WATER CRISIS IN COASTAL AREAS: DOMESTIC ADAPTATION STRATEGIES AND IMPACT ON AGRICULTURE SECTOR

By

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(2016-11-084)

THESIS

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DECLARATION

I hereby declare that the thesis entitled **"Water crisis in coastal areas: domestic adaptation strategies and impact on agriculture sector"** is a bonafide record of research done by me during the course of research and that it has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

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INTRODUCTION

Water scarcity is predicted to be worst in many regions and countries around the world, especially in the arid and semi-arid regions which results in deterioration of water quality as well (Dalezios *et al.*, 2018). It is reported that, 47 per cent of world population would be living in areas of high water stress, by 2030. Two-third of the world population would face severe water scarcity by 2025 due to population growth, unsustainable consumption patterns and uncontrolled water usage **(**UN, 2018; Chellaney, 2016). Around 2.4 billion people in Sub-Saharan Africa are already living with the most heterogeneously distributed water resources and the safe drinking water supplies in the region continues to dwindle due to unregulated water usage and water pollution (Naik, 2016). In Africa, 93 per cent of communities do not have access to groundwater and they need to depend totally on variable rainfall by 2020 (Niang *et al.*, 2014). The fresh water availability in the world is expected to fall by 50 per cent in 2030 (Prochazka *et al*., 2018).

India, like many other countries in South Asia, experience acute water scarcity and it was predicted that India would suffer from water stress with annual water availability of less than 1000 cubic meters per capita by 2025, and gross availability could fall as much as 37 per cent by mid-century (Gulati and Banerjee, 2016). In the past 50 years, per capita water availability decreased by 70 per cent in South Asia, with India's per capita availability decreasing from about 5200 m^3 in 1951 to 1588 m^3 in 2010 (Varma, 2011).

Kerala, the South Western coastal region of India is gifted with nature's bounty of water resources and rainfall. Indian Meteorological Department reports a declining trend in South West monsoon rainfall in the state during the most recent 60 years (IMD, 2013). Nair *et al.* (2014) also reported a declining monsoon trend in Kerala over last

100 years. During the summer months, several regions in Kerala encounters a seasonal drought like conditions every year. The summer period receives just around 15 per cent of the annual rainfall, though the demand during this period is high as 75 per cent of the annual requirement. It was reported that the total water demand during the summer months was about 21.5 km^3, while the accessible supply was only 14.3 km^3, posting a shortage of about 7.1 km^3, even after accounting for 5.5 km^3 of surface water available in dams (GoK, 2013b). From 1881 to 2000, the state has experienced 66 drought years (KSDMA, 2016). The per capita availability of water (1248 m^3/ person/ year) in Kerala, is less compared to several dry areas like Rajasthan (1829 m^3/ person/ year) and it has been declining over the years as the population increases (Devi *et al.,* 2015). The threshold level acknowledged by Central Water Commission for water requirement is 1700 m^3/ capita/ year (CWC, 2017).

The impacts of water scarcity vary across sectors, communities and regions. As per the estimates, out of the total global fresh water withdrawals of 3918 km^3, agricultural sector (69 per cent) is the major consumer of water, followed by industrial (19 per cent) and domestic sector (12 per cent). Among these sectors, agricultural sector is predicted to be the most sensitive and worst affected by the scarcity of water resources than any other sector (Devi *et al.,* 2015). The scarcity conditions may cause the shift in the sectoral demand/ use both due to quantity restrictions and quality concerns. For instance, the water scarcity situation in coastal zones are mainly due to quality aspects like salinity, colour change and hardness.

In Kerala, the coastal region with a total length of 560 km suffer from all these problems at varying levels. One of the potential impacts of global climate change in coastal Kerala are salinity intrusion into aquifers and wetlands (Thrivikramaji, 2008). There could be an increased coastal erosion, inundations, persistent storm events, shifts in wetlands, incursion of saline water into fresh water aquifers (GoK, 2014b). The region is one of the most vulnerable region in the country due to projected sea level rise. Around 212 sq. km of wetland could be lost with 0.5 meter increase in sea level in the state (Dwivedi and Sharma, 2005). The salinization of coastal environment is the major issue which often limits the fresh water supply. It has been reported in Ernakulam, Thrissur and Alleppey districts (Kumar *et al.,* 2015). Major livelihood activities for the coastal population are fisheries, agriculture, aquaculture, horticulture, tourism, boat building, traditional manufacturing units and allied activities. The population pressure as well as subsistence activities in the coastal region infringe on the environmental quality especially on the groundwater sources. Several reasons like loss of large extend of rivers, wetlands and paddy fields, over-exploitation of available resources and pollution have contributed to the water scarcity (Varma, 2011).

