IRRIGATION WATER: ASSESSING THE ECONOMIC EFFICIENCY AND ITS PRICING IN BANANA

By

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(2020-11-130)

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KERALA, INDIA
2023

DECLARATION

I, hereby declare that thesis entitled **“Irrigation water: assessing the economic efficiency and its pricing in banana”** is a bonafide record of research work done by me during the course of research and that is has not been previously formed the basis for the award of me of any degree, diploma, fellowship or other similar title, of any other University or Society.

Midhuna Sivanandan
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CERTIFICATE

Certified that this thesis, entitled **"Irrigation water: Assessing the economic efficiency and its pricing in banana"** is a bonafide record of research work done independently by **Ms. Midhuna Sivanandan (2020-11-130)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma or fellowship, or associateship to her.

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We, the undersigned members of the Advisory Committee of **Ms. Midhuna Sivanandan (2020-11-130)**, a candidate for the degree of **Master of Science in Agriculture**, with major field in **Agricultural Economics**, agree that this thesis, entitled **"Irrigation water: Assessing the economic efficiency and its pricing in banana"** may be submitted by **Ms. Midhuna Sivanandan** in partial fulfillment of the requirement for the degree.

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Introduction

1. INTRODUCTION

Water is an elixir of life. Various ecological life-support systems that are often challenging to value are provided by water, which is essential for life and for many human activities and industries (Al-Karablieh *et al.,* 2012). However, the world is facing challenges in dwindling freshwater supplies and other domains, such as deteriorating environmental conditions, growing demands for food and escalated population pressure (Rockstrom, 2012). The food demand is expected to increase two folds by 2050, when the global population crosses the 9 billion mark. The increased food demand swiftly drives more water use for irrigation (Mancosu *et al.,* 2015).

Agriculture is the primary sector and utilizes 80 per cent of available water. Irrigation is a major determinant in supporting global agricultural production, although its efficiency is often surprisingly low, and without irrigation, cereal production would fall by 20 per cent globally (Jägermeyr, 2015; Siebert and Döll, 2010). In many regions of the world, accessing irrigation water has become increasingly complex, making it a scarce resource for farming. As the demand for agricultural products grew, the creation of adequate irrigation infrastructure to ensure irrigation water supply became a common theme in socio-political schemes. However, the massive use of irrigation water at a highly subsidized cost/no cost and physical scarcity became the grave reality of these expansionist policies (Karagiannis *et al.,* 2003).

Groundwater is a major component of the planet's freshwater, almost 99 per cent. Hssaisoune (2020) found that groundwater levels decreased due to an unrelenting imbalance between extraction and recharge. Groundwater is often overused and inadequately managed. It provides for 50 per cent of the domestic use of the global population. Additionally, it covers 38 per cent of the irrigated land in the world. Although groundwater can help communities in terms of social, economic, and environmental factors, pollution and overuse of it present a serious threat (UNESCO, 2022).

Groundwater irrigation has increased exponentially in India since the 1970s. Around 85 per cent of the drinking water in rural regions is derived from groundwater sources. The area under bore well irrigation is getting increased over the years, which went from 1 per cent in 1960-1961 to 60 per cent in 2006-2007 (GoI, 2008).

According to the Agriculture Census (2011), tube wells replaced open wells as the primary source of irrigation (45.2%), with canals (26.2%), open wells (18.5%), and tanks (3.5%). In Gujarat, Jharkhand, Kerala, Madhya Pradesh, Maharashtra, Tamil Nadu, Damodhar Haveli, and Daman & Diu, more area was watered by open wells than by canals, tanks, or tube wells combined. The estimated number of open wells and bore wells in India is now around twenty-seven million, with bore wells accounting for more than 50 per cent (GoI, 2020). Over each decade, the percentage of groundwater used for irrigation steadily rises. With an estimated 251 km^3 of groundwater withdrawn annually from 20 million open wells and tube wells, India is the world's greatest groundwater consumer. Sixty per cent of India's electricity consumption is for groundwater extraction of agriculture. Free electricity, subsidized pump sets, and planting water-intensive crops, even in semi-arid areas, have depleted the country's groundwater levels, particularly in the northwest and peninsular southern India (GoI, 2020). Groundwater irrigation, which aided the post-green revolution in increasing agricultural output, is also to blame for India's current water shortage (UNESCO, 2022).

Like other states of India, Kerala is also facing the wrath of groundwater exploitation. The groundwater availability and occurrence vary greatly within the State depending on the local climatic, geomorphological, and hydrogeological variables. Crystalline rocks cover eighty-eight per cent of the State's entire land area with little to no groundwater potential and no primary porosity. In contrast, in alluvial formations with diversified aquifer systems, water quality becomes an occasional problem. Over the past few decades, the State's consumption of groundwater resources has increased due to the rising population, fast urbanization, and industrial development (GoK, 2012). Even though Kerala is regarded as a state with plenty of water resources, data on open well water levels indicate that the depth from ground to well water level is rising throughout the State

(Peedikakandi and Devi, 2016). Groundwater extraction for domestic, agricultural, and industrial purposes was projected to be 1.47, 1.16, and 0.01 BCM, respectively, of the 2.65 BCM total groundwater extraction for all uses in the State in 2020 (GoI, 2020).

But given that the planet's freshwater consumption and land-system change, limits are being rapidly approached or have already been reached, there is little room to expand irrigation or farmland (Steffen *et al.,* 2015; Gerten *et al.,* 2013). Therefore, to address the production gap, higher cropping intensities must be achieved on the currently cultivated land by either boosting rainfed yields or increasing the water productivity of irrigated cropping systems. The most significant task is to sustainably enhance agricultural productivity to feed the expanding population while using less water. Instead of focusing on production per hectare of land, we should enhance agricultural productivity per cubic meter of water supplied or used. The current water scarcity situation requires effective use of the available water rather than flooding the crops with an excess of it. Due to the low substitutability of water and the scarcity of resources, irrigation water use must be coordinated with efficiency and conservation goals (FAO, 2012).

However, expanding irrigation systems globally while adhering to sustainability limits requires a complex interplay between significant financial commitments, institutional water policy laws, and cultural shifts (Molle and Berkoff, 2007). Though theoretically an economic good, an irrigation service cannot be categorized as a pure private good. It is a non-merit, quasi-public good that cannot be valued according to the free market system. Highly subsidized electricity pricing has led to several negative externalities, such as over-pumping, higher energy use by crops, and the cultivation of more water-intensive crops, which have reduced water supplies in agriculture (Narayanamoorthy, 1996; Palanisami *et al.,* 2009). As a result, selecting the appropriate balance must be part of the irrigation water pricing (Parween *et al.,* 2021). The fourth Dublin principle (1992) highlighted the significance of the economic value of water use in general and irrigation water in particular, although the World Bank acknowledged the acceptable share of payment from the beneficiaries of large irrigation projects. The Rio Declaration on Environment and Development of the United Nations in 1992 (EU, 2000) and its Agenda 21 (United Nations, 1992), processes, and regulatory measures elevated this idea of the economic value of water even further.

In this context, the present study tries to focus on the economic efficiency of irrigation water and it's pricing in banana. A study was done on the Nendran variety of banana since it is known for its usage of a substantial amount of water (900-1200 mm per crop) and essential irrigation at intervals of 3-4 days (irrigated crop) for good yield (KAU, 2016).

The following were the study's objectives:

1. Identifying the sources of irrigation, private investments in irrigation, and irrigation pattern
2. Estimation of economic efficiency of irrigation water
3. Assessment on the pricing of irrigation water

Scope of the study

Farmers' perception of water as a scarce and therefore valuable resource is distorted by long-term subsidies. Low water prices are therefore likely to lead to excessive use, which will exacerbate an already precarious situation. Allowing for water prices that recover the actual cost of water supply and achieve financial sustainability is the most efficient way to end this vicious cycle. There are many studies on the economic efficiency of irrigation water and the necessity for its pricing in India (Parween *et al.,* 2021; Singh, 2007). However, there needs to be more region-based research that focuses explicitly on irrigation efficiency and pricing in the case of specific crops. The present study highlights the need for effective processes and fair pricing to ensure the viability and sustainability of irrigation water in the state of Kerala. The study results will serve as a baseline for assessing the efficacy of ongoing and upcoming irrigation schemes to frame suitable management practices for irrigation water use.

Limitations of the study

The study's findings are based on data gathered at the farm level using an structured interview schedule. Farmers seldom follows proper irrigation schedules and strategies, and are using them with less accountability for its management or usage. Farmers also cultivated banana around paddy fields which didn’t require additional irrigation. Besides, few farmers were irrigating banana manually by bailing out water from the water-filled furrows which makes the quantification of water difficult. Hence, this study was confined to farmers irrigating banana using irrigation pump sets (surface irrigation method). The responses can be biased by recall because they were based on their memories since they did not maintain any proper records of the water applied. Cross-checking and cross-questioning, however, were done to minimize the inaccuracies.

Presentation of the thesis

The study "Irrigation water: Assessing the economic efficiency and its pricing in banana" was presented in five chapters. The background and introduction of the study were presented in the first chapter, followed by a review of pertinent literature in chapter two. Chapter three includes the methodology and the tools used for the study and research findings in the next chapter. The final chapter contains the summary and conclusion.

Review of literature

2. REVIEW OF LITERATURE

An overview of previously published articles is essential in any research. This chapter scrutinizes the major past studies pertinent to the present study.

In this chapter, the categorization of the literature review has been divided into two sections. The first section comprises studies connected to analyzing the economic efficiency of irrigation water, followed by the appending assessment of irrigation water pricing in the second section.

2.1 STUDIES ON ANALYSING THE ECONOMIC EFFICIENCY

Reviews presented in this section are related to studies that analyzed the economic efficiency of different resources using the Data Envelopment Analysis (DEA) method.

Eliw (2022) examined the efficiency of irrigation water utilization in Egypt's most significant water-intensive crops. It included wheat, sugar beet, rice, maize, and sugar cane. In order to quantify production efficiency, DEA, one of the linear programming techniques, was employed. The findings indicated that the sugar beet crop was the most water-efficient for irrigation, with a maximum output of 8.81 tonnes per irrigation water unit.

Chebil *et al.* (2022) investigated the effects of increased irrigation water use efficiency in citrus production systems of North Eastern Tunisia using a stochastic frontier production function. The analyzed agricultural sample had considerable inefficiencies, and overall mean technical and water use efficiencies were 78.4 per centand 44.3 per cent, respectively. The study suggested that it was possible to apply higher irrigation water fees compared with the water price they were paying currently to the citrus production system. The study also suggested that it has to be coupled with more significant incentives for water usage efficiency and improved farmer market integrations.

Saleh and Jbara (2022) sought to compare the economic efficiency of wheat producers in Iraq who adopted pivot irrigation technology to those who did not. They employed DEA to determine economic efficiency. It was observed that the farms using the pivot irrigation system had a 22 per cent sample-wide success rate in achieving total technical efficiency compared to a 0.5 per cent success rate for those not using the pivot irrigation system. The average allocative and economic efficiency in the pivot irrigation system were 0.82 and 0.72, respectively.

Atta *et al.* (2022) aimed to evaluate the economic efficiency of wheat production using various irrigation systems in the Nubariya region in Egypt; DEA was used to examine economic efficiency. Surface, sprinkler, and drip were each estimated to have an economic efficiency of 0.75, 0.93, and 0.93, respectively. The study found that sprinkler and drip irrigation systems outperformed surface irrigation systems by lowering total costs by 19 per cent and 33 per cent and increasing total revenue by 1.8 per cent and 2 per cent, respectively.

A study compared the economic efficiency of fixed-head classic, linear, centre pivot, and tape-drip irrigation systems using DEA in the province of Kurdistan (Iraq). The findings demonstrated that, for fixed head classic, centre pivot, and linear, the average economic efficiency was 0.60, 0.73 and 0.90 for alfalfa (at variable returns to scale). As a result, it was evident that the linear irrigation system had a higher economic efficiency than the centre pivot, which in turn was more effective than the fixed-head traditional irrigation system (Ghaderzade and Zareei, 2020).

Ali *et al.* (2020) evaluated the economic aspects of the drip irrigation systems in tomato-producing areas of Egypt. The investment profitability and economic efficiency of the drip irrigation system in the study area were assessed. Utilizing DEA, the economic efficiency of tomato production was estimated. Under variable returns to scale (VRS), the average technical efficiency score was found to be 0.98. A VRS score of more than 90 per cent was achieved by nearly all farms (94%), indicating that the majority of farms were entirely VRS efficient.

The average economic efficiency score was 0.73.

An analysis of small-scale vegetable farmers in Northern Ghana who used various irrigation techniques was done to measure their economic efficiency. Estimation of efficiency scores under VRS was done using DEA. According to the findings, about 27.3 per cent of farmers were technically and economically efficient and operated on the production possibility frontier. In comparison, 3.6 per cent were found to be both economically and allocatively efficient. The mean technical score was 78.1 per cent with the variable returns to scale (Adams *et al.,* 2020).

Kane *et al.* (2018) assessed the impact of various irrigation techniques in vegetable production on rural community household well-being in Mali. The study demonstrated how using irrigation systems to grow vegetables could help smallholder farmers in rural areas improve their standard of living. Analysis was conducted using DEA and descriptive statistics. The irrigation systems employed in cultivating the principal crops were ineffective (drip, sprinkler, and Californian irrigation system). Micro irrigation systems (drip and sprinkler) were found to be comparatively more economically efficient, with drip irrigation having an efficiency score of 0.90, yieldingthe most surplus benefit, followed by sprinklers (0.75 at VRS).

Productivity levels of farms in Tadla, Morocco, under different irrigation systems, were assessed using DEA. The efficiency of these farms from a technical, allocative, and economic perspective was examined. According to the source of irrigation water, average economic efficiency ranged from 45-83 per cent, whereas thetechnical and average economic efficiency was 90 and 69 per cent, respectively, for groundwater users. The study also found that farms that only use groundwater received a higher value for irrigation water (2.19 Moroccan Dirham/m^3) than those that use both surface and groundwater or only surface water (Lionboui, 2016).

Watto and Mugera (2015) employed an input-oriented DEA model to assess irrigation water application efficiency in Pakistan's sugarcane cultivation.

The study found that tubewell proprietors had a mean technical efficiency score of 0.96, while water buyers had a mean score of 0.94. For users of tube wells, the mean irrigation water efficiency score was 0.86, compared to 0.72 for water purchasers. The study added that 45 per cent of water purchasers and 59 per cent of tubewell owners across all farms were fully technically efficient. In comparison, 36 per cent of those who owned tube wells and 30 per cent who purchased water used irrigation water efficiently. The study also revealed that sugarcane farmers have a fair amount of technical efficiency in their operations.

DEA was used in a study to evaluate the economic, technical, and scale efficiencies for grain producers in the Chebika region of Central Tunisia. The DEA model's findings revealed that the average technical, allocative, and economic efficiencies under constant returns to scale (CRS) were 70.7, 85.1, and 59.7 per cent, respectively. In order to find its determinants, calculated efficiency scores were regressed on explanatory factors using a Tobit model. Results of the Tobit regression showed that factors such as variety selection, irrigation source, association membership, irrigation management and farm size had a beneficial impact on economic efficiency (Chebil *et al.,* 2015).

The technical, allocative, and economic efficiency of pineapple cultivation in West Java Province, Indonesia, was estimated using DEA. The results of the DEA revealed that farmers produced pineapples inefficiently, with mean levels of technical, allocative, and economic efficiency being, respectively, 70.1, 34.1, and 24.1 per cent (Lubis *et al.,* 2014).

Watto and Mugera (2014) used data envelopment analysis (slack-based, SBM) and DEA sub-vector efficiency approach (SVM) to estimate the technical and irrigation efficiency of rice farms in the Punjab Province of Pakistan. They used an 80-farmer cross-sectional dataset, which included 35 water purchasers and 45 tubewell owners. The mean technical efficiency and economic efficiency for tubewell and waterconsumer proprietors was 96 and 94 per cent, 71 and 66 per cent respectively. Gains from increasing technical efficiency appeared insignificant based on the mean estimates. The findings indicated that water purchasers and proprietors of tubewell were inefficient large-scale irrigation users, with 20 and 22 per cent of irrigation water use inefficiency, respectively. These calculations suggested a significant amount of room to reduce irrigation water while keeping the same output level by using the quantities of other inputs.

Umanath and Rajasekar (2013), in their study, used DEA to assess the economic efficiency of paddy farms in Tamilnadu. The technical and economic efficiency of the farm was found to be 0.80 and 0.38, respectively. The study's findings indicated that more than 70 per cent of farms were operating below 50 per cent of allocative and economic efficiency levels.

DEA was used to examine the technical, allocative, managerial, economic, and ideal levels of input efficiency of rice producers in Iran. The findings revealed that the average managerial, technical, allocative, and economic efficiency levels were 72, 40, 28, 79, and 91 per cent, respectively (Sabuhi, 2012).

Al-Niamy and Al-Rawi, (2012) quantified the economic efficiency of supplemental irrigation in rainfed agriculture using farm data in Iran. DEA was used to calculate the study's estimates based on the variable of returns to scale. The farms using all inputs for production demonstrated that technical and allocative efficiency were 83 and 65 per cent respectively. The overall economic efficiency was around 59 per cent.

Obiero (2010) studied the economic efficiency of irrigation water use of rice in Kenya. This study used correlation and regression analysis using ordinary least squares (OLS) to ascertain the link between the quantity of irrigation water used and rice yield. In addition, the water-use efficiency examined using DEA was 68.96 per cent. Allocative efficiency was 91.31 per cent. The overall economic efficiency was 62.96 per cent. According to the study, the irrigation water used has no discernible effect on rice yield. Since the farms were operating at declining returns to scale, using more water on the current rice-growing area was not anticipated to result in a further appreciable rise in rice production.

Singh and Chand (2011) conducted a study on the economic efficiency of rice farming in India's West Delhi. The technical efficiency of the farms was calculated using the constant returns to scale (CRS) input-oriented DEA method. Technical, allocative, and economic efficiency's respective means were 69, 66, and 54 per cent. Although Delhi farmers were found to produce rice with a fair amount of technical efficiency, the study found that their allocative and economic efficiencies were significantly lower due to higher input costs (aside from irrigation water) and the useof unreasonable combinations of inputs.

A study evaluated water consumption efficiency at the farm level for irrigated farms based on surface wells in Tunisia. Private irrigation systems were crucial for rural development in the study region, but they required efficient water usage methods due to water shortages and escalating demands on these resources. DEA techniques were used to compute farm-level technical efficiency measures and sub-vector efficiencies for water use. The study found that under CRS and VRS specifications, substantial technical inefficiencies of 26 and 15 per cent, respectively, existed among farmers (Mahdi *et al.,* 2010).

Wang (2010) used DEA techniques to examine irrigation water use efficiency in China, based on input-specific technical efficiency, to develop farm-level technical efficiency measures and sub-vector efficiencies for irrigation water use. The Tobit regression technique was adopted to identify the factors influencing irrigation water efficiency differentials under the shortage of water resources. The results of the DEA analysis showed an average technical efficiency of 0.62 and a mean irrigation water efficiency of 0.31. The mean irrigation water efficiency suggested that wheat farmers could produce the same quantity of wheat using the same amount of inputs but with 69.35 per cent less water.

In their study, Kamruzzaman *et al.* (2006) examined the economic efficiency of wheat farms in Bangladesh's Khulna Division. The estimate was made using DEA. The result of the study revealed the sample farms' overall mean economic efficiency score as 0.86, which indicated that economic efficiency was 14 per cent below potential.

Wadud (2003) analyzed the estimates of technical, allocative, and economic efficiency of rice farms in Bangladesh. They compared the efficiencies using DEA and the stochastic efficiency decomposition technique. The mean values of technical, allocative, and economic efficiency for the CRS DEA (constant returns to scale DEA) frontier and the VRS DEA (variable returns to scale DEA) frontier, respectively, were86, 91, and 78 per cent. The DEA results showed that operating costs could be reduced with a better output through increased efficiency. Even though the study employed bothDEA and stochastic, averages based on DEA were more significant than those discovered on the stochastic frontier.

2.3 PRICING OF IRRIGATION WATER

Studies regarding the pricing of irrigation water are mentioned in the section.

A study was carried out in Iran's Ardabil Plain to determine the economic worth of irrigation water for important crops. The study employed a variety of production functions for crops like wheat, potatoes, alfalfa, barley, and canola, including Cobb- Douglas, Transcendental, Generalized quadratic, and Translog. While determining the marginal value of irrigation water, the Cobb-Douglas production function was shown to be the best functional form for all crops except canola. After examining the results for the crops wheat, potato, alfalfa, barley, and canola, it found that irrigation water had an economic value of 0.03, 0.09, 0.02, 0.03, and 0.05 US dollars per cubic metre, respectively (Nouri-Khajebelagh *et al.,* 2021).

Mahmoodi and Karimi (2018) assessed the average value of the marginal product of water in Tabas County in Mexico. The average production elasticity was found to be 0.56 by employing the Cobb-Douglas production function. According to estimates, the economic worth of water was 2930 Rials per cubic metre.

Frija *et al.* (2014) focused on defining the marginal water productivity of irrigated durum wheat in Semi-Arid Tunisia using the Cobb- Douglas production function. The marginal value of water was around 0.11 Tunisian Dinar per cubic metre, corresponding to 2700 cubic metre per hectare of water. It was learned that most farmers needed to be adequately utilizing irrigation water.

