost: Variable cost was used in the present study includes the cost of labour, seed value and power tiller.

Fixed Cost: Fixed cost includes the depreciation cost of land and interest on fixed capital.

Returns concepts

a. Gross returns: The total quantity of rice produced was multiplied with its selling price gives the gross returns.

b. Net returns: It is the difference between gross return and total costs incurred in rice cultivation.

3. Results and discussion

3.1 Costs and returns analysis of different rice cultivation systems

Cost of rice cultivation

The estimation of total cost of cultivation took into account explicit costs on inputs, labour cost, imputed costs of family labour and other owned factors. The table 1 depicts the details on cost of cultivation per acre for rice across different cultivation systems. The following section gives the information on different items of costs involved in rice cultivation such as variable cost and fixed cost.

Variable cost

It was found that the cost of seeds were Rs. 816 per acre in conventional method, Rs. 640 in SRI method, Rs. 573.75 in aerobic method and Rs. 646.67 in DSR method. The quantity of seed used was highest in DSR method i.e. 18.50 Kg per acre followed by the aerobic method which requires 18.13 Kg. Overall, the seed cost was high in case of conventional method because the different varieties have been used in different

cultivation systems whose prices vary across cultivation systems. FYM required for rice cultivation vary from one to 3 tractor loads. Cost of FYM was highest in case of conventional i.e. Rs.5296.30, Rs 4000 in case of SRI method, Rs.4937 in aerobic method and Rs. 4666.67 in DRI method. The quantity of fertilizer used was highest in conventional and DRI method which was 170.33 Kg and 175.17 Kg per hectare respectively.

Table 1: Cost and returns under different rice cultivation systems

(Rs. /acre)									
Sl. No	Particulars	Conventional		SRI		Aerobic		Drum seeded Rice	
		Qty	Cost	Qty	Cost	Qty	Cost	Qty	Cost
I	Variable costs								
	Seed (kgs)	13.00	816.00	7.30	640.00	18.13	573.75	18.50	646.67
	FYM (Tractor load)	2.86	5296.30	1.80	4000.00	2.12	4937.50	1.93	4666.67
	Fertilizers (Kgs)	170.33	3601.33	156.00	3680.00	160.50	3348.00	175.17	3655.33
	Plant protection chemicals		2343.07		2610.69		2740.56		3663.98
	Micronutrients		937.50		580.00		580.00		400.00
	Irrigation (acre inch)		709.20		482.00		359.00		569.00
	Human labour (Man days)	36.22	14730.37	33.40	14028.00	19.90	8457.50	22.20	8991.00
	Bullock labour (BP days)	1.00	1371.43	1.00	1200.00	0.00	0.00	1.00	1040.00
	Machine labour (Hours)	5.53	6077.78	5.64	7096.67	2.95	5275.00	6.71	7888.70
	Interest on WC @ 7 %		2511.81	14.36	2402.22	14.25	1838.99	15.79	2206.49
	Total variable costs		38394.78 (75.39)	219.50	36719.58 (75.01)	217.85	28110.30 (64.70)	241.29	33727.85 (73.31)
II	Fixed costs								
	Depreciation		1788.98		1019.95		1290.87		1059.72
	Land revenue		400.00		400.00		400.00		400.00
	Rental value of land		9000.00		9500.00		12000.00		9500.00
	Interest on fixed capital @ 12 per cent		1342.68		1310.39		1642.90		1315.17
	Total fixed costs		12531.66 (24.61)		12230.35 (24.99)		15333.78 (35.30)		12274.89 (26.69)
III	Total cost of cultivation		50926.44	219.50	48949.92	217.85	43444.07	241.29	46002.74

But the cost of fertilizer vary marginally across different cultivation systems and it was found lowest of Rs.3348 per acre, this is because of comparatively lower quantity

of fertiliser was used in aerobic method. It also observed that cost of plant protection chemicals was highest in case of DSR method i.e. Rs. 3663.98 and this is due to more usage of weedicide because of higher weed incidence. The cost of plant protection chemical in case of conventional, SRI and aerobic was found to be Rs. 2343.07, 2610.69 and 2740.56 respectively. The cost of micronutrients in conventional method was found to be highest which was Rs. 937.50 followed by SRI (Rs. 580/ acre), aerobic (Rs. 580/acre) and DSR method (Rs. 400/acre). The results also revealed that the irrigation cost was found to be highest in conventional method which was 709.20 because of higher water usage which was around 38.40 acre inches. Irrigation water cost was lowest in aerobic rice cultivation method that is around Rs. 359 per acre with water use of 18.36 acre inch. In SRI and DSR method irrigation cost was Rs.482 and Rs.569 respectively with water usage was 25.16 acre inch and 30.18 acre inch per acre respectively.

It was also found that human labour cost was major components of variable cost in specific and total cost in general. The number of human labour was used highest in conventional method i.e. 36.22 man days, which costs around Rs.14730.37. The reason for this would be, farmers might be less mechanised. It was found lowest in aerobic method of rice cultivation i.e. Rs. 8457.50 that uses 19.90 man days. The human labour cost in SRI and DSR method was found to be Rs.14028 and Rs.899. The results also reveals that, across all the rice cultivation systems bullock labour was used marginally, zero utilisation in case of aerobic and DSR method. The farmers in DSR method were more mechanised than their counterparts which was found to be 6.71 hours and total machine labour cost in this method was Rs.7888.70. The machine labour cost in conventional was Rs. 6077.78, in SRI and aerobic method it was around Rs. 7096.67 and Rs. 5275 respectively. Overall, it was concluded that the rice cultivating farmers in the study area were well mechanised.