The study focus on the water scarcity related issues in coastal areas, taking the case of coastal belt of Thrissur district. The specific objectives of the study are:

- To analyse the dimensions of water scarcity and the level of understanding of the same among coastal communities
- To identify the adaptation strategies to address the water crisis
- To identify the economic burden on households and the impact of scarcity on agriculture sector

Scope of the study

Coastal zone of the state is marked by relatively high population density and highly vulnerable to the impacts of sea level rise. The study would help to understand the intensity and different dimensions of water scarcity problems of coastal zones. The study can also help in developing different coping mechanisms for reducing water crisis in the coastal regions in precaution to future stress situations. It can also help to build up an awareness on appropriate coping mechanisms and develop capacity of farmers, extension workers, community leaders, and agro meteorologists to address the water crisis issues and its impact on coastal agriculture. The assessment of economic burden on adaptation on account of adaptation to water crisis at farm level would help to formulate policies and support mechanisms to help the farmer to overcome such burden. The results of this study help to formulate policies and support mechanism for efficient water use in the domestic and irrigation sector.

Limitations of the study

The present research work is a part of post graduate programme which has all the limitations of time, finance, mobility and other resources. The study is restricted to the coastal areas of Thrissur district. Thus, it may not be possible to generalise the findings of the study for the entire state and can only be taken as indicative in nature. Data was collected from farmers based on their memory and the chance of recall bias is high. In spite of these limitations, every effort was made by the researcher to carry out the study as possible.

Presentation of the thesis

The thesis is divided into five chapters. The present chapter gives the introduction to the research problem, covers the scope, objectives and states the limitations of the study. The second chapter deals with review of literature, relevant to the study. The third chapter details the study area, the methodological framework, analytical tools and conceptual issues. The fourth chapter narrates the results and also discusses the results in detail. The fifth and final chapter presents summary and policy prescription based on the study. The references and abstract of the thesis are given at the end.

REVIEW OF LITERATURE

Chapter II

REVIEW OF LITERATURE

Review of past studies helps for developing the concepts, methodologies, and analytical tools relevant to the study. This would enable the researcher for improving analytical framework and helps to evaluate the hypothesis and objectives of any study. In this chapter, an attempt has been made to review the past studies under following three subheadings

- Water crisis and dimensions
- Coastal communities, coastal agriculture and impact of water stress on agriculture sector
- Adaptation strategies

2.1. Water crisis and dimensions

Water scarcity is one among the major issues to be faced by the world in the 21st century. Water scarcity is commonly defined as a situation where water availability in a country or in a region is below 1000 m^3 per person per year. There are several regions which experience much severe scarcity, living with less than 500 m^3 per person per year, which could be considered severe water scarcity. The water stressed regions are under a threshold level of 2000 m^3 per person per year. Imbalances between availability and demand, degradation of surface and groundwater quality, inter-sectorial competition, inter-regional and international conflicts, further enhances the water crisis (Rijsberman, 2006).

However, population growth is the major reason for water crisis. Cosgrove and Rijsberman (2005) estimated that the world population has tripled in the 20th century, but water use has increased six fold. According to WHO estimates there are 1.2 billion people lack access to safe and affordable water for their domestic use. In rural areas alone, a large part of the 900 million people that have an income below one dollar per day poverty line are under the water crisis and they lack access to water for livelihoods (WHO, 2003). Hence, water crisis leads to the global challenges from health to malnutrition, poverty and sustainable natural resource management.

The studies on global scarcity analysis proposed that two-thirds of the world population is affected by water scarcity over the next several decades especially in the areas with low rainfall and relatively high population density (Shiklomanov, 1991; Raskin *et al.*, 1997; Seckler *et al.*, 1998; Alcamo *et al*., 1997; Vorosmarty *et al*., 2000; Wallace, 2000; Wallace and Gregory, 2002). In the physical sense, the countries in the arid zones especially Central and West Asia and North Africa are nearly or below the threshold level of 1000 m^3/capita/year are the most water scarce regions.

Several studies were predicted that more than half of the world population i.e around 4 million people living in the countries will be facing high water stress by 2025. Based on Shiklomanov's analysis on his forecasts of rising demands reported that the water withdrawals will rise by 25 per cent between 2000 and 2025 from 4000 to 5000 cubic kilometer (Cosgrove and Rijsberman, 2000). The future demand for water is highly correlated with the lifestyles as well as the assumptions on values of the next generation (Gallopin and Rijsberman, 2000).

A recent study conducted by Seckler and his co-workers (1999) on projection of water supply and demand for 118 countries for the period 1990 to 2025, concluded that within the first quarter of the 21st century, a major part of the regions in the developing countries would experience water scarcity. Despite the scarcity problems, it challenges the water quality and pollution. It has been observed that most of the poorest people are forced to consume the unsafe water ultimately leading to the skin and sanitary diseases due to the polluted water. However experts has mentioned that, for the well-being of the public health, quantity of water is even more important than the quality of water (Seckler *et al*., 1999).