Yigezu *et al.* (2014) provided empirical evidence that a policy that penalises excessive irrigation water application would drive farmers to use water-saving technologies. In order to do so, a case study from Syria was done utilizing a simple optimization model. The log-linear function (a variation of the Cobb-Douglas function) was taken to represent the production function of typical Syrian wheat fields, where yield was regressed against the quantity and quality of other inputs and the amount and application of irrigation and rainwater. Water's marginal value product was calculated to be 6.67 Syrian pounds per cubic metre.

Frija *et al.* (2013) assessed the marginal value of irrigation water and water productivity used on durum wheat in Central Tunisia. They constructed a production function in which, in addition to other production elements, the irrigation revenue of farmers per hectare was stated in terms of the utilized water volume. The average economic productivity of water was found to be 0.97 Tunisian dinar per cubic metre. The average volume of water applied to durum wheat was used to compute the irrigation water's marginal value, which was 0.12 Tunisian dinar per hectare. The findings suggested that 31.7 per cent of farmers applied water quantities above 2900 mm per hectare (the ideal economic volume of that region).

Jaghdani *et al.* (2009) provided comparative research findings that looked at the value of irrigation water in the Qazvin irrigation network in northern Iran using three distinct approaches. The contingent valuation approach, the value of water's marginal product (Cobb- Douglas production function), and the change in net rent method were used to determine the value of irrigation water. Every valuation method produced values that were greater than the official pricing. The study also showed that contingent valuation method in addition to the value of marginal product, might be a tool for modifying pricing practices to make resources more effective and efficient.

Hussain *et al.* (2009) determined the value of irrigation water alongside the Mithaluck irrigation canal in Pakistan. Data were fitted to a linear programming model after being evaluated using the residual imputation approach and the change in net income method to estimate the economic value of irrigation water. According to the findings, on a small farm, the economic value of water at discounted water availability ranges from Rs. 1.63 to Rs. 3.23 per cubic metre. Large farms' price per cubic metre ranged from Rs. 1.93 to Rs. 3.76. The price per cubic metre ranged between Rs 1.03 and Rs 2.01 for head farms and Rs 1.39 to Rs 2.74 for tail-end farms. Both methodologies produced almost identical results for the economic worth of water.

In a study, three methods, marginal water valuation, willingness to pay, and financial analysis of the project were used to try to determine the prices of irrigation water. The study was conducted for the Kerala state's Peechi irrigation project. The marginal cost of water was determined to be ₹ 62.9 per hectare, which was closer to the current water price in the canal command. The irrigation project had a per-hectare operational and maintenance cost of ₹ 529. While the command area's water fees made up just 11.73 percent of the overall costs, farmers were willing to pay more than 100 per cent of the current irrigation fees in exchange for timely delivery of sufficient water. Farmers' willingness to pay for irrigation water grew from head to tail of the command region, demonstrating the scarcity value of water (Suresh and Reddy, 2006).

Bandara and Weerahewa (2003) used the residual and production function approaches to calculate the economic value of irrigation water used in paddy agriculture in Sri Lanka. A dummy variable was used in the production function to differentiate between rainfed and irrigated areas, representing irrigation water availability. Water's estimated worth was Rs. 5,728 per acre per season, indicating that irrigation is crucial in determining the viability of paddy farming in Sri Lanka.

Sahibzada (2002) used the Cobb- Douglas production function to price irrigation water in Pakistan. The study aimed to evaluate several alternative water pricing systems, such as MVP-based, Market price-based, and average cost-based, to choose one that will ensure efficient irrigation water use. The result of the study showed that the MVP of irrigation water per acre inch was Pak Rs. 445. However, contrary to expectations, the results of the empirical analysis disproved the widespread belief that the current lower water rates caused wasteful irrigation water use. The study results showed there were water shortages rather than inefficient water use. The study suggested that farmers must be guaranteed access to sufficient and dependable water supplies at their farm gate before any recommendation to charge them a higher water price.

Hussain and Young (1985) evaluated the marginal value product and the opportunity cost of different crops in Mandi-Bahud-Din Project Areas during 1979-80. This study aimed to measure the allocative efficiency of water and other resource use on Pakistan's farms and evaluate the marginal value product of irrigation water. The productivity value of irrigation water and related resources were evaluated using the Cobb-Douglas production function analysis of farm survey data. Irrigation water was found to have a marginal value product of Rs. 15.6 per acre.

Madariaga and McConnell (1984) estimated the marginal value of irrigation water in the East, focusing on New Jersey, Delaware, Maryland, Virginia, and North Carolina. The value of irrigation water was determined using Cobb - Douglas production function. The marginal value of irrigation water was $ 1967 per acre-foot. It was found that the study area's marginal water values appeared to be higher than those of most Western US regions.

Johnson (1967) analyzed the approaches of Cobb-Douglas production function analysis and linear programming to determine their efficacy in forecasting these marginal values. Both approaches' theoretical features indicated that they are conceptually capable of producing appropriate marginal value estimations for irrigation water. The study concluded that linear programming and Cobb-Douglas production function analysis are effective ways to calculate the marginal values of irrigation water.

After reading through various academic works, it became clear that Kerala, in particular, had only hardly fewer studies on this. Hence study has been conducted to understand better the various aspects of irrigation water efficiency and its pricing, as well as to assist policymakers in developing options to protect the interests of all stakeholders.

Methodology

3. METHODOLOGY

Research methodology is a deliberate strategy used to address the issues raised by the study. The study's goals should be systematically evaluated using an organized and well-structured research methodology.

The methodology to analyze the economic efficiency of irrigation water and its pricing in banana is presented here. The research was conducted on first-hand information from farmers and previous relevant studies. The methodology that was found to be most appropriate for achieving each study goal has been chosen. The study is based on information gathered from a sample of farmers in the Chalakkudy and Kodakara blocks of Thrissur district. The banana variety, Nendran was used for the study. A brief of the chapter is mentioned below:

3.1 Description of the study area
3.2 Sampling design
3.3 Data collection
3.4 Period of the study
3.5 Efficiency types
3.6 Analytical framework

3.1 DESCRIPTION OF THE STUDY AREA

3.1.1 Thrissur district

The study was conducted in Thrissur district. The district is one of Kerala's significant commercial hubs, home to several industries, including textiles, wood, tiles, coir, fish, agricultural, and allied products. Besides the sectors mentioned above, tourism contributes significantly to the district's economy.

3.1.1.1 Location

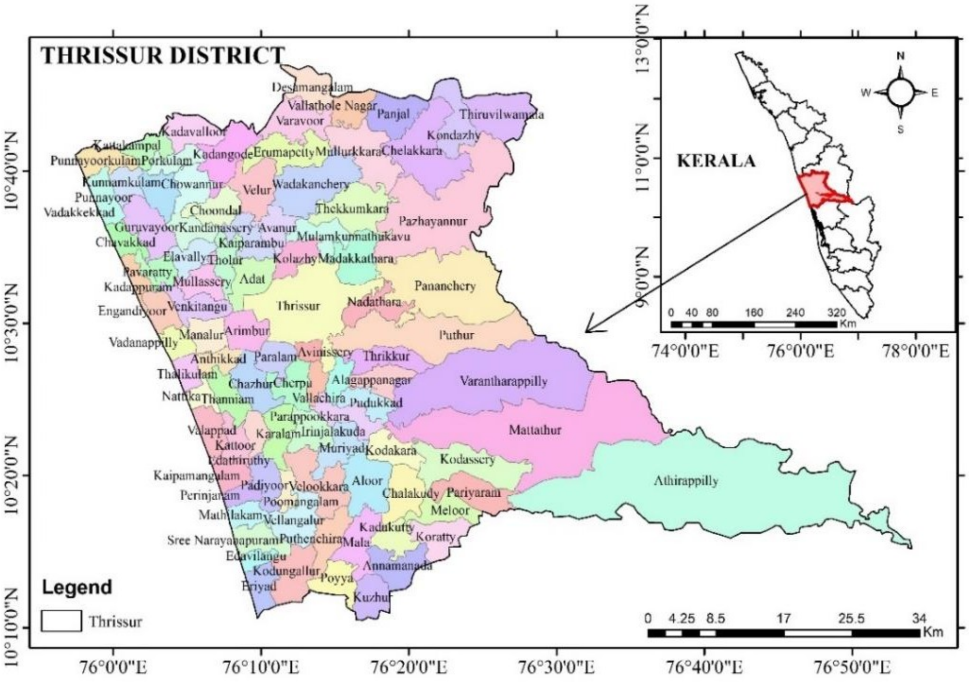
Thrissur district covers an area of around 3032 km^2. The districts of Ernakulam and Idukki are on the southern boundary, while Palakkad and Malappuram are on the district's northern border. To the west is the Arabian Sea, and to the east are the Western Ghats. Thrissur, the state's central region, is between latitudes 100 10' and 100 46' north and longitudes 750 57' and 760 54' east. Thrissur district descends south, from the Western Ghats in the east to the Lakshadweep Sea in the west.

3.1.1.2 Demographic features

3.1.1.2.1 Population

The Thrissur district had 31,21,200 residents per the 2011 census, representing 9.31 per cent of the state's overall population with a population density of 1031 people per square kilometer (Table3.1). The district's population follows the State pattern with 52.55 and 47.44 percent, respectively, of the female and male population. The population grew by 4.58 per cent annually between 2001 and 2011. By a margin of 67.17 percent, the 2011 census showed that urban residents outnumbered rural ones.

Fig.1.Thrissur district



Source: Map generated using ArcGIS

Table 3.1 Population statistics of Thrissur district

SI. No.	**Particulars**	**Numbers**	**Percentage to the total population**
1	Male population	14,80,763	47.45
2	Female population	16,40,437	52.55
3	Population density (per square km)	1031	-
4	Sex ratio (females per 1000 males)	1108	-
5	Rural population	10,24,794	32.83
6	Urban population	20,96,406	67.17
Total population		**31,21,200**	**100**

Source: Panchayat Level Statistics (2011), Thrissur; Department of Economics and Statistics, GoK

3.1.1.2.2 Literacy status

The district of Thrissur had a total literacy rate of 95.32 per cent in 2011, higher than Kerala's average literacy rate of 93.94 per cent. Females comprised 52.1 per cent of the total 26,78,548 literates. In the Thrissur district, the female literacy rate was 93.85 percent, while the male literacy rate was 96.98 per cent. The district's literacy rate status is given in Table 3.2.

3.1.1.3 Land utilization pattern

Table 3.3 provides the land use pattern for the Thrissur district (2019–20). Around 1,66,482 hectares of the district's total geographic area was under cropped area, while 1,03,619 hectares of it was covered by forests or 34.2 per cent of the district's total land area. The table shows that the net sown area and land used for non-agricultural purposes totaled 1,30,885 hectares (43.20%) and 41,153 hectares (13.58%), respectively.

Table 3.2 Literacy and its rates in Thrissur district

SI.No	Particulars	Total
1	**Literates**	**Numbers**
	Total	26,78,548
	Male	12,82,261
	Female	13,96,287
2	**Literacyrates**	**Percentage (%)**
	Total	95.32
	Male	96.98
	Female	93.85

Source: Panchayat Level Statistics (2011), Thrissur; Department of Economics and Statistics, GoK

Table 3.3 Thrissur district - Land utilization pattern (2019-20)

Land use	Area (ha)	Percentage to total (%)
Total geographical area	3,02,919	100
Forest	1,03,619	34.20
Land laid to non-agricultural uses	41153	13.58
Barren and uncultivable land	50	0.02
Permanent pastures and other grazing lands	0	0
Land under miscellaneous crops	171	0.06
Cultivable waste	9146	3.01
Fallow other than current fallow	4774	1.57
Current fallow	7622	2.51
Marshy land	0	0
Still water	5034	1.66
Water logged area	318	0.10
Social forestry	147	0.04
Net sown area	1,30,885	43.25
Area sown more than once	35597	11.75
Total cropped area	1,66,482	54.95

Source: Agricultural statistics, 2019-20, Directorate of Economics and Statistics, GoK

3.1.1.4 Occupation distribution

10,95,727 individuals in the Thrissur district were employed out of the total population. While 15.2 per cent of employees engaged in marginal work that lasted less than six months but nevertheless provided a means of sustenance, 84.8 per cent of workers described their work as their primary occupation (employment or earning for more than six months). The 10,95,727 employees working in main occupation consisted of 34,791 cultivators (owner or co-owner), while 54,538 were agricultural labourers.

3.1.1.5 Agro-climatic conditions

3.1.1.5.1 Topography and climate

The District can be categorized into three distinct zones. The highlands, plains, and coastline; are naturally formed by the terrains loping from the Western Ghats in the east.The food and cash crops are cultivated in the fertile plains and forests on the highlands. The Kole lands in the west have the lowest elevation below the mean sea level, and Karimalagopuram, on the border between Palakkad District and Chalakkudy Taluk, has a maximum elevation of 1430 metres.

The region experiences humid tropical weather, scorching summers, and reasonably good seasonal rainfall. South West Monsoon, which lasts from June to September, follows the North East Monsoon from October to December. The hot weather prevails between January to May. The post-monsoon or retreating monsoon season lasts from October to November. There are approximately 124 rainy days annually, with an average annual rainfall of 3500 mm.

In March and April, the highest daily average temperature is roughly 31^0C (83 ^{0}F) in coastal areas and 36 ^{0}C (97 ^{0}F) in the interior. The air is humid throughout the year, with a typical relative humidity of around 70 per cent. In general, winds are mild to moderate; however, localized gustnado has occurred several times in recent years.

3.1.1.6 Details of land holding

Table 3.4 shows the distribution of land holdings in the Thrissur district by number, area, and average holding size. The majority of holdings in the district were marginal in size because most farmers (98.14%) possessed average land holdings of 0.14 hectares or less. Since marginal farmers were more in number, their holdings occupied about 78 per cent of the area, followed by small farmers, with a total area of 73,219 hectares.

Table 3.4 Distribution of land holdings in Thrissur district

SI. No.	Size of holding	Numbers	Area (ha)	Average size (ha)
1	Marginal(<1ha)	7,06,361 (98.14)	73,219 (74.39)	0.1
2	Small(1-2ha)	10236 (1.42)	13635 (13.85)	1.33
3	Semi-medium(2-4ha)	2569 (0.36)	65934 (6.70)	2.57
4	Medium(4-10ha)	471 (0.07)	2457 (2.50)	5.22
5	Large(>10ha)	95 (0.01)	2520 (2.56)	26.53
Total		**7,19,732 (100)**	**98,424 (100)**	**0.14**

Source: 10th Agricultural census, 2015-16, Department of Economics and Statistics, GoK
Note: Figures in parenthesis indicate percentage to total

3.1.1.7 Water resources

3.1.1.7.1 Sources of irrigation

The district has various water resources like tanks, wells, rivers and canals. The three major waterways are Canoli Canal, Shanmugan Canal, and Puthenkode Canal. Chalakkudy, Karuvannur, and Kecheri rivers are the major rivers that pass through the districts. Periyar and Bharathapuzha flow westward at the southern and northern boundaries, respectively. The districts' principal irrigation projects are the

Chalakkudy irrigation projects, Peechi Dam, Mangalam Dam, Chalakkudy Diversion Scheme, and Vazhani Scheme. Table 3.5 lists the district's irrigated area by source.

Table 3.5 Net irrigated area (Source-wise 2019-20) in Thrissur district

SI.No	Sources of irrigation	Area (ha)	Percentage to total (%)
1	Small streams (*Thodu*/canal)	18149	29.16
2	Ponds	3123	5.01
	a. Government	51	
	b. Private	3072	
3	Open Wells	30926	49.69
	a. Government	0	
	b. Private	30926	
4	Tube wells	1165	1.87
5	Lift irrigation	798	1.28
6	Rivers and lakes	5540	8.90
7	Others	2526	4.09
Total		**62,227**	**100**

Source: Farm Guide, 2022

3.11.7.2 Groundwater resources

Groundwater in the district is found both below the water table and in restricted or semi-confined conditions. Deep fractures in crystalline rocks and the Vaikom beds (sedimentary formations) both have restricted or semi-confined situations. The depths of the open wells sunk to access the phreatic aquifers range from 3.5 to 22 mbgl (*Metres Below Ground Level*). These wells have yield that range from 1200 to 20000 lph (litres per hour). The Vaikom beds can be found between 6 and 51 mbgl below the surface,and the beds' thicknesses range from 8 to 30 metres. The laterite formations in the districts' midland areas serve as excellent water table aquifers in valleys and low-lying areas. The depth of wells tapped into the laterite formation ranges from 9 to 19 mbgl, with yields ranging between

800 and 20000 lph. The yield of wells that draw on the coastal alluvium varies from 15000 to 40000 lph.

The district's Annual Extractable Ground Water Recharge is 590 MCM (Million Cubic Metres), and the current Gross Ground Water Extraction is 341 MCM. About 58 per cent of the ground water is being extracted. Three of the district's 16 blocks are classified as "Semi-critical" (Chowannur, Mathilakam and Thalikulam). Phreatic zone or saturated zone ground water resources in storage (unconfined aquifer) are 686 MCM, and semi-confined zone groundwater resources are 627 MCM. The district's total ground water resources are1903 MCM, according to ground water resources of Kerala 2017.

3.1.2 Description of selected blocks

Chalakkudy block has six panchayats and one municipality, whereas Kodakara block has seven panchayaths. Table 3.6 lists the names of the panchayats in the blocks mentioned below. Tables 3.7 and 3.8 briefly overview the Chalakkudy and Kodakarablocks.

Table 3.6 List of panchayats in Chalakkudy and Kodakara block

LIST OF PANCHAYATS	
Chalakkudy	**Kodakara**
Kodassery	Kodakara
Pariyaram*	Puthukkad*
Meloor*	Nenmanikkara
Athirapilly	Thrikkur
Kadukutty	Alagappanagar
Koratty	Varantharapilly
	Mattathur*

Source: Panchayat Level Statistics (2011), Thrissur; Department of Economics and Statistics, GoK,

*indicates panchayats selected for the study

Table 3.7 Details of Chalakkudy block

CHALAKKUDY BLOCK		
Particulars	**Pariyaram panchayat**	**Meloor panchayat**
No.ofwards	15	17
Area (sqkm)	16.8	23.06
Population	23070	27659

Source: Department of Panchayats, GoK

Table 3.8 Details of Kodakara block

KODAKARABLOCK		
Particulars	**Matatthur panchayat**	**Puthukkad panchayat**
No.ofwards	23	15
Area(sqkm)	103.11	15.41
Population	47875	36722

Source: Department of Panchayats, GoK

Table 3.9 Block/Municipality wise number of operational holdings

Size class	**Kodakara**		**Chalakkudy**	
	Number	**Area (in ha)**	**Number**	**Area (in ha)**
Marginal(<1ha)	54577 (97.77)	6119 (71.14)	11241 (97.96)	1101 (57.99)
Small(1-2ha)	949 (1.69)	1289 (14.98)	164 (1.42)	217 (11.46)
Semi-medium(2-4ha)	256 (0.45)	646 (7.51)	35 (0.31)	101 (5.32)
Medium(4-10ha)	30 (0.06)	156 (1.82)	25 (0.22)	139 (7.34)
Large(>10ha)	15 (0.03)	391 (4.55)	10 (0.09)	340 (17.89)
Total	**55827 (100)**	**8601 (100)**	**11475 (100)**	**1898 (100)**

Source: Agricultural census 2015-16, Department of Economics and Statistics, GoK

Table 3.9 depicts operational land holdings by block/municipality, sorted by size. According to the data, the number of operational land holdings of marginal farmers in the Kodakara block is more than in Chalakkudy. Both blocks had less number of large operational holdings. 97.77 per cent of operational holdings in Kodakara are marginal, whereas, in Chalakkudy, marginal operational holdings accounted for 57.99 per cent. Only 0.3 and 0.1 per cent of the operational land holdings were large in size. The area of holdings under the marginal category seemed to be large in both Kodakara (71.14%) and Chalakudy (57.99%) since the majority of the holdings were marginal in size.

Table 3.10 shows the allocation of the study area in panchayath wise depending on land types. Pariyaram panchayath has 74.77 per cent dryland followed by wetland inthe total area. It was found that 63.61 per cent of Meloor panchayath was dryland. Mattathur panchayath had approximately 56.01 per cent of the entire area covered by dryland; similar distribution has been observed in Puthukkad also.

Table 3.10 Distribution of area in the selected panchayats

Blocks	**Panchayats**	**Area(inha)**			
		Wetland	**Dryland**	**Others**	**Total**
Chalakkudy	**Pariyaram**	363 (25.22)	1077 (74.78)	-	1441 (100)
	Meloor	521 (22.59)	1466 (63.63)	318 (13.78)	2305 (100)
Kodakara	**Mattathur**	997 (27.87)	2003 (56.02)	576 (16.11)	3576 (100)
	Puthukkad	521 (33.81)	880 (57.08)	140 (9.11)	1542 (100)

Source: Panchayat Level Statistics, 2011, GoK
Note: Figures in parenthesis indicate percentage to total

3.2 SAMPLING DESIGN

3.2.1 Selection of the district

The district, Thrissur, was selected purposively as the study area based on the data of the private well-irrigated area of the State. In 2019–20, private wells irrigated 1,17,763 hectares of the State's total net irrigated land (4,04,102 ha), with Thrissur contributing the most (26.26 %) with 30,926 hectares.