The share of total variable cost in total cost was highest in conventional method which was around Rs.38394.78 and it accounts for 75.39 per cent. It was also found that the total variable cost in SRI method was Rs.36719.58, in aerobic method it was Rs.28110.30 and in DSR method the variable cost was Rs.33727.85.

Fixed cost

The total fixed cost incurred by the farmers practicing aerobic cultivation method was highest than their counterparts, which was Rs.15333.75. It was noticed that cost incurred by the farmers in other systems vary marginally across different cultivation systems. The major component of fixed cost was the rental value of land in all the cultivation systems. Rental value in conventional, SRI, aerobic and DSR method was Rs.9000, Rs.9500, Rs.12000 and Rs.9500 respectively. Land revenue was found to be Rs.400 across all the system and it accounts small share of total fixed cost. The depreciation cost of conventional, SRI, aerobic and DSR method was Rs.1788.98, Rs.1019.95, Rs.1290.87 and Rs.1059.72 respectively.

The total cost of cultivation was found to be highest in conventional method which was Rs. 50926.44 and it is due to higher usage of human labour. The total cost was found lowest in aerobic method (Rs.43.444.07) because there is no nursery preparation and transplanting activity which reduces human labour cost. Similarly, in SRI method and DSR method the cost of cultivation was Rs.48949.92 and Rs.46002.74 respectively.

Yield and returns

The results of the table 2 indicate yield and return structure of paddy under different rice cultivation systems. Across all cultivation systems the yield was found to be highest in SRI method (33.2 quintals) due to the fact that there are more number of tillers obtained per hill i. e. 30 to 40 tillers thereby increasing the yield. The average yield in conventional method was 25.5 quintals which is followed by the drum seeded rice (23.57 quintals) and aerobic methods (23.13 quintals). Gross and net returns were highest in case of SRI method (Rs. 70336 and Rs. 21386.08) this is because of higher yield. The gross returns in drum seeded rice cultivation was found to be Rs.53426.17 then in conventional and aerobic rice cultivation method it was found to be Rs. 54493.30 and Rs. 48984.38 respectively. Net return was found to be lowest in case of conventional method which was Rs.3566.89. This was due to higher cost incurred especially for human labour. It was also found that, net return in aerobic and DSR method was Rs.5540.30 and Rs. 7423.43.

Table 2: Yield and returns of paddy under different rice cultivation systems**(Rs. /acre)**

Particulars	Conventional			SRI			Aerobic			DSR		
	Qty	Price/ Unit (Rs.)	Total (Rs.)	Qty	Price/ Unit (Rs.)	Total (Rs.)	Qty	Price/ Unit (Rs.)	Total (Rs.)	Qty	Price/ Unit (Rs.)	Total (Rs.)
Main product (qtls)	25.50	1720.00	43860.00	33.20	1730.00	57436.00	23.13	1675.00	38734.38	23.57	1755.00	41359.50
By product (Tractor load)	2.13		10633.33	2.00		12900.00	2.00		10250.00	2.07		12066.67
Gross returns (Rs.)			54493.33			70336.00			48984.38			53426.17
Net returns (Rs.)			3566.89			21386.08			5540.30			7423.43
Total Fixed cost			12531.66			12230.35			15333.78			12274.89
Total variable cost			38394.78			36719.58			28110.30			33727.85
Cost of cultivation (Rs./acre)			50926.44			48949.92			43444.07			46002.74
Cost of production (Rs./q)			1997.12			1474.40			1878.66			1952.03
Gross returns over VC(Rs./acre)			16098.55			33616.42			20874.08			19698.32
Gross returns over COC(Rs./acre)			3566.89			21386.08			5540.31			7423.43
Gross returns over COP(Rs./acre)			52496.22			68861.60			47105.71			51474.14
Gross returns per VC (Rs./acre)			1.42			1.92			1.74			1.58
Gross returns per COC (Rs./acre)			1.07			1.44			1.13			1.16
Gross returns per quintal (Rs.)			2136.99			2118.55			2118.24			2267.02
Net returns per quintal (Rs.)			139.88			644.16			239.58			315.00
Returns per rupee of expenditure (net returns per COC)			0.07			0.44			0.13			0.16

Gross return per variable cost was found to be highest in SRI method of cultivation i.e. Rs. 1.92 per acre. Gross return per COC was also highest in case of SRI method (Rs. 1.44/ac) followed by DSR (Rs 1.16/ac), aerobic (Rs.1.13/ac) and conventional (Rs. 1.07/ac) method of rice cultivation. Net return per quintal was also highest in case of SRI method (Rs.641.26) followed by the DSR (Rs.314.99), aerobic (Rs.239.58) and conventional method (Rs.139.88).

4. Conclusion

Among the different rice cultivation systems, the total cost of cultivation was found to be highest in conventional method which was Rs. 50926.44 per acre. The total cost was lowest in aerobic method (Rs.43.444.07) and similarly, in SRI method and DSR method the cost of cultivation was Rs.48949.92 and Rs.46002.74 respectively. SRI method of rice cultivation was found to be producing the highest returns because of higher yield with highest yield compared to their counterparts. Thus, the study suggests adoption of either SRI or aerobic method on a larger scale so that farmers can obtain higher returns with SRI method of rice cultivation or reduce costs with aerobic method of cultivation.

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