It was reported that in most of the countries, usable water resources were always less than the potential water resources that ultimately lead to the water crisis in the country. For example, in Spain, usable water resources are less than half of the total fresh water resources. The average annual potential water availability per capita, even considering the total freshwater resources in southern Mediterranean countries is less than 1,000 m^3 per capita per year. In Mediterranean countries, water scarcity problems are mostly derived from population dynamics, upgraded standard of living, economic and social development, and the use of water consuming technologies. Population growth and human activities also challenges quantity and the quality of the surface water and groundwater resources. Due to more demand than its availability, water scarcity crisis is common in the countries like Egypt, Israel and Libya (Iglesias *et al*., 2007).

It is important to bring focus to the effects of water quality as well as water quantity in the era of water scarcity. The concepts behind the water scarcity is of two types *i.e.* natural and man-made scarcity. Natural scarcity is associated with arid and semi-arid climates and drought whereas man-made scarcity results from desertification and improper water management. The available water when contaminated with salts, along with untreated municipal and industrial effluents containing toxic substances and heavy metals, are unsafe for drinking and other purposes which may leads to the exploitation of other water resources. Consequently, the water scarcity problem arises in such region (Pereira, 2002). Fresh water crisis rapidly raised the global challenges across the world, from health to malnutrition, poverty and sustainable natural resources management. The lack of water has a major negative impact on poorest people for productive purposes leads them to result in malnutrition, poverty and ill health (Rijsberman, 2006).

There are several reports that show a decline in the groundwater resources around the world, especially in the South and South-East Asia including India. The groundwater table showed decline in almost all canals in Pakistan since 1998 (Bhutta and Alam, 2005). In northern China, serious environmental problems were also reported due to the groundwater exploitation more than the allowable limits, which led to rapid fall in groundwater table at a rate of more than one meter every year in the past two decades. Exploitation of water resources in large scale and the development activities has led to tremendous changes in the water regime. The groundwater abstraction was increased by six times that has been resulted in the decline in groundwater table i.e. about 3-16 meters with a maximum decline of 45 meters. As a result, serious human activity-induced environmental problems, such as water quality deterioration, vegetation degradation, soil salinisation and land desert desertification were raised (Ji *et al.*, 2006).

As per Introgovernmental Panel on Climate Change (IPCC) climate change has considered as the most conspicuous threat on water sector around the world. During the past 100 years, precipitation has decreased by 50 per cent due to the climate change (Cepada *et al.*, 2004) and by 2059, the average precipitation is expected to decrease by 30 per cent. Several prolonged droughts are also predicted in upcoming decades (Downing, 1992; Cepada *et al*., 2004; Souvignet *et al*., 2008). The surface temperature is expected to increase by 3.7^{0}C to 4.8^{0}C compared to preindustrial periods where it leads to the decline in the fresh water sources and quality. It was predicted that the annual average river runoff and water availability are expected to decrease by 10-30 per cent by the middle of the 21^{st} century over some dry regions at mid-latitudes and in the dry tropics. Under the existing situation, seven per cent of global population is expected to the reduction in the renewable water resources of at least 20 per cent for each degree of global warming (IPCC, 2007).

Rijsberman (2006) observed that ‘water’ is going to be a key limiting factor in food production and livelihood generations in rural Asia and most of Africa, North-West India and Northern China. As per the Falkenmark indicator, the quantity of water need per person to satisfy our daily needs in the coming decades is not fixed. It is safe to assume the future water scarcity problems in the coming decades.

The Second World Water Forum in Hague confirmed the emerging serious threat of water crisis for the mankind (IEP, 2010). India, with the 18 per cent of the global population has only 3.55 per cent of the total freshwater resources. It has estimated that the country has only 1080 km^3 total renewable freshwater resources (Vaidyanathan, 2013). Kerala is a coastal state bestowed with abundant rainfall. The average rainfall of the state is 2943 mm/year which is about three times more than the national average. Despite high rainfall, the water retention capacity in Kerala is very low due to the geographic pattern as well as luxurious water usage by the people. Thus annual surface water and ground water potential is very low (Rao, 2008). The report shows a declining trend of monsoon and annual rainfall for the past 60 years.

However, recent years have witnessed unprecedented water scarcity, mostly attributed to climatic and demographic forces in play. Sarun and Sheela (2018) stated that Kerala is moving from wetness to dryness and reported declining water table. This is more pronounced in the coastal belts of Kerala where qualitative dimensions of water assumed paramount importance. Such as the dimensions, impact and management strategies required in the coastal areas are quite different from other parts and require detailed research.