3.2.2 Selection of blocks

Among the sixteen blocks in the Thrissur district, Kodakara and Chalakkudy were purposively selected since these two blocks account highest rate of ground water extraction and the maximum share of cropped area under banana in the district.

The area occupied by banana in Kodakara and Chalakkudy were 588 hectares and 468 hectares, respectively, accounting for 48.11 per cent of the total area under banana cultivation in the district.

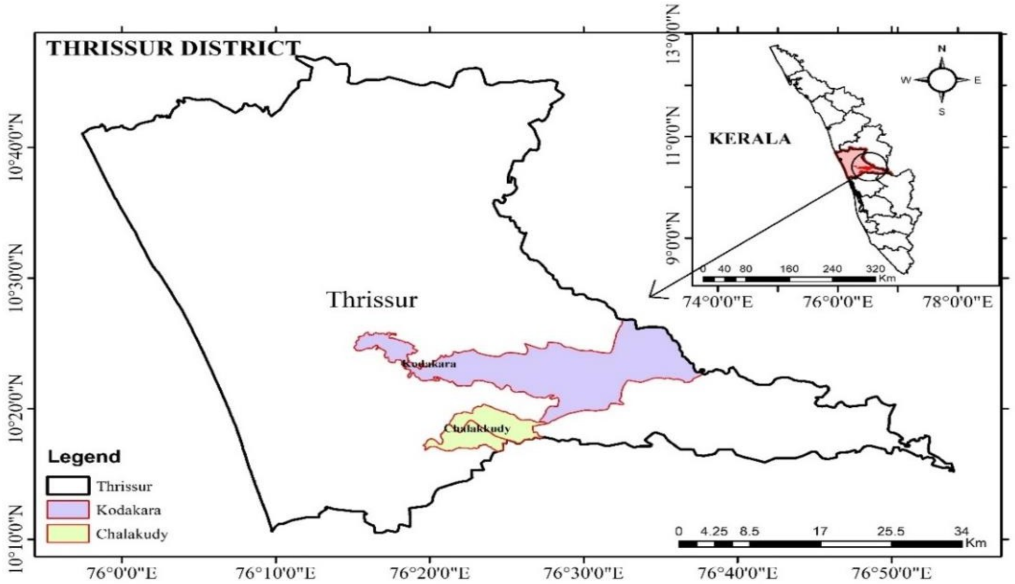
3.2.3 Selection of Panchayats

Two panchayats were purposively selected from each block, thus making a total of four panchayats. Meloor and Pariyaram from the Chalakkudy block and Mattathur and Puthukkad from the Kodakara block were chosen since they have the highest banana production in the respective blocks.

3.2.4 Selection of crops

Nendran variety was selected particularly among the bananas since it is known for its substantial use of water (900-1200 mm) and required irrigation at 3-4 days intervals (irrigated crop) for good yield. Hence the crop was chosen for the study. Commercial banana growers mainly relied on lift and groundwater irrigation despite adopting various irrigation methods.

Fig.2. Chalakkudy and Kodakara blocks



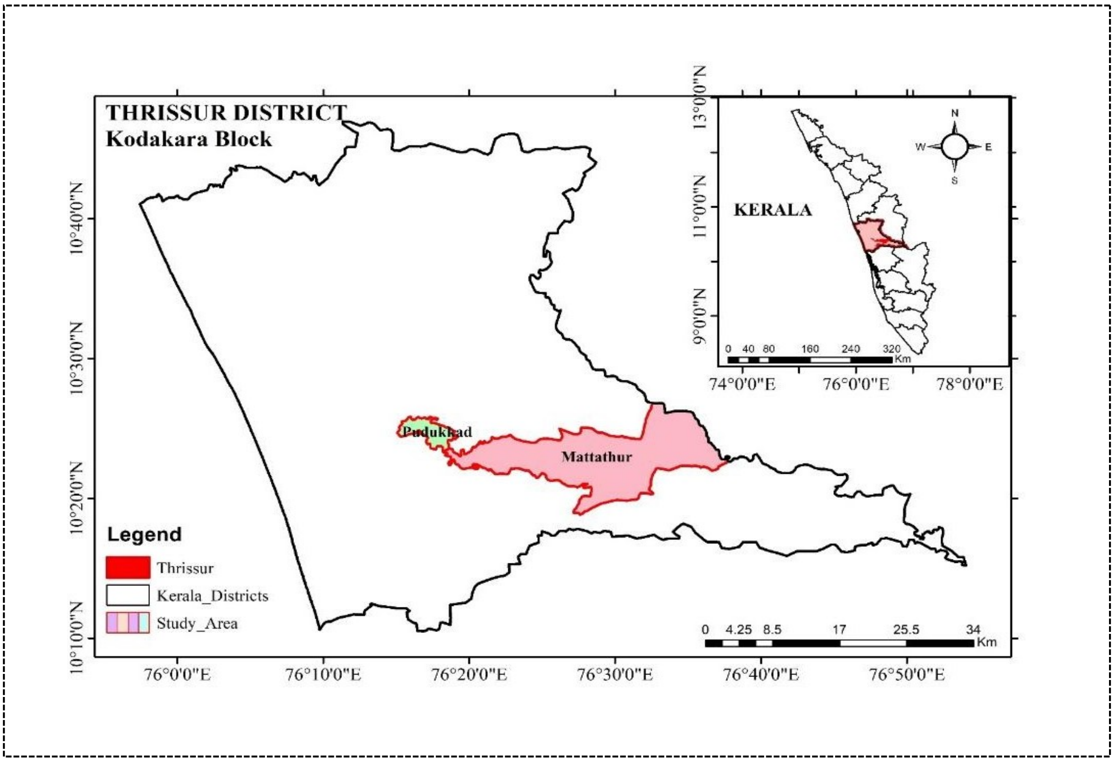
Source: Map generated using ArcGIS

3.2.5 Selection of respondents

The farmers cultivating at least 100 Nendran bananas a year were selected as sample respondents. Lists of commercial producers of the Nendran variety using surface irrigation using pumps as a method of irrigation were gathered from the respective Krishi Bhavans of the panchayaths and the office of the Vegetable and Fruit Promotion Council Keralam (VFPCK).

Thirty farmers were chosen from each panchayath, making a sample size of 120 (30 *2 *2). Farmers were later categorized based on land ownership as owner farmer and leased in farmer. The personal interview method was used to collect the data using a pre-structured interview schedule. The classification of the study area is shown in Figure 3.1.

Fig.3. Study area in Kodakara block



Source: Map generated using ArcGIS

Fig.4. Classification of the study area

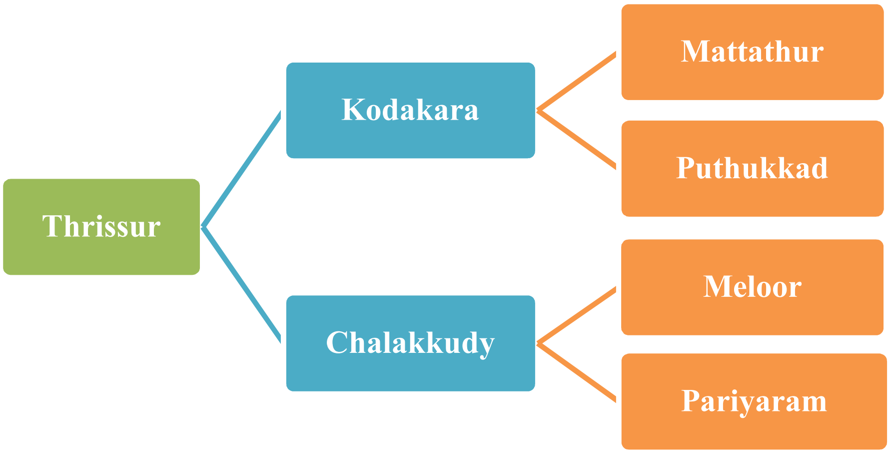
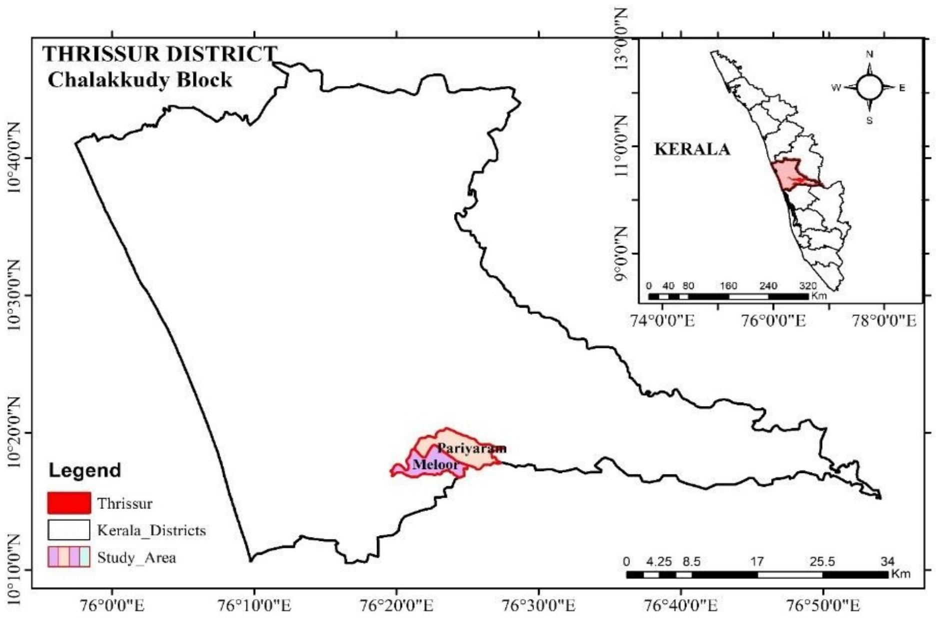


Fig.5. Study area in Chalakkudy block



Source: Map generated using ArcGIS

3.3 DATA COLLECTION

The research used both primary and secondary data. Farmers' primary data were acquired through personal interviews employing a well-structured and pre-tested schedule. The supporting secondary data were collected from published and unpublished sources. The main items of observations made in the study were

1. Socio-economic profile of the farmers
2. Source of irrigation
3. Type of irrigation
4. Private investment for irrigation
5. Quantity of irrigation water
6. Method of application of irrigation water
7. Frequency of irrigation
8. Cost of cultivation
9. The yield of the crops
10. Cost of cultivation

3.4 PERIOD OF STUDY

The study's reference period was the years 2021–2022, and the data were gathered from farmers who planted Nendran during the months of August-September in 2021.

3.5 EFFICIENCY TYPES

3.5.1 Types of efficiency

Technical efficiency, scale efficiency, allocative efficiency, and productive (also known as cost or economic) efficiency are different efficiency measures. The physical or functional relationship between resources and output is referred to as the technical efficiency of production. A technically efficient condition is achieved when the maximum potential improvement in outcome is performed using a given set of resources. A production process is considered technically inefficient if the same (or better) result could be obtained with less of at least one of the inputs supplied.

The ability of an enterprise to use inputs in the best combinations possible, given their relative pricing and the available production technology, is known as allocation efficiency. It considers the productive efficiency with which resources are employed to produce results and the efficiency with which these results are disseminated across the community. Allocative efficiency is attained when resources are allocated in such away that the welfare of society is maximized. The potential productivity benefit from growing a farm to its ideal size is measured by scale efficiency. This measure assesses the change in a firm's productivity when the firm size changes as a performance indicator. On the other hand, cost efficiency, which results from technical and allocative efficiencies, assesses a farm’s overall economic performance. The maximization of outcome for a given cost or the minimization of cost for an outcome is referred to as productive efficiency, often known as cost or economic efficiency. Economic efficiency makes it possible to compare the relative value for money of input combinations that produce directly comparable results. However, because the outputs from the various sectors are unrelated, it cannot address the effects of redistributing resources on a larger scale, such as water from agricultural to urban or industrial sectors (Palmer and Torgerson, 1999).

3.5.1.1 Efficiency of irrigation water use from an economic perspective

Efficiency is the term often used by economists, agronomists, and irrigation engineers to describe the use of water as an input in agricultural production. Agronomists measure the mass of output produced per unit of delivered water, engineers compare the volumes of water delivered and consumed, and economists attempt to explain the value of output and the opportunity costs of resources used in production. These groups, however, have different definitions of efficiency (Hillel and Rawitz, 1972; Hillel, 1990; Long, 1991).

The use of irrigation water at the regional and farm levels can be expressed from all these three perspectives. However, engineers, agronomists, and economists have different views on efficiency. Their assessments of resource conditions and recommendations for policies to improve resource use frequently differ (Wichelns, 1999). Engineering or agronomic principles underlie the current irrigation water efficiency measures. In general, three criteria are used to define irrigation water efficiency: the effectiveness of water conveyance, the efficiency of water application at the farm gate, and the reaction of a crop to the application of irrigation water (McGuckin*et al.,* 1992).

The economic significance of irrigation water and describing irrigation water efficiency on economic principles have recently gained significant attention due to the growing water shortage. The fact that economic efficiency is a criterion, as opposed to a ratio describing water use and water requirements or a measure of the output produced per unit of irrigation water, is perhaps the most significant distinction between economic efficiency and measures of irrigation or water use efficiency. Economic efficiency refers to the requirements that must be met to ensure that resources are used in a way that maximizes net benefit. An allocation is, therefore, either efficient or it is not. Economic analysis can be useful in identifying strategies for moving towards an efficient allocation of resources as well as in describing the private and public costs of a non-efficient allocation of resources (Wilchens, 1999).

Economic efficiency is theoretically attained when scarce resources are distributed and used in a way that maximizes benefits. The phrase "more can be achieved with less water" refers to better management, which typically entails increasing allocative efficiency. While irrigation water efficiency depends on the type of technology, the type of soil, environmental factors etc., allocative efficiency is closely related to appropriate irrigation water pricing. Increasing allocative efficiency is the key to raising farm income and reducing water wastage. However, the definition of irrigation water efficiency used in the engineering literature is closely related to an exclusive focus on allocative efficiency issues. Water use efficiency, also known as irrigation water efficiency, is the ratio of irrigation water applied to the amount of water actually used by the plant or stated above, a sprinkler irrigation system has the potential to use less water and increase irrigation water efficiency when compared to a flood irrigation system, but at a higher cost. A drip irrigation system, however, might be even more effective than a sprinkler irrigation system crop (Karagiannis *et al.,* 2003).

The definition of irrigation water efficiency given above assumes a certain level of management. It is not directly comparable to the definition of technical efficiency given by Farrell (1957), which involves measuring the managerial skills of irrigators. However, a sprinkler irrigation system, like any other production system or technology, may be technically inefficient due to poor management. According to observed levels of the desired output and conventional inputs, the economic measure of irrigation water efficiency is defined as the ratio of the minimum feasible to observed irrigation water use. In a broader sense, irrigation water efficiency refers to the technical effectiveness of irrigation water use in agricultural production (McGuckin *et al.,* 1992).

3.6 ANALYTICALFRAMEWORK

3.6.1 Costs and returns

The relationship between the expenses incurred and the returns received from crop production can be used to determine the profitability of a crop operation.

Cost concepts

For the examination of costs and returns in the production of bananas, the ABC cost principles specified by the Commission on Agriculture Cost and Prices (CACP) of the Government of India were employed. In order to incorporate the cost of irrigation into the cost of cultivation, variable and fixed cost of the groundwater was included. Variable costs of groundwater included pumping expenditure, operation and maintenance costs of the well, and fixed costs of groundwater included depreciation through amortized investment on drilling over the subsistence life of the well, amortized investment on irrigation pump sets, pump house, electrification charges, groundwater storage structure (constructed if any), conveyance structures, accessories investment for a period of 10 years. The cost and returns of banana cultivation were done separately for farmers cultivating in owned and leased land. For farmers cultivating banana on leased land, amortized cost of digging a well and amortized cost of a pump house was not considered in the fixed costs.

The following are the costs associated with the analyses in the current study:

i. Cost A1 comprises:

1. Hired human labour

Determining the value of human labour included accounting for labour used in various cultural practices, from land preparation to harvesting. The value of hired labour was determined by the actual wages paid for the labour in the study area.

2. Hired machine power

Machine power was valued by multiplying the cost per hour basis and the time machine operated.

3. Cost of planting materials

Evaluated the price at which suckers are purchased for cultivation.

4. Cost of manures and fertilizers

By multiplying the actual amounts of various manures and fertilizers used with their respective prices in the current year, expenditure on purchased quantities of these materials has been calculated.

5. Cost of plant protection chemicals

The cost of fungicides and insecticides has been determined by multiplying the physical quantities used by each product's associated current market price.

6. Cost of stakes/supports

Plastic rolls used for supporting the plant were valued by multiplying the number of bundles of rolls used by their current market price.

7. Land revenue/tax

This amount, which equaled Rs.796 per hectare, was considered to be the actual rate paid to the revenue department.

8. Pumping expenditure

Pumping expenditure for irrigation has been calculated by the following formula

Pumping expenditure = Working hours of irrigation pumpset x Horse power of the irrigation pumpset x 0.75 kWh x Rs. 2.3 per kWh.*

(Diwakara and Chandrakanth, 2007)

*₹ 2.3 per kWh is the power tariff fixed by the KSEB for agricultural purpose in 2022 in Kerala.

9. Depreciation

A 10 percent annual depreciation rate was used to calculate the farm equipment depreciation rate. The following formula was used to determine the depreciation of the farm implements.

Depreciation = $\frac{\textbf{Original cost of the asset} - \textbf{junk value}}{\textbf{Useful life of the asset}}$ (Reddy *et al*., 2009)

For calculating the depreciation of the well, pump house, pump sets, and conveyance structures amortized cost method has been used. The formula used are given below.

Amortized investment on well = (Compounded investment on well) * $\frac{(1+i)n1 * i}{(1+i)n1-1}$

i= interest per year, n_1= Average age of well

Compounded investment on well =Well cost∗ $(1+i)^{(AA);}$

AA = The difference between year of data collection and the year of well construction.
n > AA for functioning well

Amortized investment on pumpset

= (Compounded investment on pumpset) * $\frac{(1+i)n2 * i}{(1+i)n2-1}$

n_2 = Average life of pumpset, i = interest rate per year

Amortized investment on conveyance structure

= (Compounded investment on conveyance structure) * $\frac{(1+i)n3 * i}{(1+i)n3-1}$

n_3= average life of conveyance structure, i= interest rate per year

(Diwakara and Chandrakanth, 2007)

10. Interest on working capital

A 10 percent annual interest rate was applied to interest on working capital.

11. Miscellaneous expenses

This comprises items such as transportation charges, maintenance charges etc.

ii. Cost A_2= Cost A_1+ rent paid for leased in land

The actual rent paid by the farmers who leased in land for banana cultivation is the rent for the leased-in land. This averaged out to Rs. 30 per plant.

iii. Cost B_1 = Cost A_1 + Interest on the value of owned fixed capital assets (excluding land)

Iron and wooden tools, machinery, and other items are among the fixed capital items. This was subject to a10 per cent interest on depreciation.

iv. Cost B_2 = Cost B_1 + Rental value of owned land (less land revenue) and rent paid for leased in land.

Owned property's rental value was estimated based on the prevailing rental rate in the area. As previously stated, this cost Rs. 30 per plant.

v. Cost C_1 = Cost B_1 + Imputed value of family labour

The cost of the family labour was imputed based on the local wage rates paid to hired labour in the study area.

vi. Cost C_2 = Cost B_2 + Imputed value of family labour

vii. Cost C_3 = Cost C_2 + 10 per cent of Cost C_2 (Managerial cost of the farmer)

(Rathod and Gavali, 2021)

Benefit-Cost ratio

The benefit-cost ratio is a concept in profitability that describes the returns realized for each unit of outlay. Calculated B: C ratios greater than one show a viable enterprise. The benefit-cost ratio was done separately for farmers cultivating in owned and leased land. The following formula is used to calculate it.

$$\textbf{Benefit- cost ratio (BCR)} = \frac{\textbf{Gross returns}}{\textbf{Total cost}}$$

3.6.2 Yield determinants of banana cultivation

This study used a parametric function approach to find yield determinants of banana cultivation. In this method, the relative contribution of the independent variables to the dependent variable was calculated using the production function. To ascertain yield determinants, Cobb-Douglas production function were employed.

The algebraic form of Cobb-Douglas production function is written as

$Yi = a\pi X_i^{bi}$ (Gujarati *et al.,* 2004)

The functional form is written as;

$$Y = ax_1^{b1} x_2^{b2} x_3^{b3} x_4^{b4} + u$$

This is modified into a log-linear model by the application of logarithms to either side resulting in

$$\text{Log } Y = \log a + b_1 \log X_1 + b_2 \log X_2 + b_3 \log X_3 + b_4 \log X_4 + u$$

Where, Y = Yield of banana

X_1 = Quantity of water applied (m^3/ha)

X_2 = Quantity of human labour (No.of man days/ha)

X_3 = Quantity of manures and fertilizers (kg/ha)

X_4 = Quantity of plant protection (No of sprays/ha)

u = error term

bi's are the regression coefficients of explanatory variables.

The log-linear transformation enables the ordinary least squares (OLS) method to solve the Cobb-Douglas production function. The coefficients in the multiple linear regression model describe the change in Y caused by a unit change in one independent variable with all other variables constant, remaining constant. However, in the log-linear regression model, the coefficients represent elasticities, or the percentage change in Y due to a unit per cent change in one independent variable *ceteris paribus*.

In this work, the yield of banana is denoted by the Y, while the production factors (quantity of irrigation water, quantity of manures and fertilizers, quantity of human labour, and quantity of plant protection methods, respectively) are denoted by the letters X_1, X_2, X_3, and X_4. The error term is designated as u, and the intercept is a. The coefficients of partial regression are b_1, b_2, b_3, and b_4. These are also known as elasticities of production.

They show the percentages by which the value of output increases for every 1 per cent increase in the use of a particular production factor, with all other factors remaining constant. Whether the sum of the coefficients (b_1, b_2, b_3, and b_4) is one, more than one, or less than one, the function allows for constant, increasing, or decreasing returns to scale.

3.6.2.1 Quantification of irrigation water

This study was confined to banana-growing farmers who irrigate the crop using irrigation pump sets. The researcher physically measured the quantity of irrigation water used by assessing the discharge rate of the irrigation motor pump of 120 sample farmers in the study area. The field or practical measurement of the discharge rate was carried out by recording the number of seconds taken to fill a container of a known volume for each farmer and converting it to a litre per hour for all sample farmers.

$$\textbf{Flow rate} = \frac{\textbf{Volume of the container (L)}}{\textbf{Time required to fill (s)}} \qquad \text{(Thomas, 2010)}$$

The total quantity of irrigation water used in a season was calculated by multiplying the discharge rate of the pump (litre/hour), the number of hours to irrigate the cropped area for one irrigation, frequency of irrigation per month (Number) and duration of crop irrigated in months together for each sample farmers.

3.6.3 Determination of economic efficiency of irrigation water use

A production process involves using a combination of inputs to produce an output. Analyzing the efficiency of such a production requires a methodology that considers all of the specified inputs. Farrell (1957) proposed that the efficiency of a decision-making unit (a farm) can be decomposed into technical and allocative efficiency, and combining these two give economic efficiency. Consequently, economic efficiency is defined as an enterprise's ability to produce a specific amount of output at the lowest possible cost for a particular technological level (Farrell, 1957; Kopp and Diewert, 1982).

The two main goals of efficiency measurement are the minimization of input and the maximization of output. These goals are described as input and output-oriented measures, respectively. Managing production inputs to maximize output is part of the input approach, whereas managing output to maximize input use is part of the output orientation.This study used the input approach to the efficiency analysis because farmers can more easily control the management of the production factors than the output (Coeli *et al.*, 1998).

The production function must be derived from the sample data for efficiency measurement using parametric or non-parametric techniques (Farrell, 1957). Like a Cobb-Douglas form, a stochastic function is fitted to the data using the parametric method (Coeli *et al.,* 1998). However, the Cobb-Douglas model does not consider how measurement errors and other white noise might affect the production function (frontier). Using the stochastic frontier production function, which includes a random error term, overcomes this limitation (Aigner *et al.,* 1977).

The mathematical programming techniques proposed by Boles (1966) and Afriat (1972) were later used to create the data envelopment analysis technique (DEA). To create a multi-factor (multiple inputs and outputs) productivity analysis model, Charnes *et al.* (1978) expanded Farrell's (1957) concept of measuring technical efficiency (TE) relative to a production frontier and introduced the DEA. The Charnes *et al.* (1978) DEA model presumed constant returns to scale (CRS). When increasing input usage does not increase output proportionally, constant returns to scale are often not economically feasible. Later, the DEA model with variable returns to scale (VRS) was introduced by Banker *et al.* (1984). Technical and allocative efficiency (AE) are the two main scalar efficiency measures for the input-oriented approach (Farrell, 1957). These two measurements combined provide economic/cost (CE) efficiency (Kumbhaker and Lovell, 2000). So, to derive economic efficiency, it is necessary first to determine these constituent parameters.

$$\mathbf{CE}_{\mathbf{(CRS/VRS)}} = \mathrm{TE}_{(\mathrm{CRS/VRS})} \text{ x } \mathrm{AE}_{(\mathrm{CRS/VRS})}$$

(Coeli *et al.,* 1998)

Hence to define the best-practice frontier, the DEA method was used. It is a non-parametric and mathematical method that compares performance efficiency and benchmarking of decision-making units (DMUs). By determining the ratio of all outputs to all inputs for each farm, the technique uses mathematical programming to measure efficiency. This technique can calculate efficiency measures like technical, scale, allocative and cost efficiency. The benefit of the method is that no apriori functional form specification is necessary. The DEA has been widely used to calculate each DMU's efficiency score using cross-sectional data in various fields (Moesen and Persoon, 2002).

Efficiency in DEA can be given as weighted sum of yield produced over weighted sum of resources used as given below.

$$\boxed{\mathbf{h_0(u,v) = \Sigma_r u_r y_{r0} / \Sigma_r v_i x_{i0}}}$$

u_r= Weight assumed for yield, r = 1,2,3….,s

v_i = Weight assumed for resources, i=1,2,3,4….,m

The amount of input utilization and the amount of output to be produced are x_{yj} and y_{rj}, respectively, where x_{yj} and y_{rj} are non-negative values. The relative efficiency of DMU_j has been measured by the following mathematical equation.

$$\boxed{\mathbf{h_0} = \frac{\sum_{r=1}^{s} uryr0}{\sum_{i=1}^{m} vixi0}}$$

Where,

h_0 = Efficiency score

Y= Yield of crop

x_i = Quantity of water applied

A relative efficiency score equal to 1 indicates that DMUs are relatively efficient, while a relative efficiency value below 1 illustrates that DMUs are relatively ineffective.

This study evaluated irrigation water utilization in one sector for one specific crop (banana) (agriculture). Therefore, a technical efficiency measure using DEAP 2.0. software was employed. Due to the assumption that farmers work in an environment of imperfect competition and financial constraints, the variable returns to scale was chosen.

3.6.4 Pricing of irrigation water

Model specification

The pricing of irrigation water was determined by employing the Cobb-Douglas production function approach.

The algebraic form of function is written as

$$Y=a\pi X_i^{bi}$$ (Gujarati *et al.,*2004)

The functional form is written as;

$$Y = ax_1^{b1} x_2^{b2} x_3^{b3} x_4^{b4} + u$$

This is modified into a log-linear model by the application of logarithms to either side resulting in

$$\text{Log } Y = \log a+ b_1 \log X_1+ b_2 \log X_2+ b_3 \log X_3+ b_4 \log X_4+ u$$

Where, Y =Yield of banana

X_1 = Quantity of water applied (m^3/ha)

X_2 = Quantity of human labour (No. of man days/ha)

X_3 = Quantity of manures and fertilizers (kg/ha)

X_4 = Quantity of plant protection (No. of sprays/ha)

u = error term

bi's are the regression coefficients of explanatory variables.

The Cobb – Douglas function was estimated using the OLS method, assuming the error term (e) to be randomly and normally distributed. The analysis results were subjected to tests such as the coefficient of multiple determination (R^2) and F test carried out for testing significance.

$$\mathbf{F}_{(k,\, n-k)} = \frac{R^2}{1-R^2} \times \frac{n-k}{k}$$

Where k and (n-k) are degrees of freedom

Marginal Factor cost (MFC)

The marginal factor cost (MFC) can be defined as the change in total input cost that occurs due to using an additional unit of input without changing the level of other inputs.

Marginal Value Product (MVP)

The increase in gross returns from using an additional input while maintaining the level of other inputs is indicated by the marginal value product (MVP). The marginal products were calculated at geometric mean levels of variables by using the following formula

MPP = b_i (G.M of Y_i / G.M of X_i)

Where,

G.M of Y_i=Geometric mean of the output

G.M of X_i = Geometric mean of i^{th} independent variable

b_i = regression coefficient of the i^{th} independent variable

MVP can be calculated by using the formula

MVP = P_y * (MPP)

Where,

P_y = Price of one unit of banana (₹/kg)

Hence, in the case of the quantity of water applied, the marginal value of the water of each ha.m^3 is the marginal physical product times the output price. The efficiency can also be judged using the following criteria, or this is based on k values (MVP_i/MFC_i=ki). 'k_i' value refers to the ratio of marginal value product and marginal factor cost.

1. If k_i>1,indicates the underuse or sub optimal use of the resource
2. If k_i=1,indicates the optimal use of the resource which is known as allocative efficiency
3. If k_i <1,indicates excessive use of resource

Results and Discussion

4. RESULTS AND DISCUSSION

The findings of the collected data were presented in this chapter. The data were analyzed and turned into substantial, valid inferences utilizing analytical methods to accomplish the research's objectives. In the following sub-sections, the results are presented:

4.1. The sources of irrigation, private investments in irrigation, and irrigation pattern in the study area
4.2. Socio-economic profile of banana farmers
4.3. Yield determinants in banana cultivation
4.4. Costs and returns in banana cultivation
4.5. Economic efficiency of irrigation water
4.6. Pricing of irrigation water

4.1 THE SOURCES OF IRRIGATION, PRIVATE INVESTMENTS IN IRRIGATION, AND IRRIGATION PATTERN IN THE STUDY AREA

4.1.1 Hydrology and drainage of Thrissur district

The district's principal rivers are the Bharathapuzha, Kecheri Puzha, Karuvannur Puzha, and Chalakkudy Puzha. The Bharathapuzha (209 km) originates from the Anaimalai hills. The river has five tributaries: Gayathripuzha, Kannadipuzha, Kalpathipuzha, Cheerankuzhy and Thuthapuzha. The Machad hills are where the Kechery river originates, also known as the Wadakkanchery river. It flows westward till it reaches the Chettuvai backwaters. It is 51 km long, and the Vazhani dam is built on this river basin. In Arattupuzha, the Manali and Karumali rivers merge to form the Karuvannur river. This river is 65 kilometres long. Peechi Dam, built over the Manali river, and Chimmoni Dam, built across the Karumali river, aid in flood control and irrigation. The Chalakkudy river drains an area of around 1704 square kilometres and is the longest river in the region. Ten kilometres east of Kodungallur, it merges with the Periyar river. The two major projects across the river are the hydroelectric dams at Peringalkuthu and Sholayar.

The Karuvannur River, formed by merging the Manali and Kurumali rivers from the Peechi and Chimmony reservoirs, serves as the district of Thrissur's primary drainage system. 31.5 per cent of the district's total land area (95,453 hectares) comprises the catchment. In Arattupuzha, on the eastern edge of the Cherpu and Irinjalakuda blocks, the Manali and Kurumali rivers converge to form the Karuvannur River. After that, the Karuvannur River runs westward, cutting through the Irinjalakuda block before splitting in two at the block's western border. The northern part flows north along the western and eastern limits of the Thalikulam, Anthikad, and Mullassery blocks up to the Chettuva backwaters, emptying into the Arabian Sea. The Canoli Canal, the main irrigation and drainage canal of the Kole lands situated east of this route, was created by altering the river's course northward and artificially reestablishing the connection in several locations.

Between the western and right borders of Mathilakam and Vellangallur blocks, the southern arm of the Karuvannur river flows southward before entering Krishnankotta Kayal, which is dispersed over Kodungallur Municipality and Poyya in Mala block. This river basin includes the entire Kodakara block. Two Rivers, Chalakkudy and Periyar, drain the district's southernmost area. The catchment of the Chalakkudy River is a sizable drain that spans the states of Tamil Nadu and Kerala. The river flow within the rich forest catchments in the two states is diverted into six dams located within the forested land.

The Lower Sholayar and Poringalkuthu dams are located in the Thrissur district. The Chalakkudy River originates from the confluence of the Sholayar. The Chalakkudy River flows south to the Peringalkuthu reservoir. From Peringalkuthu, it flows southwest along the boundary of Chalakkudy block, cuts across the middle of Chalakkudy block, moves through Chalakkudy Municipality, and finally flows to the middle of Ernakulam district. After rejoining the district, it flows along Mala Block's southeast border until merging with the Periyar River and entering the Krishnankotta- Marthandom Kayal stretch. The eastern half of Mala Block, except its northern sector, Chalakkudy Municipality, and the whole Chalakkudy Block drains into the Chalakkudy River.

4.1.2 Major and minor irrigation schemes in Thrissur district

Four large irrigation projects are under the authority of the Irrigation Division in Thrissur, while 924 schemes and three class schemes are under the Minor Irrigation Division, and a portion of the Idamalayar irrigation project (IIP) is under the IIP Division in Chalakkudy. Dams, weirs, regulators, and canals are a few examples of majorirrigation systems in the district. Peechi, Chimmony, and Vazhani are the three major dams in the Thrissur district. The district has three minor dams: Poomala and Pathazhakundu in Thrissur taluk, and Asurankundu in Thalappilly taluk. In addition, there are diverting weirs in Cheerakuzhy and Thumburmuzhi.

Residents in the coastal and rural regions of the district use ponds and tanks for irrigation. The district has two irrigation projects: the Peechi Irrigation Project and the Vazhani Irrigation Project. An earthen dam was built across the Kecheri River at Vazhani as part of the Vazhani Irrigation Project, while a masonry dam spans the Manali River at Peechi.

4.1.3 Irrigation Sources and irrigation pattern in the study area

The different irrigation sources in the study area include ponds, tube wells, streams, and canals, whereas irrigation patterns included surface irrigation, drip irrigation, and sprinkler irrigation. Most farmers relied on surface irrigation methods as it was easier for them to manage as no complex technology was involved in it. Only a few farmers in the study area adopted micro-irrigation technologies such as drip and sprinkler irrigation. The reluctance of farmers to adopt such measures was mainly due to the high initial investment cost and maintenance problems such as clogging of the drip lines and breakages of pipes etc. The spatial data collected from the Land Use Board, Thrissur on sources of irrigation were mapped using ArcGIS and are presented in Fig. 6 to Fig. 9. Fig. 6 and Fig. 7 illustrates the ponds, canals and drains present in Kodakara block respectively, whereas Fig 8. and Fig. 9 represents the public ponds and drains in Chalakkudy block.

4.1.3.1 Irrigation schemes in the study area

Chalakkudy Diversion Scheme

The Chalakkudy River Diversion System (CRDS), established in 1958, is the biggest of the four significant diversion facilities under the irrigation department. It was intended to irrigate 14,942 hectares of region exclusively used for rice farming. The major canals of the canal system are 100 km long, while the branch canals and distributaries are with a length of 280 km. The scheme's goal was to make irrigation easier in 29 Local Self Governments in the districts of Thrissur and Ernakulam. A Left Bank Canal and a Right Bank Canal, which together span 14 towns, are reached by the diversion. Water is distributed to the command area via the RBC (Right Branch Canal), which branches out from Thumboormuzhi by 24 branch canals and their distributaries. Echippara is the first branch of it. Along the main canal, there are other branches, including Kaduppassery, Anallur, Kottenellur, Ashtamichira, Annamanada and Alathur, Kuttikad, Kundukuzhipadam, Thessery, Chalakkudy-Pariyaram combined branch, Vellikulam thodu, Mattathur, Mettipadam, Areswaram, Kalikkakunnu, Aloor, Potta, Blachira, Kodakara, Perambra, Muriyad, Kallettumkara, Thazhekkad, Ten panchayaths of the Thrissur district, including Athirappilly, Pariyaram, Kodassery, Mattathur, Kodakara, Chalakkudy, Aloor, Mala, Muriyad, and Vellookakara, are transited by the right bank canal. LBC (Left Branch Canal) consists of the Adichily, Meloor, Thanguchira, Kalady, Edakunny, KV main, Boothamkutty, Karukutty - Karayamparambu, Chirangara, Mambra, Kizhakummury, Marangadan, Peechanikkadu and Parakadavu branches.

Fig 6. Ponds and canals in Kodakara block

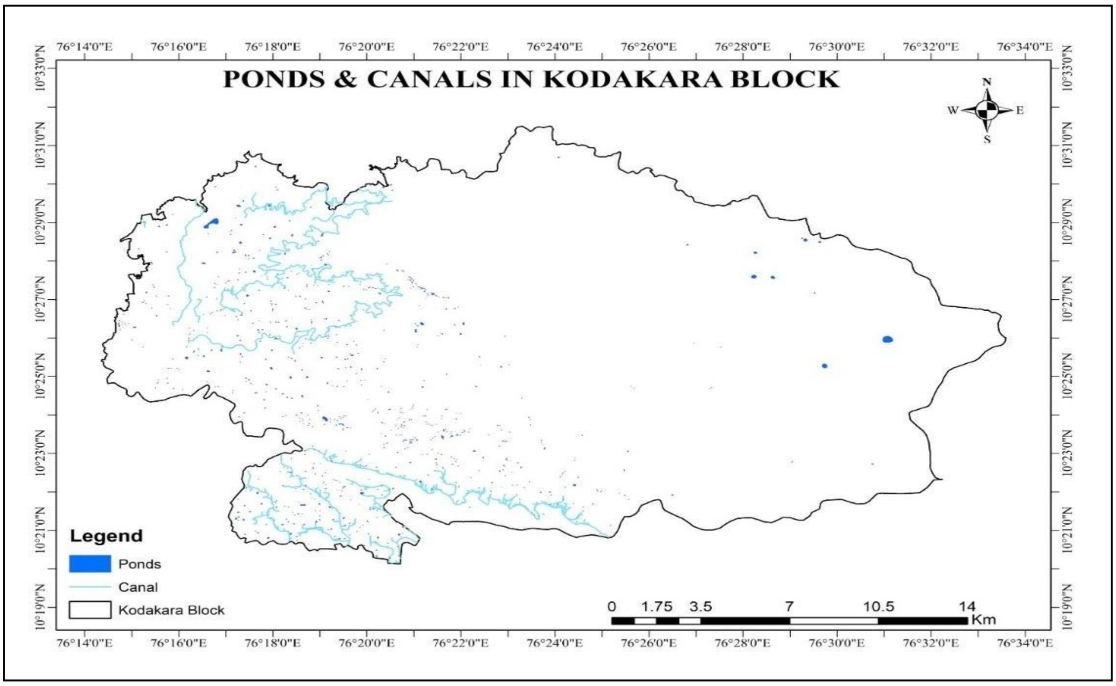
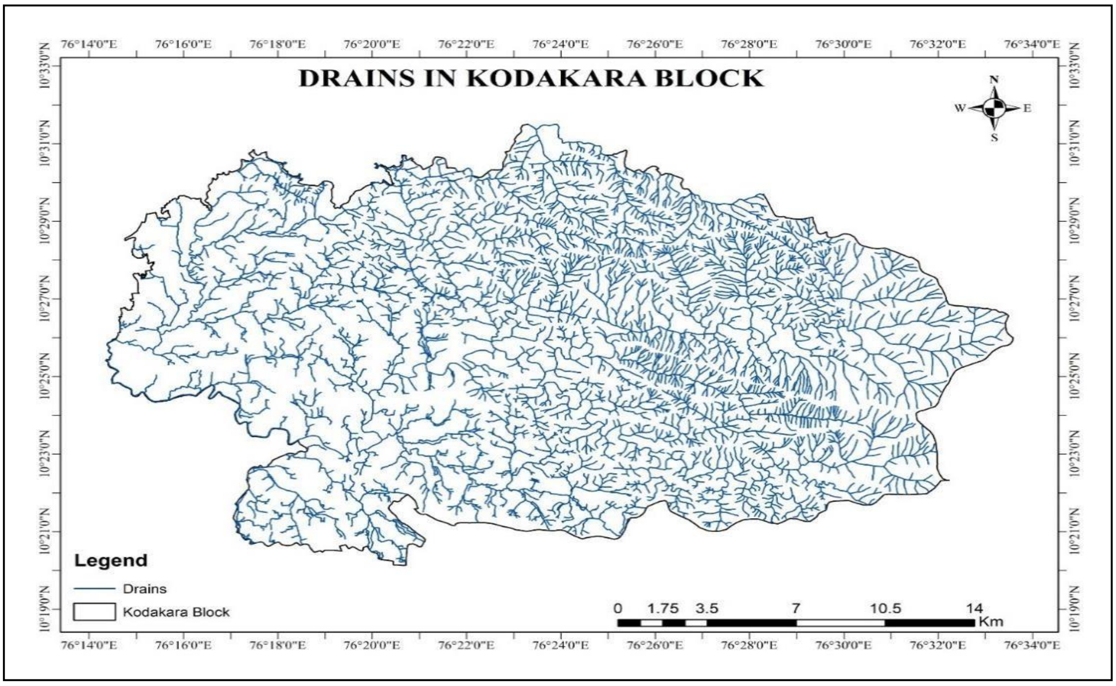