2.2. Coastal communities, coastal agriculture and impact of water stress on agriculture sector

A coastal zone is defined as a "geographic region consisting of the "long narrow boundary between land and ocean that is a dynamic area of natural change and of increasing human use". A coastal zone forms a continuum between terrestrial and marine oceanic ecosystems. Coastal area is viewed as a "receptacle": salinity changes, algae blooms, toxicity and sedimentation (Vernier, 2012). Population growth, pollution, habitat degradation, multiple resource use conflicts and overexploitation of resources are the five major anthropogenic factors causing marine environmental degradation and depletion of coastal resources (Norse, 2005). Nayak (2000) opined that the coastal water quality is one among the critical issue in the perspective of coastal zone management.

A recent study by Mishra and Sahu (2014a) reveals that the unavailability of water due to the declining trend of rainfall along with the increasing trends of temperature for all the seasons for coastal Odisha has adversely affected farm level net revenue in the region. Another major issue faced by the coastal communities is the saltwater intrusion. It can be defined as the landward movement of saltwater, resulting in an increase of salt concentration in fresh groundwater aquifers. The impact of saltwater intrusion into coastal areas was reported in several regions (Primavera, 1997; Ahmed and Troell, 2010; Flaherty *et al*., 2000). In the South-Western parts of Bangladesh, salt water intrusion has not only changed the productivity and the land use pattern, but also affected freshwater supplies for irrigation (Deb, 1998). The groundwater table has reduced drastically due to the withdrawal of groundwater through pumping and consequently fresh groundwater was contaminated by salt water (Barraclough and Finger-Stich, 1996; Flaherty *et al*., 2000). Sea level rise coupled with reduced flows from upland during winter season increases the saline water intrusion in to the land and salinity increase. Agriculture is the most vulnerable sector to saltwater intrusion, especially in coastal low-lying areas, and it has been assumed that some parts of coastal area experience underground saltwater intrusion by the next 30 years and it will decline the coastal agriculture (Hossain, 2013; Duan, 2016). The salinity of water affects plants adversely which leads to stunted growth, increased succulence, stunted fruits and stems and smaller leaves also. There are no crop plants that tolerate sea-water salinities of 35,000 mg/liter even yields of the most tolerant crops are affected when irrigation water salinities exceed 4000-5000 mg/liter (Bernestein, 1975).

India has a coastline of about 7,500 km and nearly 250 million people live within a distance of 50 km from the coast. The coastal zone has a huge diversity of coastal ecosystems like mangroves, coral reefs, sea grasses, salt marshes, sand dunes, estuaries, lagoons, etc., which are characterised by distinct biotic and abiotic processes. Coastal environment plays a vital role in nation's economy by virtue of the resources, productive habitats and rich biodiversity. The coastal population is dependent on fisheries, agriculture, aquaculture, horticulture, tourism, boat building, traditional manufacturing units and allied activities (Saha, 2017). Kerala is a coastal state with a total length of 560 Km of coastline with population density higher than the state average. Since most people live in the coastal area, population pressure is even higher and economic and subsistence activity infringe on the environmental quality of the region which has affected the groundwater sources too. Now, with the change in cropping pattern and agricultural practices, coupled with the construction of dams in high ranges, the farmers in the coastal belts have to pump water from the ground. This has resulted in the establishment of more bore wells and seriously affected the (fresh) water table in the coastal districts like Alappuzha. It has been reported that the coconut and paddy cultivation as an occupation has now been reduced to 12 per cent and 10 per cent, respectively. Over the years, the changes in the land use pattern in the coastal belt has been creating considerable negative effects on the ecology and sustainability of the ecosystem. The Pokkali paddy cultivation was very common in all the coastal villages during rainy season, which prevents the intrusion of saline waters into the land and also facilitates for fresh water infiltration to the ground (Sahi *et al.,* 2006).

Worldwide, agriculture is having highest water demand, hence impact of water stress was highly affected in this sector. Agriculture is the largest single user of fresh water, accounting for 70 per cent of human water use. However, irrigated agriculture provides the livelihood for most part of the world rural population and supplies a large portion of the world's food. The water requirement associated with food production for the staggering world population are huge. At present, irrigated agriculture is largely affected by the scarcity of water resources (Pereira, 2002)**.**

Australia is one of the major food producing country in the world. But, recent drought has changed agricultural and food production of the country. Emerging water scarcity problems and a greater demand for water by non-agricultural sectors attributed a worse impact on Australian agricultural production (Goesch *et al*., 2007). From 2001 to 2006, a drastic reduction in the irrigated area in the Murray–Darling Basin, was observed consequently, irrigated rice production was also fell from 1643 kilotonnes in 2000–2001 to 1003 kilotonnes in 2005–2006 and 18 kilotonnes in 2007–2008 (ABS, 2008). Climate change, especially variation in the seasonal rainfall patterns is the major constraint in Australia's agricultural regions. Drought related water scarcity broadly influenced Australia's most agriculturally intensive food producing regions, the gross agricultural output was reduced by 20 per cent or more and a significant impact on export earnings was also observed (Horridge *et al*., 2005).