Fig 7. Drains in Kodakara block



Source: Map generated using ArcGIS

Fig 8. Public ponds in Chalakkudy block

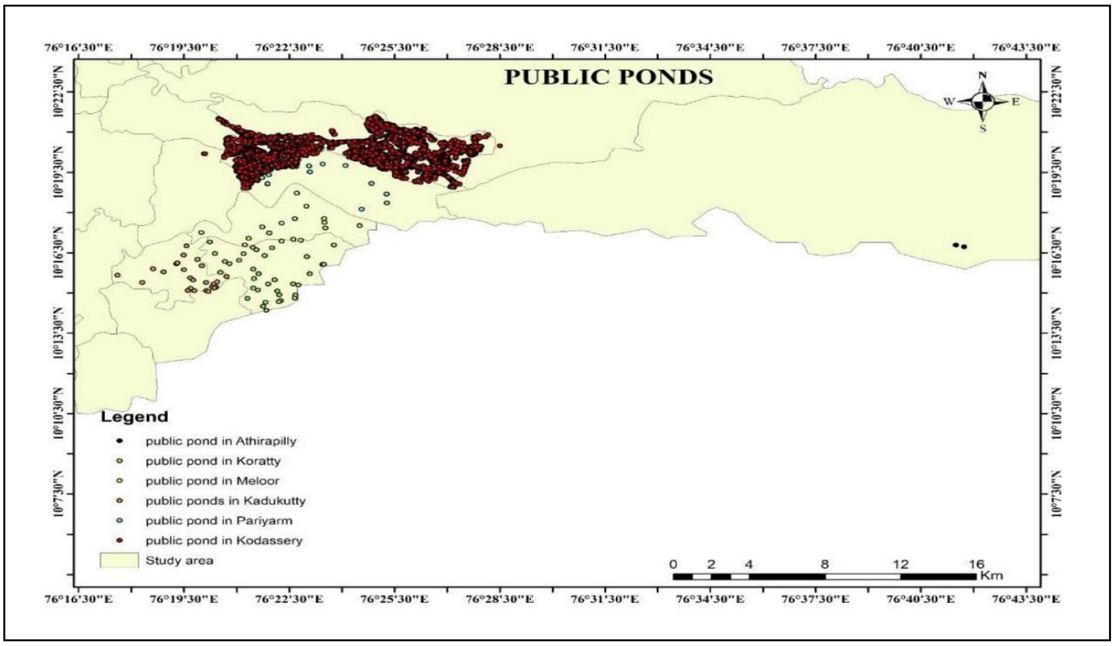
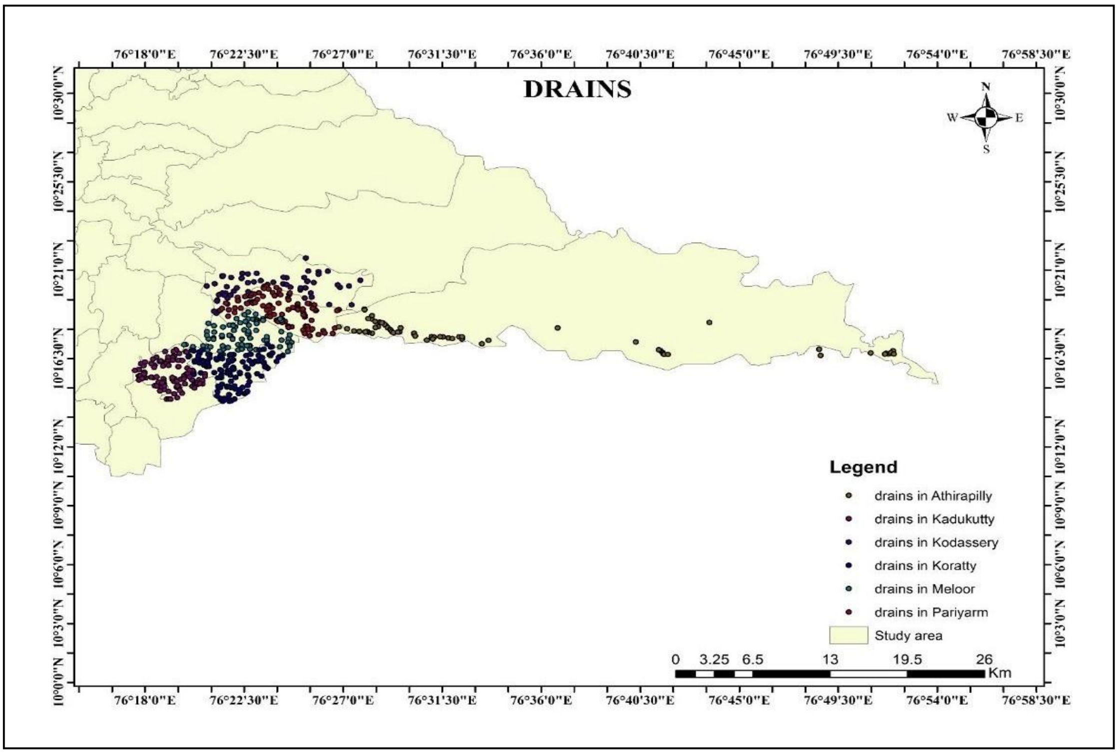


Fig 9. Drains in Chalakkudy block



Source: Map generated using ArcGIS

4.1.3.2 Agriculture and Irrigation

In the case of the change in cropping and irrigation pattern in canal areas of the Chalakkudy diversion scheme, water availability has decreased due to the development of the Peringalkuth Left Bank Hydroelectric Project and Sholayar dam.

Once the CRDS was established, there was a constant water supply and a well - organized irrigation schedule since paddy cultivation requires intermittent flooding. The area irrigated for paddy had been steadily decreasing since the late 1980s. At the same time, commercial crops like coconut, plantains, and nutmeg had seen an increase in cropping intensity, much like the rest of Kerala. Paddy had been replaced by coconut as the primary crop in Pariyaram, Chalakkudy, and Aloor, located in the top, middle, and tail parts of the Right bank canal, and similarly in Mukkanoor, Meloor, and Karukutty. Arecanut, nutmeg, and plantains were these regions' subsequent three main crops. Coconut and arecanut trees need to be watered frequently at the seedling stage and fortnightly afterwards, unlike rice, which requires much water to grow. Given that CRDS was created specifically for paddy cultivation, the irrigation pattern has changed since there was a change in the cropping pattern. Nowadays, the RBC releases water once every 14 days until January, after which it releases water every 17 to 18 days. On the LBC, a release occurs once every 22 days starting in January.

Farmers have turned to alternative methods to adapt to these changes, including lift irrigation, storage tanks, dug wells, panchayath-instituted *Thodu* (streams), and *Chiras* (natural ponds) rely on indirect recharge through canal water seepage. In 2005–2006, 80–85 per cent of the region at the head end was irrigated directly from canals. It has decreased to 60 per cent in 2015–16, along with a rise in reliance on wells and other irrigation sources such as ponds and other storage facilities created by the private or public sector. Coconut, arecanut, and plantains are irrigated utilizing lift Irrigation (LI) structures, tanks, and ponds since they require fewer irrigations than nutmeg, tapioca, yam, and colocasia.

Ineffective canal irrigation has been caused by inadequate canal maintenance, deterioration of sprouts and shutters, and a lack of appropriate water pathways for fields far from the sprouts, reducing output. Farmers switched from paddy to crops with varied irrigation schedules, making canal irrigation secondary.

Although transitioning from low-value subsistence crops to high-value commercial crops requires secured irrigation during crucial dry months, we see today in the CRDS command area a blend of governmental, private, and community driven irrigation systems. The type of crop planted and a farmer's ownership status of the land are the two key elements that affect the investment in wells made by farmers. Since the productivity of these crops depends largely on timely irrigation, and almost every house in the area has a well or tubewell for irrigation, the direct reliance on the canal has significantly decreased. It was observed that large farmers that cultivate nutmeg, tapioca, plantains, and tubers rely primarily on private dug wells.

Lift irrigation systems, in contrast to well irrigation investment, are made individually, and the former has had extensive community response. Lift irrigation systems provide water when needed, unlike canals, where water delivery is time-dependent. At Meloor panchayat, under the control of CRDS, an array of lift irrigation systems supported by the government, jointly administered by the government and farmers, and collectively owned and controlled by farmers. They have also added a pump operator who keeps track of the allotted time and manages payment collection. The water users themselves maintain field waterways. The existence of water allocation regulations, a monitoring system, a solid organizational structure, and competent and equitable leadership are necessary for efficient allocation through these systems.

4.1.4 Private Investments in Irrigation

To find private investments in irrigation, depreciation of the amortized cost of the well, the amortized cost of irrigation pump set, amortized cost of pump house, the amortized cost of conveyance structure and amortized cost of storage structure (if any),with miscellaneous cost was calculated at 2 per cent interest rate per year.

The annual interest rate (i) is assumed to be 2 per cent. Even a moderate interest rate of 4 per cent, but examined over say, 20 to 30 years, will surpass the investment in leaps and bounds since, the mechanism of compounding/discounting follows the typical exponential connection between present and future values. This is not practical since it does not account for the real rate of growth in well irrigation investment. Sustainable groundwater extraction for watershed development is covered at a real interest rate of 2 per cent. It is important to keep in mind the ongoing discussion surrounding the usage of discount factors in economic analysis.

A theoretical conundrum surrounding the evaluation of public policies and programmes has been the selection of the discount rate. Whether the discount rate should be in the range of 0–3 percent or 5–10 percent is a topic that divides economists and others (Lind, 1997). The discount rate should be low for far-off futures, according to one conclusion of an intense argument among economists (Weitzman, 1998; Gollier, 2002; Newel and Pizer, 2003; Pearce *et al.,* 2003). According to an elaborate assessment by Pearce *et al.* (2003), the discount rate is no longer a fixed value but instead shifts over time in a decreasing way. The rate of investment per well is 2 per cent. However, if we divide the total amount invested on irrigation wells over, say, 30 to 40 years by the total number of operational wells as of 2006, then the investment for each successfully operating well would have grown. Therefore, it is untrue for economists to claim that 2 per cent is a low percentage. Although the low rate of investment per well is appropriate, it could not be economical if we take externalities into account (Diwakara and Chandrakanth, 2007).

Hence, the cost of drilling, the average age of the wells, and a 2 per cent interest rate were taken into account when amortizing investments in irrigation wells. In the case of the pump set, pump house, and conveyance pipe and accessories, the working life was assumed to be ten years.

Private investments for irrigation for both owned and leased land were computed. For leased farmers, the amortized cost of the well and amortized cost of the pump house were excluded. The details of private investments are depicted in Table 4.1 below. Private investment for irrigation for farmers cultivating on their land was ₹ 19,479 per hectare, whereas, in leased land, the amount accounted for ₹ 8183 per hectare. A higher investment in farmers cultivating the owned land can be seen since they bear the amortized cost of the irrigation well and pump house constructed in their farms. In contrast, for leased farmers, such costs are not included since they are already installed in the leased farm for use, and hence no separate investment for that. It was also found that the pumping expenditure (electricity charges) for irrigation was not incurred by either owned or leased farmers. Electricity charges are subsidized and almost free in the state; hence, such expenditure was not borne by the farmers.

Table 4.1. Private investments in irrigation in the study area

Investment in irrigation	**Amount (₹ /ha) (Owned land) n=70**	**Amount (₹ /ha) (Leased land) n=50**
Depreciation (Amortized cost of well + Amortized cost of pump house+ Amortized cost of irrigation pump set+ Amortized cost of conveyance structure + Amortized cost of storage structure if any)	18415	7162
Miscellaneous	1064	1021
Total	**19479**	**8183**

4.2 SOCIO-ECONOMIC PROFILE OF BANANA FARMERS

By categorizing the sample population according to age, gender, farming experience, literacy level, annual income, average family size, and size of the land holding, the socio-economic characteristics of sixty sample banana farmers from the blocks of Kodakara and Chalakkudy were analyzed.

4.2.1 Age

The sample farmers were divided into five age groups (Table 4.2.). Most of the farmers were between the ages of 51 and 60. These farmers comprised 38.33 and 41.66 per cent of the Kodakara and Chalakkudy blocks, respectively. 15 and 20 per cent of the farmers from Kodakara and Chalakkudy, respectively, were in the 61-70 age group. Only 4.16 per cent of sample farmers were between 30 and 40 years old, while 6.66 per cent were over 70 years old. The findings imply that the middle-aged group participated more proactively in banana cultivation. Many of the middle age farmers also took banana cultivation in their own land as a source of income during corona period. The result also emphasized that youth participation in banana cultivation is not promising.

4.2.2 Farming experience

According to their level of farming experience, the sample farmers were divided into five categories, as shown in Table 4.3. The table shows that 35 per cent of the respondents had farming experience ranging from 10 to 20 years. 23 and 30 per cent ofthe farmers in Kodakara and Chalakkudy had between 21 and 30 years of farming experience. In the Kodakara block, 13 per cent of sample farmers had experience from 31 to 40 years, whereas 17 per cent were in the Chalakkudy block. Around 7 per cent of respondents had been farmers for over 40 years. These tables show that the vast majorityof sample respondents have a great deal of experience in cultivating banana.

4.2.3 Education status

Analyzing the sample respondents' education qualifications resulted in classification into five categories (Table 4.4). It was observed that 40 per cent of the sample population had secondary education and 22 per cent below the secondary level. It was a good sign that over one-third of the sample could follow the scientific practices efficiently. 16.67 per cent of the farmers had a diploma-level education. The Kodakara Tyre factory in the study area offers major employment opportunities for the people in the study area with diploma-level education. It was observed that after retiring from the factory, these people tend to turn to banana farming as a source of income. About 7 per cent of the population were graduates, highlighting the reluctance of highly qualified people towards farming.

Table 4.2. Classification of sample respondents based on age

Age group (years)	Kodakara Block	Chalakkudy Block	Total sample
30-40	3 (5.00)	2 (3.33)	5 (4.16)
41-50	20 (33.33)	18 (30.00)	38 (31.66)
51-60	23 (38.33)	25 (41.66)	48 (40.00)
61-70	9 (15.00)	12 (20.00)	21 (17.50)
>70	5 (8.34)	3 (5.00)	8 (6.66)
Total	**60** **(100)**	**60** **(100)**	**120** **(100)**

Note: Figures in the parenthesis indicate per cent to column total

Table 4.3. Classification of farmers based on the experience in farming

Farming experience (Years)	Thrissur district		
	Kodakara Block	Chalakkudy Block	Total sample
< 10	11 (18.33)	9 (15.00)	20 (16.66)
10 to 20	22 (36.67)	20 (33.33)	42 (35.00)
21 to 30	14 (23.33)	18 (30.00)	32 (26.67)
31-40	8 (13.34)	10 (16.67)	18 (15.00)
>40	5 (8.33)	3 (5.00)	8 (6.67)
Total	**60** **(100)**	**60** **(100)**	**120** **(100)**

Note: Figures in the parenthesis indicate per cent to column total

Fig 10. Classification of sample respondents based on age in the study area

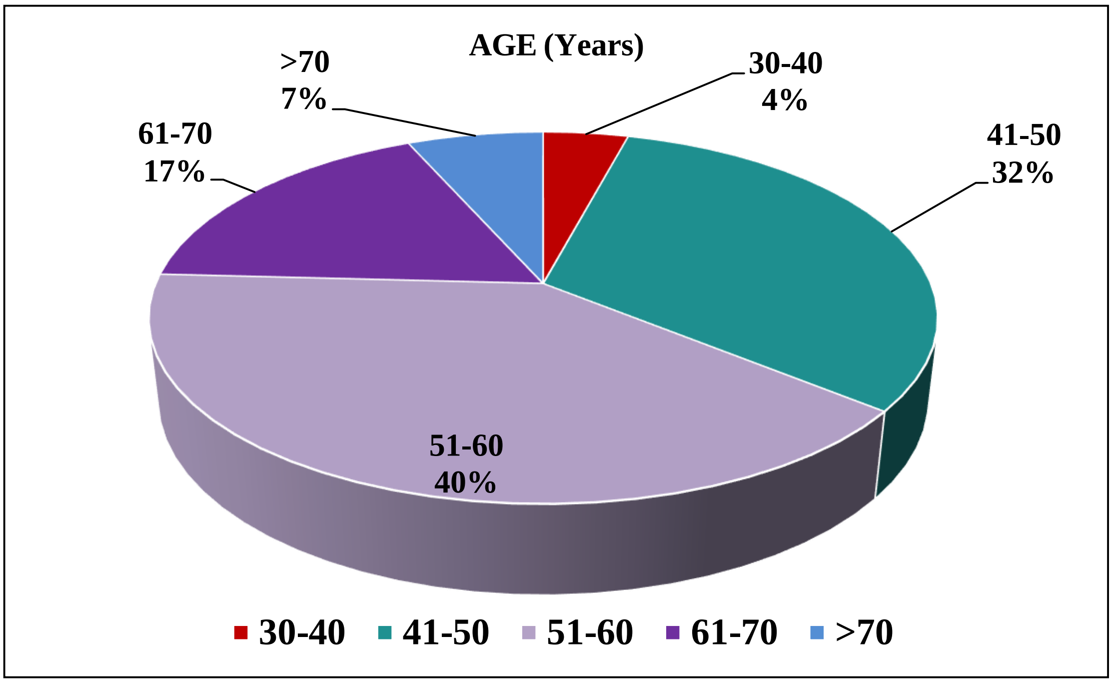


Fig 11. Classification of sample respondents based on experience in the study area

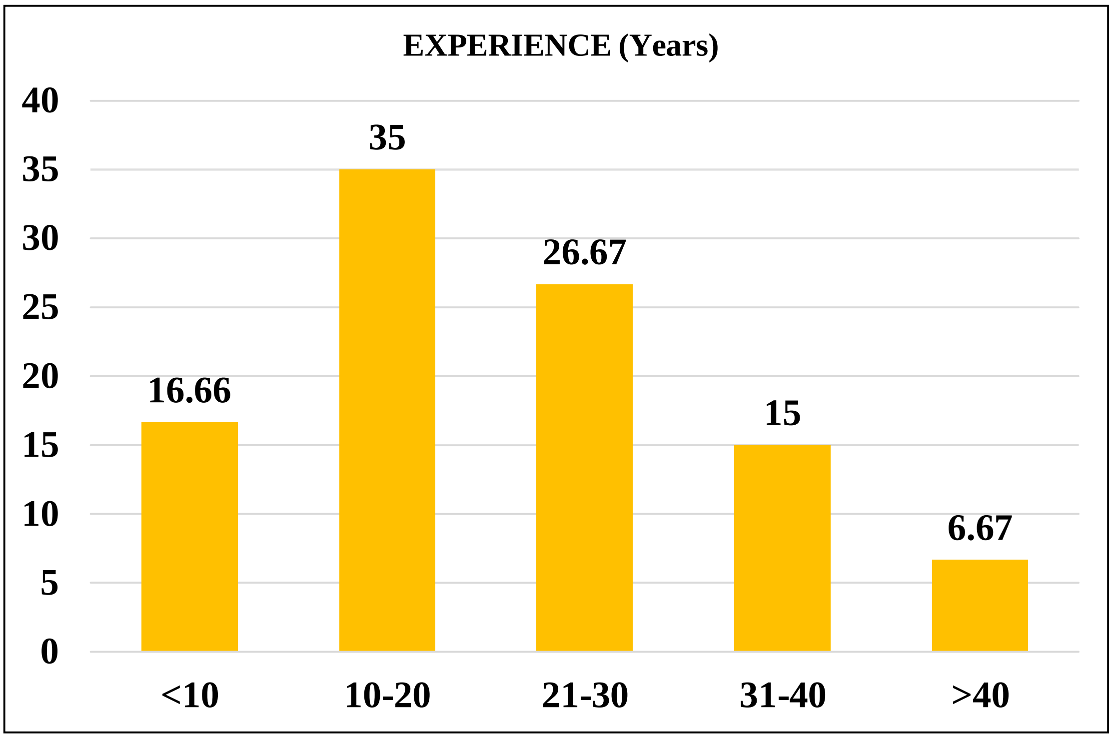


Table 4.4. Education status of sample respondents

Educational status	**Thrissur district**		
	Kodakara	**Chalakkudy**	**Total sample**
Below secondary	16 (26.66)	11 (18.34)	27 (22.50)
Secondary	22 (36.66)	26 (43.33)	48 (40.00)
Higher Secondary	7 (11.67)	10 (16.66)	17 (14.16)
Diploma	11 (18.34)	9 (15.00)	20 (16.67)
Graduate and above	4 (6.67)	4 (6.67)	8 (6.67)
Total	**60 (100)**	**60 (100)**	**120 (100)**

Note: Figures in the parenthesis indicate per cent to column total

4.2.4 Family size

The details of the family size of the sample respondents are presented in Table 4.5. With the increase in family size, more family labour is expected to be available forfarming operations. The family size was divided into three categories: small (having less than 4 members), medium size with members ranging from 4-6 and large, comprising more than six members. The majority of the sample respondents in the Kodakara block (50%) were under a small family size, followed by the medium category (43.34%). While in Chalakkudy block majority share (78.33%) accounted for a medium family size comprising 4-6 members. Out of 120 samples, only 6 per cent of the respondents had large family sizes. The results showed that family labour would not be available in Kodakkara for farming due to its skewed size; in contrast, there was ample scope in Chalakkudy since medium-sized families were more in number.

Table 4.5. Distribution of sample farmers based on family size

Size of family (No. of members)	Thrissur district		
	Kodakara Block	Chalakkudy Block	Total sample
Small (<4)	30 (50.00)	10 (16.66)	40 (33.33)
Medium (4-6)	26 (43.34)	47 (78.34)	73 (60.83)
Large (>6)	4 (6.66)	3 (5.00)	7 (5.84)
Total	60 (100)	60 (100)	120 (100)

Note: Figures in the parenthesis indicate per cent to column total

Fig 12. Classification of sample respondents based on education in the study area

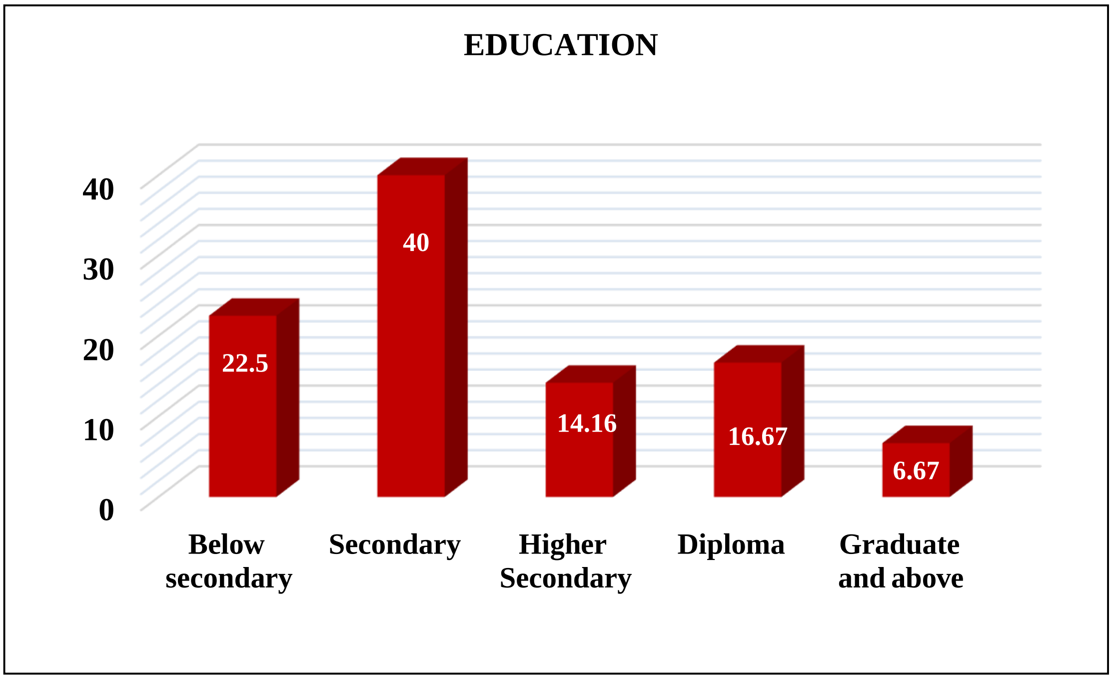
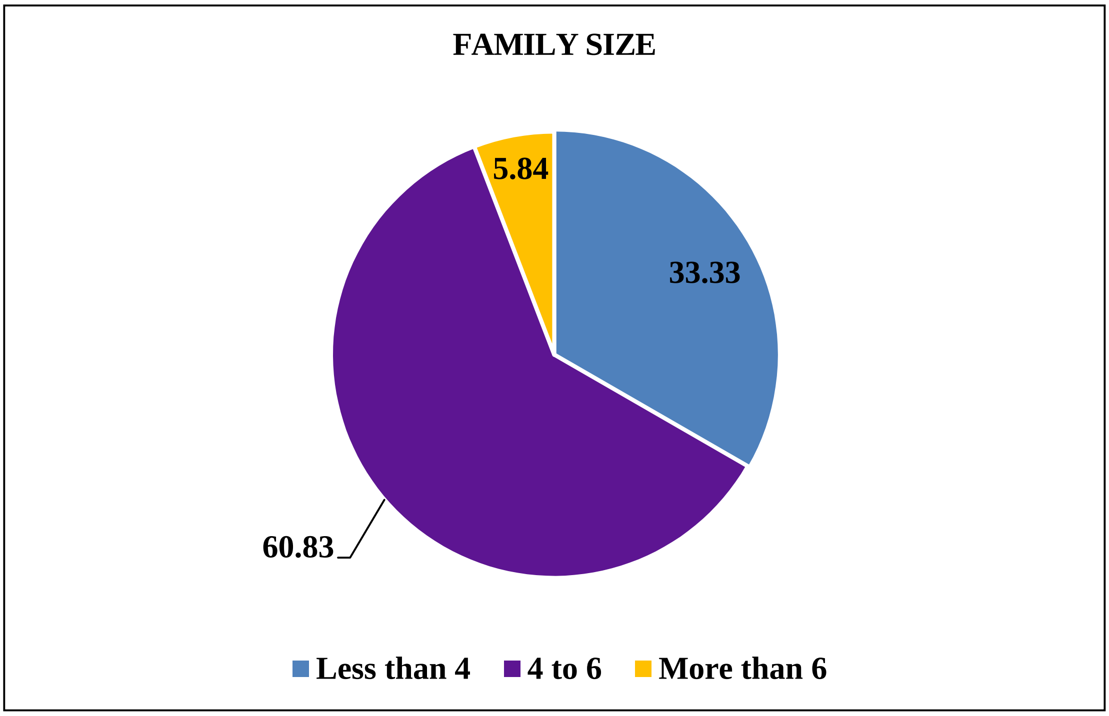


Fig 13. Classification of sample respondents based on family size in the study area



4.2.5 Land holding size

The landholding size of the sample respondents in the study area is depicted in Table 4.6. The respondents were categorized into three categories, marginal (having landholding less than 1 hectare), small (landholding size ranging from 1-2 hectares) and large (landholding greater than 2 hectares). The grouped data showed that most farmers belong to the marginal farmers' category. Eighty-eight per cent of sample respondents from Kodakara and 93 per cent from Chalakkudy fell under this category. None of the respondents from Kodakara and Chalakkudy were large farmers. The small landholding size restricts the farmers from enjoying large economies of scale in farm operations.

4.2.6 Annual household income

The distribution of farmers according to annual household income levels was divided into five categories and displayed in Table.4.7. The data showed that 22.50

per cent of farmers had annual household incomes of less than ₹ 1 lakh. In contrast, 43 per cent of farmers had incomes between ₹ 1-2 lakhs. The farmers receiving income between ₹ 2-3 lakhs and above four lakhs accounted for only 10.50 and 10.83 per cent, respectively. Most of the farmers had incomes of less than ₹ two lakhs, pointing towards the inability of significant investments in irrigation.

Table 4.6. Classification of sample respondents based on landholding pattern

Land holding	**Thrissur district**		
	Kodakara Block	**Chalakkudy Block**	**Total sample**
Marginal (1ha)	53 (88.34)	56 (93.34)	109 (90.84)
Small farmers (1-2 ha)	7 (11.66)	4 (6.66)	11 (9.16)
Total	**60** **(100)**	**60** **(100)**	**120** **(100)**

Note: Figures in the parenthesis indicate per cent to column total

Table 4.7. Classification of sample respondent based on annual household income

Annual household income (Rs)	**Thrissur district**		
	Kodakara Block	**Chalakkudy Block**	**Total sample**
< 1Lakh	11 (18.34)	16 (26.67)	27 (22.50)
1-2 Lakh	29 (48.34)	23 (38.34)	52 (43.33)
2-3 Lakh	10 (16.66)	11 (18.33)	21 (10.50)
3-4 lakh	4 (6.66)	3 (5.00)	7 (5.84)
> 4 Lakh	6 (10.00)	7 (11.66)	13 (10.83)
Total	**60** **(100)**	**60** **(100)**	**120** **(100)**

Note: Figures in the parenthesis indicate per cent to column total

Fig 14. Classification of sample respondents based on landholding size in the study area

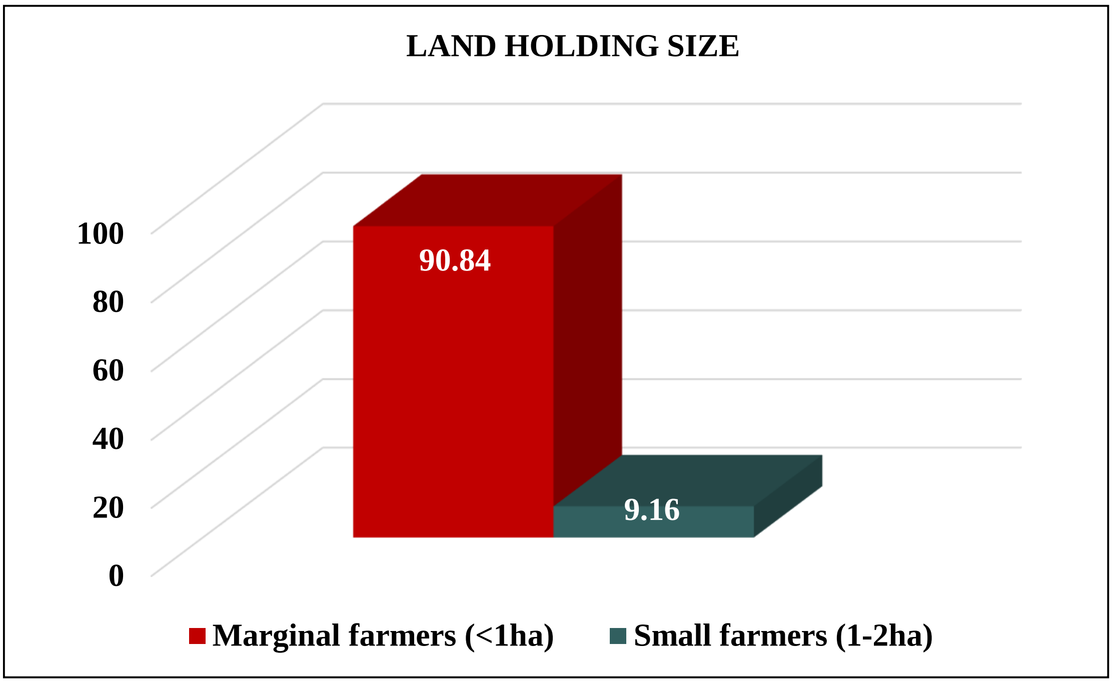
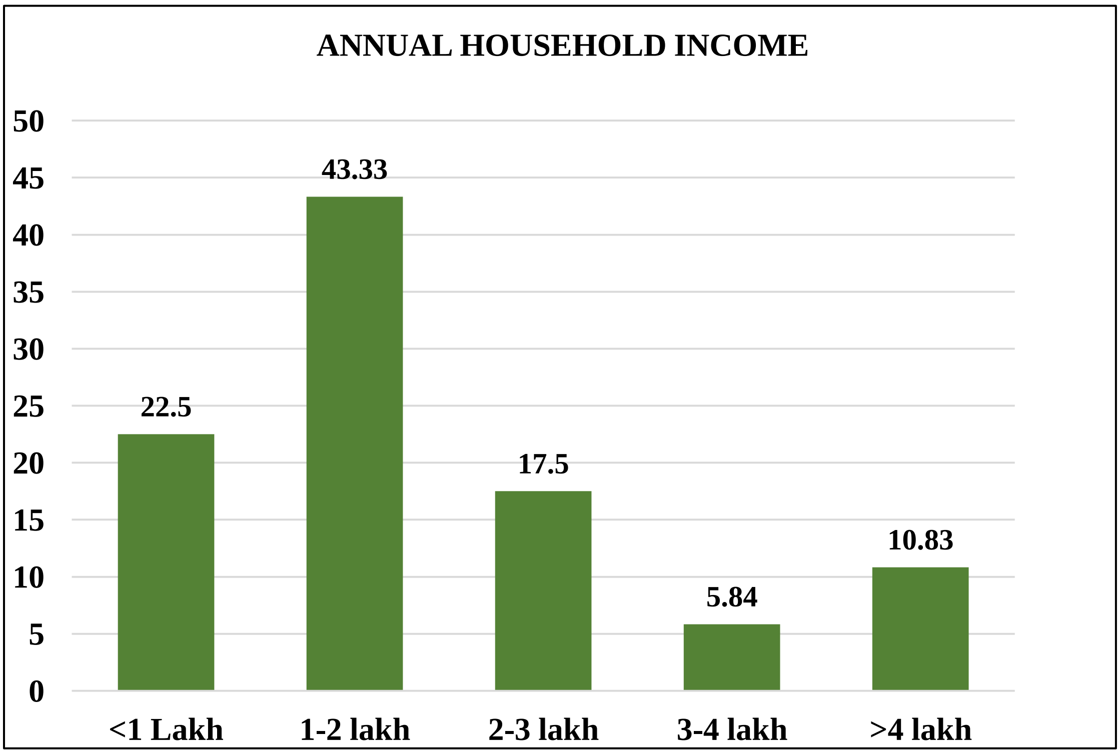


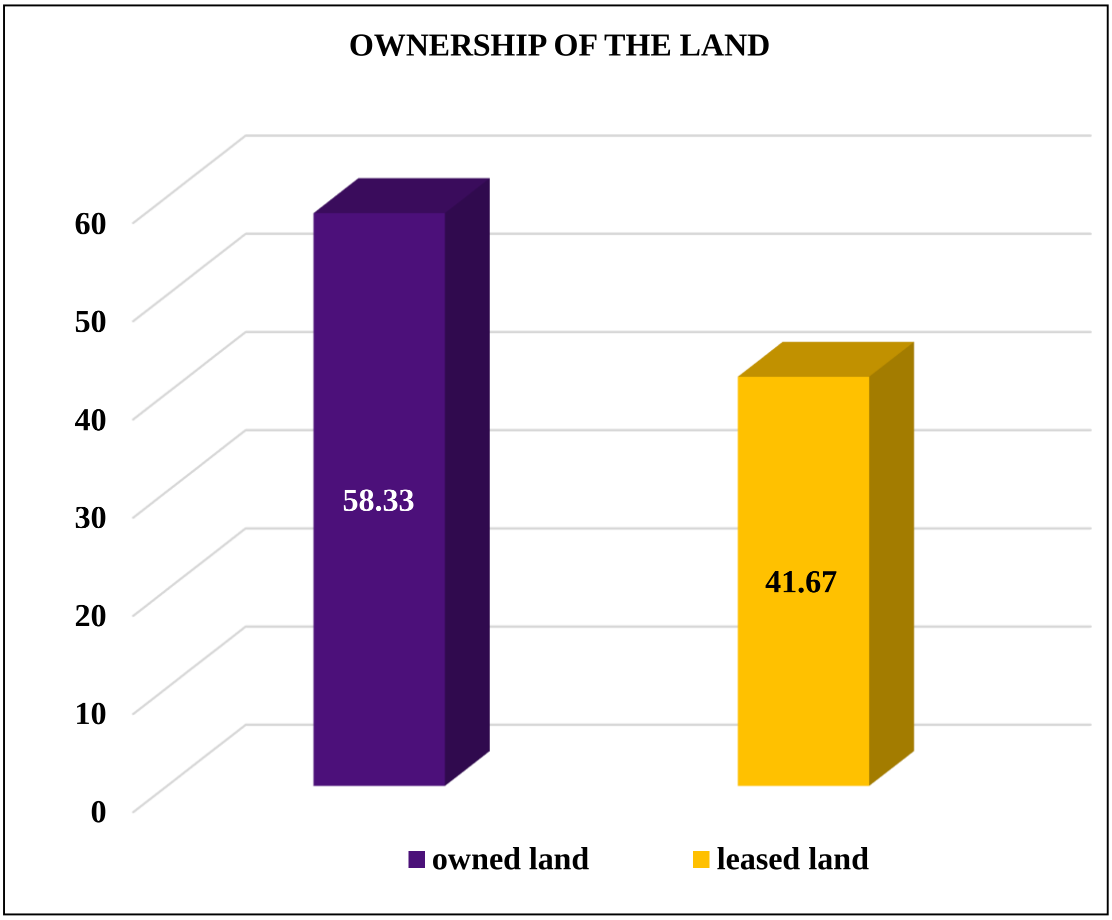
Fig 15. Classification of sample respondents based on annual household income in the study area



4.2.7 Ownership of land

Categorization of land based on ownership of land has been done. 58.33 per cent of the farmers in the study area had their own land for cultivation of banana. Remaining 41.66 per cent of farmers leased in land in order to cultivate banana (Fig. 16).

Fig 16. Classification of sample respondents based on ownership of land in the study area



4.3 YIELD DETERMINANTS IN BANANA CULTIVATION

The regression analysis was conducted using MS EXCEL to get the Cobb - Douglas production function for banana cultivation in the study area. The significantinputs for banana cultivation were taken as explanatory variables, with yield as the dependent variable. The explanatory variables included were the quantity of water applied (m^3/ha), manures and fertilizers (kg/ha), human labour

(No. of man days/ha), and plant protection (No. of sprays/ha). Table 4.8 below lists the input elasticities (coefficients) and analysis results for the study area and its implications.

Table 4.8. Estimated regression model for yield response in banana

SI. No.	**Parameters**	**Coefficients**	**Standard error**	**Average value**	**t stat**	**p-value**
1	Intercept	2.05	0.41	-	4.9	2.9 E^{-06}
2	Quantity of water applied (m^3/ha)	0.46	0.06	2484	7.6	6.7 E^{-12}**
3	Manures and fertilizers (kg/ha)	0.28	0.03	8011	7.1	7.4 E^{-11**}
4	Human labour (No. of man days/ha)	0.37	0.06	274	5.4	2.6 E^{-07**}
5	Plant protection (No. of sprays/ha)	-0.2	0.03	12	-6.22	0.28
6	**R^2**	**78.31**				
7	**Adjusted R^2**	**77.55**				
8	**F value**	**61.74**				
9	**No. of observations**	**120**				

** 1 per cent level of significance

The standard error of the estimate, ANOVA and the F-test assessing the contribution of each independent variable using the t-test or examining the coefficient of multiple determination can be used to evaluate the model (Webster, 1995). The parameter's value reflects the amount of error in any estimation made using the regression model.

The standard error of the estimate's smaller value indicates less dispersion, which denotes a higher prediction and forecasting accuracy for the model. The amount of the change in the dependent variable was explained by each independent variable in the regression model is measured using the coefficient of multiple determination, or R^2, to assess the explanatory power of the model.

The regression analysis's findings show that the R squared value was 78.31, indicating that 78.31 per cent of the variation in the dependent variable was explained by the explanatory factors included in the model. The F value was found to be 61.74. The findings showed that at a 1 per cent significance level, the quantity of water applied,quantity of manures and fertilizers, and quantity of human labour had significant p values. The values of the coefficients of these factors were 0.46, 0.28, and 0.37, respectively. The standard error was found to be 0.40. The result suggested that the regression plane defined by the model fit the data reasonably well, along with the low standard error of the estimate. The results indicated a strong positive relationship existed between the yield, quantity of water applied, manures and fertilizers, and humanlabour used for banana cultivation.

The values of regression coefficients were found to be 0.46, 0.28, 0.37 for the quantity of water applied, manures and fertilizers and human labour. These numbers show that for every 1 per cent change in the quantity of water applied from the average value, a 0.46 per cent increase in yield can be observed when other variables are kept constant, indicating that water has a significant effect in increasing the yields. Water is a crucial agricultural resource for better plant development, nutrient uptake, photosynthesis, temperature regulation, and pest and disease control. Effective irrigation techniques are vital for ensuring the sustainable use of water, thus improving the production and quality of crops.

Shrief *et al.*'s (2015) used regression models to describe the influence of various irrigation regimes on grain yield and water use efficiency in bread wheat and made comparable observations about the importance of water on crop yield. Similarly, in the case of manures and fertilizers, yield increases by 0.28 per cent for a one per cent change from the average value in the manures and fertilizers while others are at *ceteris paribus*. The application of manures to the soil is found to have a positive impact on increasing crop yield by improving the soil conditions by enhancing the soil micro fauna and flora. It also conserves soil moisture and reduces moisture stress during hot and humid conditions.

The application of fertilizers is also found to increase crop yield by increasing nutrient availability, thereby enriching the soil with the required nutrients for crop growth and development. Therefore, timely and adequate application of manures and fertilizers in the required amounts would improve crop growth, enabling farmers to reap better returns.

An increase in yield by 0.37 per cent can be seen with every additional per cent of human labour from the average value changed. In order to assure the best crop development, production, and quality, human labour is crucial in agriculture since it entails a wide range of tasks that call for special knowledge, abilities, and skills. Human labour is necessary for agricultural methods since it provides flexibility and adaptability to changing weather conditions, field conditions, and crop demands.

4.4. COSTS AND RETURNS IN BANANA CULTIVATION

Estimates of overall costs and returns are essential for determining whether a system is profitable or not. Estimates of the overall cost of cultivation by input and returns per hectare for banana cultivation were calculated, incorporating the cost of irrigation. Separate cost of cultivation was estimated for owned farmers and leased farmers. The total cost of cultivation highlights resource use by banana farmers. The average total cost of cultivation was ₹ 4,80,877 and ₹ 5,04,066 per hectare for owned and leased farmers, respectively.

Table 4.9 shows the cost of inputs used in banana cultivation by farmers (owned and leased) in the study area. The table clearly shows that banana cultivation is highly labour-intensive. Around 22.69 and 23.93 per cent of the total cost of cultivation was contributed by hired labour in owned and leased land, respectively. The high cost of hired labour indicates how labour-intensive banana cultivation is.

Additionally, Kerala's relatively higher wage rate, compared to other states, adds to it. Family labour played a significant role in the harvesting process because not all the bunches were harvested together since they did not all reach maturity simultaneously.

Family labour accounted for 23.55 and 17.57 per cent for owned and leased land, respectively. Labour was required from land preparation to harvesting. There was no practice of bullock labour for preparatory cultivation in the study area. However, machine labour was used by a few farmers for land preparation. It accounted for 1.58 and 1.95 per cent of the total cost of cultivation for owned and leased farmers, respectively. Many farmers could not adopt machines for land preparation since they were either marginal or lands were highly fragmented.