A study conducted by Wittwer and Griffith (2011) revealed the economy-wide small region impacts during and after drought. Real gross domestic product was reduced by 20 per cent reduction in some regions though irrigation water trading and farm factor movements alleviated losses. Water stress during flowering, pollination and seed development stages are more critical than vegetative and late maturity stages. Providing water for the critical stages are very significant. Water management under limited availability, yields better along with other water management practices.

A recent study by Narayanan and Sahu (2016) noticed that delayed rainfall and no rainfall were the most serious implications of climate change that affect households in eastern coastal part of India. Another study by Xia *et al*. (2016) found the impacts of climate change on crop production in North China. Since monsoon continues to be a driving force, rainfall variation substantially reduces the agricultural production (Gautam, 2016). The story of rice production in Asia shows the declining water quality as well as water resources are threatening the sustainability of the irrigated rice based production system. Drought is one of the major constraint in rainfed rice cultivation. Thus it is essential to explore a new pace to increase the production with less water for food security and sustaining environmental health.

In the case of South Asian countries, it was discovered that overexploitation of groundwater in the last decades has caused serious challenges on agriculture. On an estimate, it has found that the average groundwater table fell down by 1–3 meter per year in the North China Plain, by 0.5–0.7 meter per year in the Indian states of Punjab, Haryana, Rajasthan, Maharashtra, Karnataka and northern Gujarat and Tamil Nadu. Eventually it leads to the economic burden for the farmers through increased costs of pumping, salinity intrusion, fluoride contamination, land subsidence and the formation of cracks and sink holes (North China Plain). These major groundwater depletion became one of the most challenging issue for China and other parts of South Asia (Postel, 1997; Shah, 2000).

In the Ganges delta of Bangladesh and eastern parts of India, overexploitation of groundwater resulted in wells falling dry during summer season which lead to the specific problem of appearance of Arsenic. There are evidences that shows the effect of water scarcity in irrigated rice areas in China *i.e*. it was reduced by 4 million during 1970-1990 (Barker *et al.*, 1999).

2.3. Adaptation strategies

Adaptation refers to a particular adjustments in a system to better cope with external stress. The potential or ability of a system to adjust to exposures in order to regulate damages, take advantage of opportunities or cope with effects (Smit *et al.*, 2000; Yohe and Tol, 2002; Adger *et al*., 2007).

Adaptations refers to adjustments in ecological-socio-economic systems in response to actual or expected climatic stimuli, their effects or impacts. Smit and Wandel (2006) specified adaptation in the background of human dimensions of global change usually refers to a process, action or outcome in a system (household, community, group, sector, region, country) in order to better cope with, manage or adjust to some changing condition, stress, hazard, risk or opportunity. According to IPCC (2007) adaptation is an adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Adaptation was mainly classified as anticipatory, autonomous, and planned adaptation. Adaptation that takes place before impacts of climate change are observed (or proactive adaptation) are usually known as anticipatory where adaptation that does not constitute a conscious response to climatic stimuli but is triggered by ecological changes in human systems (or spontaneous adaptation) are known as autonomous adaptations and at last adaptation as a result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return, maintain, or achieve a desired state are known as the planned adaptation (IPCC, 2007).

By increasing the adaptive capacity, the level of vulnerability can be decreased. Adaptive capacity changes among different countries, communities, social groups and individuals, and over time. The adaptive capacity of a community is closely associated with local processes and conditions which, in turn, are affected by socio economic as well as political processes. It is broadly influenced by assets and access to resources like economic wealth, technology, information, infrastructure, knowledge and skills, social capital and institutions (Watts and Bohle, 1993; Adger, 2003; Klein and Smith, 2003; Smit and Wandel, 2006).

Intergovernmental Panel on Climate Change (IPCC, 2007) defines adaptation costs as the costs of planning, preparing, facilitating, and implementing adaptation measures, including transaction costs. The costs of adaptation to climate change for developing countries was first estimated by the World Bank in 2006 that was ranged from $9 billion to $41 billion a year (WB, 2006). United Nations Framework Convention on Climate Change (UNFCC, 2007) described adaptation cost as the costs of both planned and private adaptation measures. The study considered the costs of adaptation by major sectors (agriculture, forestry, and fisheries; water supply; human health; coastal zones and infrastructure) rather than costs across all sectors which was estimated around $26–$67 billion a year by 2030.

Adaptation strategies adapted by the farmers are tend to be different. Large farmers adopts capital intensive coping mechanisms like drilling additional wells, deepening of existing wells and adoption of drip irrigation. Small and medium farmers resort to less capital intensive measures like dependence on water markets (Nagaraj *et al*., 2003). In agricultural sector, water management strategies include engineering measures like water distribution through pipes and micro-irrigation methods, management measures like irrigation forecasting and water scheduling and agronomic measures like deep ploughing, straw and plastic mulching and use of improved strains.