The share of planting material to the total cost of cultivation accounted for 4.60 and 4.83 per cent for owned and leased land farmers, respectively. Most of the Nendran growers bought planting materials from Tamil Nadu as they believed they were much cheaper than the locally available ones and of better quality. They were less susceptible to pests and disease attacks and gave better yields. Others bought it either from local markets or from neighbours. Even though sword suckers were available for the farmers, most did not use them. Very few farmers in the study area used Nendran suckers obtained from the first crop as planting material, but subsequent suckers were not used for the second crop as they gave poor yield. Hence they are purchasing fresh suckers for the next crop. Additionally, it was noted that the farmers in the study area applied significant quantities of manures and fertilizers, expecting a higher banana yield.

Manures accounted for 6.44 per cent (owned land) and 8.45 per cent (leased land) in the total cost of cultivation. Whereas for fertilizers, it accounted for 9.76 (owned land) and 13.01 (leased land), respectively. The leased farmers are applying more fertilizers and manures in order to reap maximum yield. Most of them do lease farming in the same land for a continuous three years and later change the area. Typically, sample farmers apply a base dose of organic manures like green manure, cow dung, and ash. Followed by chemical fertilizers such as urea, mussoriphos, Muriate of Potash and mixtures like 10:26:26 and 16:16:16 were applied.

In Nendran, chemical fertilizers were given in five to six equal doses, the first about two months after planting, the second after three months, the third after four months, and the fourth after five months, respectively. Many farmers applied up to seven times, hoping it would increase the yield.

Table 4.9. Input- wise cost distribution of banana cultivation

Sl. No.	Particulars	Cost (₹ /ha) Owned land n=70	Cost (₹ /ha) Leased land n=50
1	Hired labour (₹ /day)	1,09,159 (22.69)	1,20,649 (23.93)
2	Family labour (₹ /day)	1,13,247 (23.55)	88,588 (17.57)
3	Machine labour (₹ /hour)	7,612 (1.58)	9,866 (1.95)
4	Planting material (₹ /sucker)	22,141 (4.60)	24,383 (4.83)
5	Lime (₹ /kg)	3,045 (0.63)	3,809 (0.75)
6	Manures (₹ /kg)	30,977 (6.44)	42,624 (8.45)
7	Weedicide (₹ /litre)	221 (0.04)	643 (0.12)
8	Plant protection chemicals(₹ /litre)	15,516 (3.22)	19,944 (3.95)
9	Fertilizer (₹ /kg)	46,959 (9.76)	65,588 (13.01)
10	Propping (₹ /kg of bundle)	20,250 (4.21)	20,232 (4.01)
11	Pumping expenditure (₹ /unit)	1,559 (0.32)	1,546 (0.30)
12	Miscellaneous (₹)	3,424 (0.71)	3,639 (0.72)

13	Total working capital	3,74,192 (77.81)	4,01,513 (69.65)
14	Interest on working capital	33,677 (7.00)	36,136 (7.16)
15	Total operational cost	4,07,869 (84.81)	4,37,649 (86.82)
16	Depreciation	19,681 (4.09)	8,554 (1.69)
17	Land revenue	796 (0.16)	796 (0.15)
18	Rental value of leased in land	0.00	51,027 (10.12)
19	Rental value of owned land	45,892 (9.54)	0.00
20	Interest on fixed capital	6,637 (1.38)	6,038 (1.19)
21	Total fixed cost	73,007 (15.18)	66,417 (13.17)
22	**Total cost**	**4,80,877** **(100)**	**5,04,066** **(100)**

Note: Figures in parenthesis are percentages to the total cost

The application of weedicides only accounted for 0.04 (owned) and 0.12 (leased) per cent, and large farmers only used it. Generally, the weeding practices were done along with the fertilizer application. Hence, the farmers did not incur a separate charge for the weeding operation. Similarly, the cost of plant protection measures was only 3.22 (owned) and 3.95 (leased) per cent because most farmers mainly used them as curative rather than preventive measures. Ekalux and Bordeaux's mixture were the two prominent plant protection chemicals used by the farmers.

The cost of propping accounted for 4.21 (owned) and 4.01 (leased) per cent of the total cost of cultivation. Banana plants were supported with bamboo or arecanut poles and wrapped in polythene sheets or sacks after bunch appearance. The heavy bunch is highly vulnerable to strong winds; hence propping is almost mandatory. However, the farmers opined that bamboo and arecanut poles were expensive (₹ 100/pole), could be used only for two to three years and sometimes needed to be sourced from the Palakkad district, incurring high transportation costs.

Most farmers were using plastic ropes and rolls to support the plant. Compared to bamboo/arecanut poles, plastic ropes have been reusable for several years.

4.4.1 Returns and Productivity of banana cultivation

The average yield, gross income per hectare, and cost of production per kilogram of bananas, separate for owned and leased land incorporating the cost of irrigation, are summarized in Table 4.10.

The output was determined by calculating the number of bunches obtained and the price of each bunch based on its actual weight. In the study area, 19.79 tonnes of bananas were produced per hectare. During the growing season, it was noticed that the farmers in the area would receive some returns from flower stalks (by-products). However, only a few farmers are selling it. Since the return was only ₹ 5 per stalk, most farmers discarded it. However, the returns from the by-product were also considered in estimating gross income. The total cost of cultivation for bananas was found to be ₹ 4,80,877 for farmers cultivating bananas on their land, with a gross income of ₹ 7,42,858, with the cost of producing 1 kg of banana amounting to ₹ 24.7.

Table 4.10. Yield and returns in banana cultivation

Sl. No	Particulars	Owned land	Leased land
1	Average yield of banana (kg/ha)	19,418	20,169
2	Returns banana (₹ /ha)	7,37,918	8,21,142
3	Returns by product (Flower stalk) (₹ /ha)	4,939	5,013
4	Gross return (₹ /ha)	7,42,858	8,26,155
5	Cost of cultivation (₹ /ha)	4,80,877	5,04,066
6	Net returns (₹ /ha)	2,61,981	3,22,089
7	Cost of production (₹ / kg)	24.7	23.3

While for leased farmers, the total cost of cultivation accounted for

₹ 5,04,066 with a gross return of ₹ 7,75,269 owing to more number of plants per hectare in their land when compared to the owned farmers. The cost of producing 1 kg of banana accounted for ₹ 23. According to GoK (2022), cost C for small farmers accounted for ₹ 6,24,090 per ha, which was in line with the cost obtained from the study results.

4.4.2 Cost concepts and benefit-cost ratios

Table 4.11 displays estimates for various cost concepts and benefit-cost ratios. The best indicator of income for determining whether crop production is economically viable is net income, which was found to be ₹ 2,61,981 per hectare for owned land and ₹ 3,22,089 for leased farmers. The benefit-cost ratio shows how much output is produced for every rupee spent on input.

Table 4.11. Benefit-Cost ratios in banana cultivation for various cost concepts

SI. No	Income measures	Amount (₹ /ha) Owned land	Amount (₹ /ha) Leased land
1	Cost A_1	3,15,100	3,58,413
2	Cost A_2	3,15,100	4,09,440
3	Cost B	3,67,629	4,15,478
4	Cost C	4,80,877	5,04,066
5	Gross income	7,42,858	8,26,155
6	Net income	2,61,981	3,22,089
7	BCR at Cost A_1	2.3	2.4
8	BCR at Cost A_2	2.3	2.0
9	BCR at Cost B	1.9	2.0
10	**BCR at Cost C**	**1.5**	**1.6**

The analysis revealed that the ratios were greater than one in all cases. The ratios based on costs A_1, A_2, B, and C were 2.3, 2.3, 1.9 and 1.5, respectively, for owned farmers, which shows the returns generated from a rupee invested in banana cultivation were found to be 1.5 at cost C, for every one rupee invested farmer is getting ₹ 1.5 in return, indicating a profitable enterprise. For leased farmers, the ratios based on costs A_1, A_2, B, and C were 2.4, 2.0, 2.0 and 1.6, respectively, showing that the returns generated from a rupee invested in banana cultivation were found to be 1.6 at cost C, for every rupee invested the farmer is getting ₹ 1.6 in return, which also indicated profitability of the crop. The leased farmers are doing intensive cultivation methods and getting better returns compared to owned land farmers.

The study conducted by Rathod and Gavali (2021) in Maharashtra obtained a B: C ratio of 2.06 for banana cultivation, and this was consistent with the above result regarding the cost and returns of banana cultivation in the present study.

4.5 ECONOMIC EFFICIENCY OF IRRIGATION WATER

4.5.1 Irrigation water use

The amount of water impacts other nutrients' availability and the timing of cultural activities, affecting crop growth. There are interactions between water and other inputs. The time and quantity of water provided during growth significantly determine plant growth and development. Depending on availability or scarcity, the harvest may be good, reduced, or a complete failure. Banana is a crop that responds well to irrigation. Nendran is usually irrigated between December and April-May, mostly twice a week. Banana need proper irrigation to achieve maximum bunch weight.

The study was confined to farmers using pump irrigation of groundwater for cultivation as the water was not easily quantifiable in other irrigation methods, and only a few farmers adopted drip or sprinkler irrigation. Some farmers had private ponds on their farms, while some directly pumped water from the river to the field as and when needed using pump sets. Since many of the sample farmers had private wells and the electricity subsidy provided for agricultural practices, they are pumping water for irrigation.

The discharge rate of the motor pumps for 120 sample farmers was measured using the physical method. The total quantity of irrigation water used in a season was calculated by multiplying the discharge rate of the pump (litre/hour), the number of hours to irrigate the cropped area for one irrigation, frequency of irrigation per month (number) and duration of crop irrigated in months together for each sample farmers. The study was limited to this method because most of the irrigated farms had private sources of irrigation and didn’t have gauges or instruments in the water sources to measure them, unlike in a canal irrigated system where gauges are present to measure irrigation water

Even though drip irrigation was effective in banana cultivation, many farmers did not install it for various reasons, such as frequent clogging and breakage of the drip lines while applying organic manures as basal dose and its high initial installation cost. The free power supply for pumping allows the farmers to use water irrationally.

Hence the farmers are unaware of the amount of irrigation water applied and are not maintaining the data, unlike other paid resources used for cultivation.

4.5.2 Different efficiencies of irrigation water in the study area

An effort has been made in the study to examine the efficiencies of irrigation water used in banana cultivation. Data Envelopment Analysis (DEA) model was used to measure the technical efficiency, cost efficiency or economic efficiency and allocative efficiency in banana cultivation

DEA is a system of mathematical programming that facilitates the determination of individual efficiency based on its output and inputs, and it matches with other units considered in the analysis. The solution to the DEA model provides relative measures for each respondent in the study. In the present study, the yield was compared to the quantity of water applied. Technical efficiency is the value with which a specified set of resources are utilized to produce an output. It is considered technically efficient if a farm produces maximum output from the minimum inputs.

Allocative efficiency was computed for individual farmers. It is an output level where marginal cost (MC) equals the price (P). It is the condition of a farm to produce a crop where the marginal cost is equivalent to the price. Cost or Economic efficiency is the product of technical and allocative efficiency. The only possible values for cost efficiency are positive ones that are either less than one to indicate inefficiency or equal to one to indicate efficiency. DEA was done in DEAP 2.0 software to assess whether banana farmers in the study area are economically efficient. The calculation of the economic efficiency of the crop under study is discussed below.

The values of technical, allocative and economic efficiency of irrigation water applied at variable returns to scale are presented in Table 4.12. With a mean of 60.9, technical efficiency (TE_{VRS}) values varied from 27.6 to 100. Hence a mean value of 60.9 per cent technical efficiency suggests better opportunity for increasing returns through efficiency enhancement.

The mean value of allocative efficiency was 87 per cent at variable returns to scale (VRS). Allocative efficiency was higher than technical efficiency, implying that perhaps the returns from banana cultivation can be maximized by enhancing technical efficiency rather than allocative efficiency. For banana cultivation, mean cost efficiency was found to be 53 per cent at variable returns to scale.

Table 4.12. Efficiency of irrigation water applied- Banana

Sl. No	Parameters	Technical efficiency	Allocative efficiency	Economic efficiency
1	Maximum	1.00	1.00	1.00
2	Minimum	0.28	0.27	0.26
3	Mean	0.61	0.87	0.53

The findings concerning the examined efficiency parameters have several implications. One such finding has to do with the degree of technical efficiency. This parameter is seen to vary greatly among the sampled farms, with a minimum of 27.6 and a maximum of 100 per cent, implying inefficiencies ranging from 0.00 per cent to 72.4 per cent under variable returns to scale. The results obtained from the study are in line with previous studies of irrigation. A similar result was found in the productivity levels of farms in Morocco by Lionboui (2016) under different irrigation systems. In the study, according to the source of irrigation water, average economic efficiency ranged from 45-83 per cent, whereas the technical and average economic efficiency was 90 and 69 per cent, respectively, for groundwater users.

The statistics from the sample in the present study demonstrated that the farms could have been more economically efficient. The functional relationship between these three criteria suggests that increasing the technical rather than the allocative efficiencycan significantly increase the economic efficiency of banana growing in the study region. The main reason for a mean technical efficiency of 60.9 per cent can be attributed to the method of irrigation (surface irrigation) practised in the study area. More than 80 per cent of the world's irrigated land uses surface irrigation techniques; however, the application efficiency at the field level ranges between 40–50 per cent (Grafton, *et. al.*, 2018). With an efficiency of less than 40 per cent, groundwater is administered mostly via flood irrigation.

The competitive installation and deepening of bore wells, as well as field application via flooding, can result in a number of social, economic, and environmental consequences (Janakarajan and Moench, 2006). Uncontrolled flooding typically causes the field to get too much irrigation at the head area and insufficient at the tail end. In the case of the surface irrigation method, when water is applied to crops without prior preparation of the land and any boundary to guide or restrict the flow of water on the field, application efficiency will be much lowered. Hence in the current scenario, changing the mode of irrigation method to micro-irrigation methods (MI), such as drip irrigation, could improve the efficiency of the irrigation water in the study area, which is reported to have the highest groundwater extraction in the district.

There are numerous advantages of micro-irrigation over surface irrigation. The MI, namely drip and sprinkler, aid in the targeted application of water to the crop's root zone, either drop by drop as in the drip system or a spray of tiny droplets on crops similar to rainfall as in the sprinkler system, achieving higher water application efficiency and distribution uniformity. The drip system is more suited to orchard crops such as fruits, vegetables and plantation crops, but the sprinkler system is better suited to field crops. MI boosts water efficiency by 50-90 per cent (Saleth and Amarasinghe, 2009). An assessment of the economic performance of micro-irrigation for fruit crops reveals that, despite its greater initial cost, this technique can save a significant amount of water while producing higher returns (Behera and Sahoo, 1998).

Micro-irrigation has the ability to improve both the public benefit and net farm returns. Crop yield increases and lower labour costs are just a few of the farm-level advantages in water scarce areas. When alternative irrigation systems are replaced, micro-irrigation has the potential to produce larger farm-level net returns and greater net values from agriculture and of water can be made available to farmers for other uses (Wichelns, 2007). By increasing water use efficiency and lowering greenhouse gas emissions, MI helps to relieve pressure on groundwater resources. MI has the ability to serve as a tool for both supply and demand side management. The breakage and other damages that could be done to the pipes and distributaries during the intercultural is the major concern in MI. After installation, it's important to make sure that the drip systems are properly maintained, including their filters. Regular maintenance of MI systems by vendors and promoting private businesses or custom-hiring centres are options.

In a comparison study on the economics of banana farming under conventional and drip irrigation, Dave *et al.* (2016) found that a net profit of 52.76 per cent was achieved with an investment of ₹ 1,50,098 per ha, which is somewhat less than the non- drip rate of ₹ 1,51,735 per ha. Another study by Pramanik *et al.* (2014) demonstrated the profitability of drip irrigation compared to traditional methods for cultivating banana. Khalifa (2012) noted that drip irrigation yielded the highest irrigation water productivity (1.43 and 1.40 kg/m^3 respectively) when evapotranspiration was 120 and 100 per cent, while surface irrigation yielded the lowest (0.30 kg/m^3).

The average quantity of irrigation water currently used in the study area was 2.4×10^3 m^3 per ha for 1373 plants per hectare, which was compared with the study results carried out in Agricultural Research Station, Chalakkudy (Kerala Agricultural University), to determine whether irrigation water is being overused or underused. The study was conducted during 2009-2014 on system intensification for better water productivity in banana (Nendran) (ARS Chalakkudy, 2021). The study results showed that irrigating crops at 100 per cent irrigation (10 mm CPE- Cumulative Potential Evaporation), *i.e.* 20 litres of water per plant per day, is required for the banana to significantly increase the bunch yield per plant. The study found that the water requiredwas 1.3 x 10^3 m^3 per hectare (1373 plants/ha). On comparing the results of the present study, an overuse of 1.1 x 10^3 m^3 per ha was found in the study area. It is mainly attributed to the surface irrigation method followed in the study area.

Thus the quantity of water which was found overused in the study area could be converted to potential savings if more efficient water irrigation methods are adopted and could also be used to raise other crops or increase areas of banana cultivation. Also,it could be released for other non-agricultural purposes.

4.6 PRICING OF IRRIGATION WATER

In order to analyze the marginal value of irrigation water, the Cobb-Douglas production function was employed. The ordinary least square (OLS) method was used to estimate the production function. The F test was used to evaluate the overall goodness of fit, and the t-test was employed to evaluate the significance of the estimated elasticitycoefficients. The dependent variable used in the study is the yield of banana (kg/ha). In contrast, independent variables included were the quantity of water applied (m^3/ha), quantity of manures and fertilizers (kg/ha) and human labour (Number of man days/ha)and plant protection (No. of sprays/ha).

The average volume of irrigation water applied per ha is equal to 2.4×10^3 m^3 per hectare, which is very high compared to the estimated water needs of the banana crop in the region (around 1.3 x10^3 m^3/ha). The Cobb- Douglas production function parameters were estimated using MS Excel software. The results of the coefficients andrelated tests are already discussed along with the Table 4.8.

Returns to scale

The output will proportionally increase or decrease when all of the production factors are simultaneously increased or decreased, according to the definition of returns to scale. If the total of all the regression parameters equals 1, the returns to scale can be considered constant returns to scale. In increasing returns to scale, the total of the estimates is greater than one and less than one in decreasing returns to scale. Returns to scale are represented by the total of the regression coefficients ($\sum bi$) for all inputs used in the function. The sum of elasticity estimates was found to be 0.9, indicating decreasing scale returns.

Marginal Valuation of irrigation water in banana cultivation

The Marginal Value Products (MVPs) of significant factors of production in the production function analysis were worked out and compared with the Marginal Factor Cost (MFC) or Marginal Input Cost (MIC) to determine the marginal value and also the resource use efficiency of different inputs. The results are presented in Table 4.13.

The ratio of MVP to the price of manure and fertilizers was 1.3. Since the value of the ratio of MVP to the price of manures and fertilizers was greater than one, indicates that there is underutilization of manures and fertilizers, and there is a need to increase their use. The ratio of MVP to the price of labour was found to be 0.07. It indicates that labour is over utilized, and its use needs to be rationalized. Similarly, in the quantity of water applied, the ratio of MVP to MFC was found to be 0.8, which indicated the overuse of water resources in banana cultivation.

Table. 4.13. MVP, MFC and k values of Cobb-Douglas production function

Sl. No.	**Particulars**	**MVP (₹)**	**MFC (₹)**	**k=MVP/MFC**	**Remarks**
1	Quantity of water applied (m^3/ha)	**22.31**	26.17	0.8	**Overuse**
2	Quantity of manures and fertilizers (kg/ha)	13.28	10.01	1.3	Underuse
3	Human labour (No. of man days/ha)	28.31	372	0.07	Overuse

The same result was observed in the previous analysis, where 1.1×10^3 m^3 per hectare was overused in the place where only 2.3×10^3 m^3 per ha was required. A similarstudy by Frija *et al.* (2013) observed that the overuse of irrigation water in wheat in Tunisia resulted in poor returns to the farmers.

The marginal value product of water was ₹ 22.31 per m^3 of water applied in the study area. In other words, farmers in the study area use irrigation water worth ₹ 55418 per hectare (2.48×10^3 m^3 per ha) when only ₹ 29003 (1.3×10^3 m^3 per ha) is needed. By cutting back on the excessive irrigation water use in banana plants, an additional ₹ 24,530 per hectare can be viewed as possible savings. Marginal pricing for irrigation water in the study area was ₹ 2 paise per litre. This price would have gone much higher if the resource cost of groundwater had been considered. Without considering the watercosts, the cost of cultivation will be lower. This can be regarded as the prime reason for excessive water use.

The cost of electricity used to pump irrigation water is still not included in the ₹ 22.3 per m^3 price of water. If we are to add ₹ 22.31 per m^3 of water cost to the cost of cultivation, the total cost of cultivation changes from ₹ 48,0877 to ₹ 5,39,465 per hectare for owned farmers and from ₹ 5,04,066 to ₹ 5,63,198 per hectare for leased farmers.

That is extra of ₹ 58,588 per hectare for owned farmers, and ₹ 59,132 leased farmers would have to be incurred more. In this case, the B: C ratio for leased and owned farmers reduces to 1.3. Since groundwater is a resource shared by all, individual farmers in the study area work to maximize their extraction for better yields. Farmers are not incentivized to conserve water or restrict their water use. When such mechanisms are in place and functioning, farmers are motivated to adopt more conservation measures proactively.