According to Luo and Lin (1999), adaptation strategies are mostly considered as a process that involving socio-economic and policy environments, producer's perceptions, and elements of decision making on the perspective of vulnerability. The standard approach for adaptation practices which is referred as the 'scenario approach' mostly involves the technical adjustments such as changes in cropping pattern, choice of different crops, adopting efficient irrigation systems for the impacts (Smit and Skinner, 2002; Wall and Smit, 2005).

It is accepted that groundwater recharge is the centric adaptation strategy as a precaution for the future water crisis in India. For strengthening groundwater which is a prime source of irrigation in the country, new check dams and other recharge structures should be constructed (Shah, 2009). Conjunctive use of groundwater and surface water is effective incorporated with irrigation water users to reduce total evapotranspiration and non-recoverable seepage which ultimately helps to increase agricultural production without compromising groundwater resource sustainability (Foster *et al*., 2010).

Under the declining groundwater scenario, eco-friendly and water economising technologies like drip irrigation, skip-furrow irrigation, trash mulching, irrigating at critical stages of growth and laser leveling of field and the use of stress tolerant varieties are promising methods for the sustainable production of the water intensive crops like sugarcane (Shrivastava *et al*., 2011). Susha (2011) studied the adaptation strategies to climate change followed by paddy farmers of Kuttanad and Kole regions of Kerala. Cultivation of improved varieties, crop rotation, adjustment of planting time and SRI (System of Rice Intensification) were major adaptation strategies. A study conducted by Kumar (2012) in Coimbatore region showed that, the adopters of drip irrigation could reduce the water requirement in banana by 150 per cent from 21317 to 8506 m^3 per ha. There was higher yield, gross income, yield per unit of water and returns per unit of water in the drip irrigated farms compared to farms where conventional irrigation systems were practiced. Similar attempt by Chandrakanth *et al.* (2013) in Karnataka reported higher net returns for tomato, mulberry and grapes (Rs. 2,696/-, Rs. 1,384/- and Rs. 4,723/- respectively) compared to that of conventional irrigation farms (Rs.1,040/-, Rs.525/- and Rs.769/- respectively). Similarly, net return per rupee water, net return per acre inch of water and net return per acre were higher for drip irrigated farms than conventional irrigated farms for all these three major crops.

Accompanying the demand and supply management strategies were seemed to be successful in Maharashtra state. Reduction in pumping by 5-10 per cent and improved recharge of 20-30 per cent could reverse groundwater decline in Bhima-basin region of Maharashtra. The states which are experiencing severe groundwater resource depletion, like Punjab has initiated policy measures such as incentivising shift from intensive cropping pattern, reforms in agricultural power sector and supply and demand side measures. The state also made an effort for crop diversification plan towards less water consuming crops like maize and cotton and a crop shift plan from paddy and wheat to maize, pulses, oil seeds *etc*. under central government scheme RKVY (Rashtriya Krishi Vikas Yojana) for attaining water sustainability. Water saving practices such as direct seeded rice, irrigation scheduling based on tensiometer readings and avoiding flood irrigation were also being promoted in the state. Shifting to crops like maize would reduce irrigation water use but profitability of the crop is also low.

Water saving practices alone would not ensure groundwater resource sustainability (Kaur *et al.,* 2015; Pandy, 2014).

Following fertigation through drip irrigation system helps farmers for the effective use of water and fertilizer while considering the intensive agricultural system. A study conducted in new alluvial zones of West Bengal revealed the economic viability of drip fertigation compared to traditional surface irrigation system in banana crop. It was discovered that water saving with drip irrigation was about 41.7 per cent and 40.4 per cent in plant and ratoon crop respectively. Moreover due to this technology, labour cost was reduced by 15-20 per cent (Pramanik *et al.,* 2014).

Farm responses are mainly classified as two types, short term decisions and long term decisions. Short term decisions are mainly used to mitigate an impact which is often called as ‘adjustments’ or ‘tactical responses. In case of long term decisions, a change in the feature of farm operation, such as the changes in the crop, livestock, even changes in the management system. Such changes often called as adaptations or strategic responses. These responses leads to a distinguishable changes in the farming system in long term perspective (Easterling *et al*., 1992b; Burton *et al*., 1993).

There are researches that shows adaptation to water stress can be done through proper investments in water management techniques. Several management approaches were adopted for improving the water productivity as well as reducing the soil evaporation (Rockstrom, 2003). These strategies involves capturing the available water and allowing it to infiltrate into the root zone and efficient water usage *i.e* increasing water productivity by improving the plant water uptake capacity and/or reducing nonproductive soil evaporation (Rockstrom *et al*., 2010).

Water harvesting is another important technological strategy to cope up with the water stress. It often distinguished as in-situ water harvesting (the capture of local rainfall on farm land) or ex-situ water harvesting (the capture of rainfall that falls outside the farm land) (Oweis and Hchum, 2001). In the context of excessive dependence on groundwater irrigation, rain water harvesting and crop-diversification in favour of less water intensive crops, watershed development and dry land farming are taken as the alternative policy options for sustainable growth in agriculture (Sasmal, 2014).