Water conservation goals are limited by the intensive cultivation of water intensive crops, thus ensuing overuse of water. The findings indicate that most farmers in the study area use more water than crop needs. Heavy electricity subsidies have encouraged deep tube well installation despite the area's hydrologic characteristics. Since the farmers do not bear the electricity charges of working the irrigation pump sets, they rarely pay attention to using water wisely. Most of these farmers tended to behave in such a way that they would keep the irrigation pump sets on without any regulation. Pumping of irrigation water was stopped not when the irrigation was adequate but according to the time they returned to their field after other allied works. The vast majority of farmers planted roughly 2000 plants per hectare and typically irrigated their banana plants in two rounds for one irrigation. With a brief break in between, they run pump sets continuously from morning to noon and from noon to dusk without any control.

Unchecked extraction for agricultural purposes and heavily subsidized power tariffs have decreased groundwater levels significantly (World Bank, 2010). The Government of India had approved provisions for charging industry and domestic users a groundwater conservation charge (GWCF) from June 1, 2019, for consumption above a specific threshold. Groundwater used for irrigation, which uses the majority of it, is exempted (Koshy, 2018). Unrestricted groundwater consumption for irrigation would presumably continue. If the viability of the power sector and sustainable water supplies are considered, the growing reliance on groundwater is a serious concern. For the irrigation sector to avoid overusing groundwater, there must be regulation in its use. With regulation in practice, farmers would restrict their water use and increase water use efficiency. The consensus is that farmers will be pushed to increase water use efficiency and conservation when power and water prices rise or are done. The water regulatory authority should regulate various water usage and their pricing. Rajaraman (2005) examined the cost of irrigation water in the Indian state of Karnataka and identified local user groups as a potential solution for enacting a flat tariff and monitoring any unauthorized water trading.

A study in China suggested that farmers should pay not only the irrigation water rates but also the pumping costs of water (Webber *et al.*, 2008). According to Chaudhuri and Roy (2019), a volumetric water pricing system should be implemented, and automatic metres should be utilized to charge for the actual volume of water used. However installing water metering in each and every farm is difficult in a vast country like India.

Kerala introduced irrigation water prices in 1974, even though the first water policy was only enacted in 1987 (CWC, 2013). However, even now State still lacks relevant studies and understanding of the 'water pricing' themes. In the case of water tariffs in Kerala, the minimum charge for monthly consumption above 50,000 litres of water was only ₹ 500 (₹ 1 paisa/litre), wherein later, Kerala Water Authority hiked the water prices in the State by ₹ 1 paisa per litre in 2023 to bring down consumption of water (Anonymous, 2023).

If the revenue collection process is not improved and streamlined, the rationalized irrigation water pricing structure alone will not be sufficient. In most states, there is a significant discrepancy between the revenue assessed and the money received by the government (Parween *et al.*, 2021). This could be seen in the case of Kerala before the revision of the water tariff where, for the distribution of 1000 litres of water, the revenue received was ₹ 10.92, and the loss incurred was ₹ 11.92, indicating the lacunas in the revenue collection of Kerala WaterAuthority. Improving the supply side is one strategy for achieving the irrigation sector's dependability. A different approach may be to control the water demand in the agricultural sector. Options for demand management and market mechanisms include the implementation of reasonable irrigation water pricing, the development of water markets, the strengthening of water rights systems, the revision of energy bills and supply regulations, and promotion and incentives for the adoption of contemporary water-saving technologies like micro irrigation systems (Parween *et al.*, 2021).

The issue requires effective legislation to restrict water intensive crops in water-scarce areas, which can be accomplished with the aid of agricultural plans and water budgeting. Adopting water budgeting and pricing at the state level following cropping patterns would be much more feasible and attainable because water management and the growth of the water sector will be under state control.

Water metering is also one of the solutions to efficiently minimize water wastage. Farmers' water usage for irrigation and other agricultural purposes can be measured and tracked with water metres.

Farmers may optimize their irrigation methods, minimize over watering or under watering, and ensure that water is utilized only as much as required by precisely measuring their water usage. It also results in less waste and better water efficiency. It also helps the farmers to rationalize the wateruse without affecting crop output. Any inefficiencies like leakages or overuse of water can be effectively tracked through metering.

Farmers can lower their overall water costs and maximize their cost savings by applying water conservation measures based on the data provided by metres. By giving precise records of their water consumption, water metres assist farmers in proving their adherence to water usage rules. It makes water management more transparent and accountable, essential for preserving agricultural operations' long-term viability and sustainability. Farmers can see trends, improve irrigation plans, and use precision agriculture by tracking water use data over time. This data-driven strategy supports sustainable agriculture practices, increases production, and reduces resource waste.

Summary and Conclusions

5. SUMMARY AND CONCLUSIONS

The present study entitled “Irrigation water: Assessing the economic efficiency and its pricing in banana” analyzed the sources of irrigation, private investments in irrigation and irrigation patterns, economic efficiency of irrigation water and assessment on its pricing on banana.

The study was based on both primary and secondary data. Thrissur district in Kerala was purposively selected since it had the state's most reported private wells. Kodakara and Chalakudy, blocks of Thrissur districts, were purposively selected owing to the highest share of cropped area under banana. These blocks were also reported to have the highest groundwater extraction in the district. Sixty farmers from each block who irrigated banana using pump irrigation was randomly selected to make up a sample size of 120. The secondary data was collected from the Government of India and Kerala publications, the Department of Statistics and Planning, the Department of Agricultural Economics and Statistics, the Land Use Board, Thrissur, and the Block Level Statistics.

The socio-economic characteristics of the respondents, like age, gender, education, annual household income, experience in farming, land holding size, and ownership of land, were analyzed using the primary data. The respondents were grouped into five categories based on their age, and it was found that 40 per cent were aged between 51-60 years. Only 4 per cent of the sample correspondents had aged between 30-40 years, highlighting the reluctance of young farmers to take up banana cultivation. It was found that 40 per cent of the respondents possessed only secondary school education, and 35 per cent of the correspondents had experience of 10-20 yearsin cultivating banana. Ninety-one per cent of the sample respondents were marginal farmers with land holdings of less than one hectare. The annual income of nearly 43.3 per cent of the respondents was between ₹ 1,00,000 - ₹ 2,00,000 per year. The majority of the sampled farmers (61%) had a medium-sized family of 4-6 members. The surveyed farmers' categorization based on land ownership was also done; 58.3 per cent of the respondents cultivated banana on their own land, whereas 41.7 per centleased in land for banana cultivation.

Different sources of irrigation for banana, such as private wells, ponds, canals and rivers, were identified in the study area. The majority of the farmers used private wells for irrigation, and the different irrigation patterns found in the study area were surface irrigation, drip irrigation and sprinkler irrigation. Most farmers relied on surface irrigation since management was easy and only simple accessories were required for its operation. Only a few farmers practiced drip and sprinkler irrigation mainly due to its high initial investment cost and maintenance problems such as clogging and breakage of drip lines. Moreover, many farmers found it challenging to apply bulky organic manures to the root zone of banana with drip lines installed.

Private investments in irrigation for banana was also calculated separately for owned and leased farmers by considering the depreciation costs, including amortized cost on the well, amortized cost of the irrigation pump set, the amortized cost of conveyance structure and amortized cost of storage structure along with the miscellaneous cost. For leased land, the amortized cost of the well was excluded. The private investments in irrigation for owned and leased land accounted for ₹ 19,479 perhectare and ₹ 8183 per hectare, respectively.

Regression analysis was done using MS Excel to produce the Cobb-Douglas production function to find the yield determinants of banana cultivation. The quantity of water applied, quantity of manures and fertilizers and human labour were found significantly influence the returns from banana at a one per cent level of significance. The fitted regression equation had an adjusted R square value of 78.31 per cent, and the returns to scale were decreasing. The analysis result showed that for a percentage change from the mean value in the quantity of water applied, the yield increases by 0.46 per cent. Similarly, for a percentage change in the mean value of the manures and fertilizers, the yield increases by 0.28 per cent. Banana yield increases by 0.37 per cent when a percentage change from the mean value of human labour is made. Thus it was concluded that the quantity of water applied, quantity of manures and fertilizers and human labour significantly enhanced banana yield.

The economic efficiency of irrigation water used in the study area was analyzed using the Data Envelopment Analysis Program (DEAP) software. The results showed the technical, allocative and economic efficiencies of irrigation water. The technical efficiency values ranged from 27 per cent to 100 per cent, with a mean value of 61 per cent suggesting ample scope in increasing the technical efficiency of irrigation water (39%). Whereas the allocative efficiency ranged from 27 per cent to 100 per cent with a mean value of 87 per cent showing an increase of 13 per cent could be made. Economic efficiency is the product of technical and allocative efficiency, and the values ranged from 26-100 per cent with a mean value of 53 per cent. It indicated an increase of 47 per cent in economic efficiency can still be made to achieve the optimum level. Classification of farmers according to the economic efficiency of irrigation water showed that 32.5 per cent of the farmers had an economic efficiency ranging from 50-60 per cent.

In order to assess whether the study area overuse or underuse the irrigation water, the present research results were compared with a study conducted at Agriculture Research Station, Chalakudy, on System intensification for better productivity in banana (Nendran) during 2009-2014. According to their study result irrigation water requirement of banana (10 mm CPE- Cumulative Potential Evaporation) was found to be 20 litres per plant per day. Hence for an average of 1373 plants per hectare, 1.3×10^3 m^3 per hectare irrigation water is required. But the average irrigation water usage of the study area using the primary data was found tobe 2.4×10^3 m^3 per hectare, clearly showing an overuse of 1.1×10^3 m^3 per hectare. This overuse is mainly attributed to the surface irrigation method and poor motivation towards the importance of water conservation.

The cost and returns of banana cultivation were analyzed using ABC cost concepts. The total cost of cultivation for banana was worked separately for owned and leased farmers. The total cost of banana cultivation was found to be ₹ 4,80,877per hectare for owned farmers, whereas, for leased farmers, it accounted for ₹5,04,066 per hectare with net returns of ₹ 2,61,981 (owned) and ₹ 3,22,089 (leased), respectively. In both cases, hired labour had the biggest share in the total cost of cultivation (22.69% - owned, 23.93% - leased). The average yield of banana per hectare from the owned and leased land was found to be 19,418 and 20,169 kg, with cost of production of ₹ 24.7 and ₹ 23.3 per kg of banana. The benefit-cost ratio was 1.5 and 1.6, respectively, indicating that banana cultivation was stable and profitable.

The marginal pricing of irrigation water under the study area was analyzed using the Cobb-Douglas production function, and the marginal value was found to be ₹ 22.31 per m^3 of water used. Hence in monetary terms, it can be stated that farmers currently use irrigation water, which has a value of ₹ 53544 (2.4×10^3 m^3 per ha), where only ₹ 29003 (1.3×10^3 m^3 per ha) is required. An extra ₹ of 24530 can be considered as the potential savings that can be made by limiting the use of irrigation water as per the requirement of the crop. This will have a positive result not only on monetary terms but also in conserving the natural resource, water. The ratio of MVP to MFC for the quantity of water applied was also found to be 0.8, which indicated the overutilization of the irrigation water applied. For the purpose of increasing the economic efficiency and pricing of irrigation water used for banana cultivation, the following policy recommendations are proposed:

- Farmers can be encouraged to increase micro-irrigation (MI) and water-saving technologies to produce more crop per drop of water. Location-specific demand- supply scenarios should be considered when prioritizing sites to spread micro- irrigation techniques. Since many of the farmers in the study area showed reluctance to adopt MI technologies due to its high initial installment costs and maintenance problems, it may be financially assisted by the Government and capacity-building sessions on managing MI technologies should also be provided to the farmers.

- The problems of small farms regarding scale economies, financial limitations, and post-installation servicing requirements must be addressed in MI development initiatives at the local level. Ensuring competition among different businesses can assist in developing irrigation systems with desirable properties suitable for small farms at a cheaper cost. Water recharging and recycling must be considered a crucial component of the overall plan for developing water resources and connected to the funding programmes supporting MI. Additionally, subsidy programmes can be revised over time to provide water conservation and savings incentives. MI projects may be a valuable adaptation and mitigation tactic in the context of climate change and water stress.

- Most farmers irrigate banana using their private wells, they neither have to pay for the water nor the electricity charges, which results in its indiscriminate use. Such irrigation related energy use contributes to greenhouse gas emissions. Electricity prices for agricultural activities are subsidized in the state. This leads to over exploitation of both energy and water. Hence a power tariff policy with a view to long term sustainability can be considered to regulate the over consumption of energy.

- Promoting extension and awareness initiatives for farmers and grass-roots field functionaries about irrigation scheduling, water management, and crop alignment. Farmers can be made aware that inefficient irrigation practices can be harmful to the environment. Over irrigation can cause water logging, salinization of soils, and groundwater depletion.

- Promoting community based water harvesting systems can be done in the study area since these two blocks have the district's highest groundwater extraction rate. Diverse water sources, including rainwater harvesting, should be taken advantage of wherever possible to maximize irrigation efficiency.

- Management and development of the water sector are under state control, introducing water budgeting and water metering in policies might enhance irrigation efficiency.

Plate I: Survey with farmers- Kodakara

Plate II: Survey with farmers- Chalakudy

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Appendices

APPENDIX I
Kerala Agricultural University

Irrigation water: Assessing the economic efficiency and its pricing in banana in Thrissur district

Questionnaire for banana cultivating farmers

Block: Panchayat: Date:

1. Socio-economic details of the farmer:

A. Name of the respondent :

B. Age :

C. Gender :

D. Address :

E. Contact number :

F. Educational qualification

- **a.** Below SSLC ☐
- **b.** SSLC ☐
- **c.** Plus Two ☐
- **d.** Diploma ☐
- **e.** Graduate & Above ☐
- **f.** Specify (If anyother)……………… ☐

G. Experience in farming (years) :

H. Number of members in a family :

2. Income details:

A. Annual income

<1 Lakh	**1 Lakh-2 lakh**	**2 lakh- 3 lakh**	**3 lakh- 4 lakh**	**>4 lakh**
☐	☐	☐	☐	☐

B. Source of income:

a. Farming alone

b. Farming+ Business

c. Farming + Government job

d. Farming + Self employed

e. Specify, if any other : ____________________________

3. **Family details**

SI No	Name	Relationship with respondent	Age	Education	Occupation

4. **Land details:**

Ownership status	Total (Acres)
Own land	
Leased-in	
Leased out	

Land	Rental Value	
	Per Acre	Total
Leased in		
Leased out		

Specify, if any other: ____________________________

5. Cropping pattern followed

6. Crop details:

Sl. No.	**Crop and Variety**	**Area (acres)**	**Yield (Kg)**	**Spacing**	**Price realized Rs/Kg**	
					Current year	**Previous year**
1						
2						

7. Source of irrigation

A. Rainfed ☐ B. Irrigated ☐

If irrigated, through which source?

a. Canal ☐

1. What is the distance from canal to the field?
2. What is the width of the canal?
3. How much area is irrigated using canal water?
4. How much time does it take to reach water from canal to field?
5. For how long the canal water is used?
6. Source of water for the canal

b. Open well ☐

1. Depth of the well :
2. Age or life of well :
3. Motor power :

c. Bore well ☐

1. Age or life of borewell :
2. Depth of the well :
3. Motor power :
4. Amount of water received at the main field :

d. **Others** ☐

8. Type of irrigation

A. Flood or Furrow irrigation

  1. Width of the furrow :
  2. Length of the furrow :
  3. Depth of the furrow :

B. Drip irrigation

  1. No of emitters per plant :
  2. Discharge of each emitter :
  3. Time of pumping :

C. Sprinkler

  1. No of sprinkler head :
  2. Discharge of sprinkler :
  3. Time of pumping :

D. Trench

E. Others

9. Investment for irrigation

1. Cost of pump set :
2. Repair cost of pumpset :
3. Cost of conveyance structure :
4. Age of pumpset :
5. Cost of construction of tanks :
6. Cost of hose and accessories :
7. Cost of drip and installation, if installed any :
8. Cost of pump house:
9. Age of pump house

10. Irrigation frequency

A. Frequency of irrigation

B. Working hours of motor per irrigation:

C. Number of irrigation per season:

11. Cost of cultivation

Cultivation practice	Labour cost			Machine cost	Qty	Unit price	Total cost
	Male	Female	Total				
Planting							
Planting material							
Manures and Fertilizers							
Irrigation							
Weeding							
Plant protection							
Propping							
Harvesting							

12. Constraints, if any in availability of water for irrigation

APPENDIX II

Sources of secondary data with duration

Particulars	Period	Sources
Spatial data of sources of irrigation in the study area	2023	Land Use Board, Thrissur
Hydrology and drainage of Thrissur district	2019-2020	Central Ground Water Board (www:cgwb.gov.in)
Major and minor irrigation scheme in Thrissur district	2019-2020	Central Ground Water Board (www:cgwb.gov.in)

IRRIGATION WATER: ASSESSING THE ECONOMIC EFFICIENCY AND ITS PRICING IN BANANA

By

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ABSTRACT OF THE THESIS

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ABSTRACT

Water has distinct properties that influence both its allocation and use as a valuable resource in agriculture. Irrigation is a critical component of agricultural production. According to the UNESCO World Water Development Report (2022), India is the world's top groundwater extractor. About 80 per cent of all withdrawals are made in the agricultural sector, and India has a low irrigation efficiency of 38 per cent when compared to developed nations (GoI, 2018). When water, the elixir of life, is becoming scarce due to over exploitation, increasing or at least maintaining its efficient use is imperative.

In order to achieve effective and equitable use, the Fourth Principle of the Dublin Declarations of 1992 defines water as an economic good. It encourages the conservation and protection of water resources. With the adoption of the Fourth Dublin Principle, there was a historic shift in the focus on the economic aspects of water use in general and irrigation development in particular. Numerous researchers have looked into water valuation as a tool for managing irrigation systems, reducing water consumption, and improving water allocation. Hence, evaluating irrigation water's economic effectiveness and value becomes relevant in the current scenario. It is in this context, the study was carried out with specific objectives *viz*., identifying the sources of irrigation, private investments for irrigation and irrigation pattern, estimating the economic efficiency of irrigation water and making an assessment of its pricing.

The study was based on primary data collected from Kodakara and Chalakkudy blocks of Thrissur district owing to their maximum share of cropped area under banana and groundwater extraction in the respective blocks. 60 farmers from each blocks using pump irrigation as a source of irrigation in banana cultivation are randomly sampled to make a total of 120 sample respondents.

The sources of irrigation in the study area were found to be wells, tube wells, ponds, canals, and rivers, wherein most of the farmers relied on wells for their irrigation.

The irrigation pattern of the study area included surface irrigation, drip irrigation, and sprinkler irrigation. Most farmers use surface irrigation method due to its easy management. Drip and other micro-irrigation techniques were less adopted due to their high initial investment costs and maintenance problems. The Private investment for banana farmers cultivating banana on owned and leased land was calculated by considering depreciation and miscellaneous costs. It accounted for ₹ 19,479 per hectare for owned land and ₹ 8,183 per hectare for leased farmers.

The cost of cultivation for banana cultivation was worked out separately for owned and leased farmers using ABC cost concepts. The total cost of banana cultivation was found to be ₹ 4,80,877 per hectare (owned land) and ₹ 5,04,066 per hectare (leased land) with net returns of ₹ 2,61,981 and ₹ 3,22,089 per hectare, respectively. The benefit-cost ratios were found to be stable, with 1.5 (owned land) and 1.6 (leased land), respectively.

The determinants of yield in banana cultivation were analyzed using the Cobb-Douglas production function. The yield of banana was regressed with different variables like the quantity of irrigation water applied, manures and fertilizers, human labour and plant protection. It was found that the quantity of irrigation water, manures and fertilizers and human labor as the major determinants of banana cultivation.

The economic efficiency of irrigation water in the study area was assessed using Data Envelopment Analysis Program. The analysis showed that the technical, allocative and economic efficiencies had a mean values of 60.9, 87.1, and 53 per cent. Analysis revealed that there exists scope for increasing the efficiency of irrigation water in the study area.

The average quantity of irrigation water currently used in the study area was 2.4×10^3 per hectare for 1373 plants per hectare, which was compared with the study results carried out in Agricultural Research Station, Chalakudy, to determine whether irrigation water is being overused or underused. The study was conducted during 2009-

2014 on system intensification for better water productivity in banana (Nendran) (ARS Chalakudy, 2021). The study results showed that irrigating crops at 100 per cent irrigation (10 mm CPE- Cumulative Potential Evaporation), *i.e.,* 20 liters of water per plant per day, is required for the banana to increase the bunch yield per plant significantly. The study found that the water required was 1.3×10^3 m^3 per hectare (1373 plants/ha). On comparing it with the results of the present study, an overuse of 1.1×10^3 m^3 per hectare was found in the study area. It is mainly attributed to the surface irrigation method followed in the study area.

The marginal pricing of irrigation water under the study area was analyzed using the Cobb-Douglas production function, and the marginal value was found to be ₹ 22.31 per m^3. The ratio of MVP to MFC for the quantity of water applied was also found to be 0.8, which indicated the overutilization of the irrigation water applied.

Thus, the farmers in the study area are currently overutilizing the irrigation water, and the mean economic efficiency of the farm was only 53 per cent, wherein improvement can be made by promoting the use of micro-irrigation technologies such as drip instead of surface irrigation. Also, promotion of extension and awareness activities relating to water harvesting, irrigation scheduling, water management, and crop alignment for farmers and grass root level field functionaries has to be carried out to enhance the irrigation efficiency of the farms in the study area.