Water management problems are not only relevant to the water quantity but also the water quality. In the Mediterranean region, groundwater is one of the most discussed problem. Despite the result of overuse of aquifers and other anthropogenic activities, contamination of surface and groundwater bodies was mainly contributed from pesticides and optimisation of fertilization with crop uptake. As a long term strategies, for the drought management in the Mediterranean region, they promoted legislation with different perspectives and levels of integration into the overall water management policy. The early warning and monitoring system was also succeeded by the regional cooperation, moreover also by the awareness governments (Iglesias, 2007).

It has been discovered that access to safe water for all people is the key to a successful development strategy. Adequate amount of safe water is the most valued resource in reducing the poverty and diseases which also helps improvement in standard living of the poor people (UN 2006). United Nations Millennium Development Goals (MDGs) aimed at reducing the proportion of people without the access to clean water by 2015 (WHO, 2000). So that adaptive water management strategies along with the climatic variability should be properly screened for addressing future negative impacts (Mukhebir, 2007).

Urgency in securing relative water demand, in the developing countries, insufficient amount of clean water supply even in the water rich areas, and absolute scarcity in the arid and semi-arid tropics gradually increasing nowadays. Forthcoming global scale changes in population growth and economic development over the next 25 years, will challenge the future relation between the water supply and demand to a much greater degree. So that investments in the long term strategies and a regular hydrological monitoring are needed for a proper water management as an adaptive strategy (Vorosmarty *et al*., 2000)

California (USA) has successfully implemented tiered water pricing and incentive programme for a market based management strategy. Farmers were allowed to choose specific irrigation methods and management practices while implementing economic incentive scheme for reducing water use and improving water management and farmers were provided with trainings on deciding optimal water use strategies. It was observed that water usage has been reduced when compared to their historical water use data. In developing countries like India, the scheme could be implemented. But it seemed to be difficult due to the lack of volumetric water measurement mechanism for the implementation of similar schemes (Wichelns, 2003).

Alam (2015) observed the factors influencing farmer's adaptations to water scarcity in Rajshahi district of Bangladesh and concluded that 98 per cent of the farmers are following any one of seven practices as an adaptation strategy *viz*., increased groundwater irrigation (56%), crop diversification and farming calendar adjustment (24%), land use change (10%), increased surface water irrigation (4%) and water conservation and conservation tillage (6%). The probability of adaptation to extreme weather conditions was influenced by factors *viz*., level of education, household income, tenure rights, farming experience, access to electricity and better climate awareness whereas factors like gender, age and farm size were not having significant influence. Afterward, the share of water allocated for other demands by cities and industry and for hydropower generation, rather than irrigating the field. Hence in 1990s, water allocated for irrigation was significantly reduced to 20 per cent and as a consequence, rice production was also declined (Bin *et al.*, 2001).

The quality of water also affects the agricultural yield. Water used for irrigation purpose always contains measurable quantities of dissolved substances often called as salts. The suitability of irrigation water on field is determined by the quantity and kind of salts present. With the poor quality of water, several soil and cropping issues were reported around the world. It is noticeable that, using the good quality water, very infrequent or no problem were found. The challenges associated with the poor quality water will vary but the most common challenges are salinity, permeability and toxicity. Salinity problems occurs due to the accumulation of salts in the crop root zone through irrigation water which makes the plant difficult for water uptake that can be resulted in reduced growth or crop failure. The effects of salinity problems may vary according to the growth stage, some plants shows the symptoms similar to the drought stress like early wilting or some plants may exhibits a bluish green colour and heavier deposits of wax on leaves. The permeability problems arises when there is a reduction in infiltration rate through the soil due to the presence of specific salts. Hence the crop is not adequately provided with the water and results into cropping difficulties through crusting of seed beds, waterlogging of surface soil and accompanying disease, salinity, weed, oxygen and nutritional problems and the overall crop yield gets reduced. Another major problem associated with water quality is toxicity that occurs when certain constituents usually one or more specific ions in the water are accumulated along with the water uptake and results in reduced yield (Rhoades *et al.,* 1992). Various other problems related to irrigation water quality include excessive vegetative growth, lodging and delayed crop maturity (Ayers and Westfort, 1985).

Specifically for water and agriculture, IWMI has been calling for a similar focus on increased water productivity through an approach that is very similar to Gleick's "soft path", in various publications over the last 7-8 years and this focusses on increasing water productivity for food production and rural livelihoods, *i.e.* a CGIAR system-wide initiative called Comprehensive Assessment of Water Management in Agriculture and the CGIAR Challenge Program on Water and Food. Together these represent a major effort by the international community to address water scarcity in agriculture.

METHODOLOGY

Chapter III

METHODOLOGY

Appropriate methodology is important in achieving the objectives of the study. This chapter describes procedures and methods adopted in the selection of the study area, sampling design, nature and sources of data, conceptual framework and various statistical tools and techniques employed in analysing the data.

3.1 Description of the study area

3.1.1. Thrissur district

The study was conducted in the coastal tract of Thrissur district of Kerala, located in the central part of the state. The district is situated at a latitude of 10.41^0 N, longitude of 76.36^0 E. The total geographical area of the district is 3029.19 sq. km and it is bordered on the north by Palakkad and Malappuram districts, east by Palakkad, south by Ernakulam district, and on the west by the Arabian Sea. According to 2011 census, the district has a population of 2974232 out of which 1422052 are females and 1552180 are males. The density of population is 982 persons per sq. km and the sex ratio is 1108 females per 1000 males (GoK, 2017).

The district features a tropical monsoon climate. Summer lasts from March to May followed by the South-West monsoon from June to September. The months of October and November form the North-East monsoon season. The average daily temperature ranges from $35\text{-}37^0$C where the average summer temperature is 35^0C and average winter temperature is 20^0C with an annual precipitation of 3100 mm. The major soil types of the district are laterite soil, brown hydromorphic soil, hydromorphic saline soil, coastal alluvium, riverine alluvium and forest loamy soil.

3.1.2. Land utilization pattern of Thrissur district

The land use pattern of the district is presented in Table 3.1. The total geographical area of the district is 302919 ha. Out of the total geographical area, 53 per cent area is cultivated. The land under non-agricultural uses and waste lands together account for 13 per cent and the rest are forest land.

Table 3.1. Land use pattern of Thrissur district 2016-17

Sl. No.	Particulars	Area in Hectares	
		Thrissur	Kerala
1	Total geographical area	302919 (100)	3886287 (100)
2	Forest land	103619 (34.20)	1081509 (27.83)
3	Land put to non-agricultural uses	39026 (12.88)	441934 (11.37)
4	Barren and uncultivable land	91 (0)	11780 (0.30)
5	Permanent pastures and other grazing land	0	0
6	Land under miscellaneous tree crops	201 (0)	2450 (0.06)
7	Cultivable waste land	10170 (0.03)	101379 (2.60)
8	Fallow other than current fallow	6031 (0.01)	55530 (1.42)
9	Current fallow	9813 (0.03)	72008 (1.85)
10	Marshy lands	0	106 (0)
11	Still water	5034 (0.01)	98434 (2.53)
12	Water logged area	318 (0)	3210 (0.08)

13	Area under social forestry	147 (0)	2556 (0.07)
14	Others	31564 (10.42)	777 (0.02)
14	Net area sown	128469 (42.41)	2015482 (51.86)
15	Total cropped area	170978 (56.44)	2584000 (66.49)
16	Cropping intensity (%)	134	128

(Figures in parentheses shows per cent to total geographical area) (Source: Agricultural Statistics, 2016-17)

3.1.3. Cropping pattern

The cropping pattern of the district is shown in Table 3.2. The major crop is coconut with an area of 80504 ha, *i.e.* nearly 47 per cent of the gross cropped area followed by paddy, nutmeg, arecanut and fruit crops. Paddy cultivation in the district extends to 21100 ha, of which 13632 ha are under Kole cultivation which is a unique system of cultivation below Mean Sea Level situation.

Table 3.2. Cropping pattern of Thrissur district 2016-17

Sl. No.	Crop	Thrissur (ha)	Kerala (ha)
1	Paddy	21100 (12.34)	171398 (6.63)
2	Coconut	80504 (47.08)	781496 (30.24)
3	Arecanut	6096 (3.56)	97696 (3.78)
4	Nutmeg	6920 (4.05)	22065 (0.85)

5	Blackpepper	1901 (1.11)	85207 (3.29)
6	Banana	2213 (1.29)	57158 (2.21)
7	Total fruits	24299 (14.17)	368871 (14.27)
8	Total vegetables	3099 (1.81)	46732 (1.80)
9	Others	24945 (14.59)	954273 (39.93)
10	Total cropped area	170978	2584007

(Figures in parentheses shows per cent to total geographical area) (Source: Agricultural Statistics 2016-17, Directorate of Economics and Statistics, Kerala)

3.2. Sample selection

The study area was identified as Chavakkad, Thalikulam, Mathilakam Block Panchayats (BP) and Kodungallur Municipality of Thrissur district. They border the Arabian Sea (Fig. 3.1). The sample for the study was drawn by the method of two stage random sampling. All the wards (under the Grama Panchayaths/ Municipality) were categorised into two categories, those wards of which atleast one boarder is sea and other do not have sea coast. Three wards from each category were selected randomly, (a total of 24 wards) from the three BPs and one Municipality. From the selected wards, five households each were randomly chosen as sample respondents. Thus the total sample size was 120 households (24* 5 = 120).

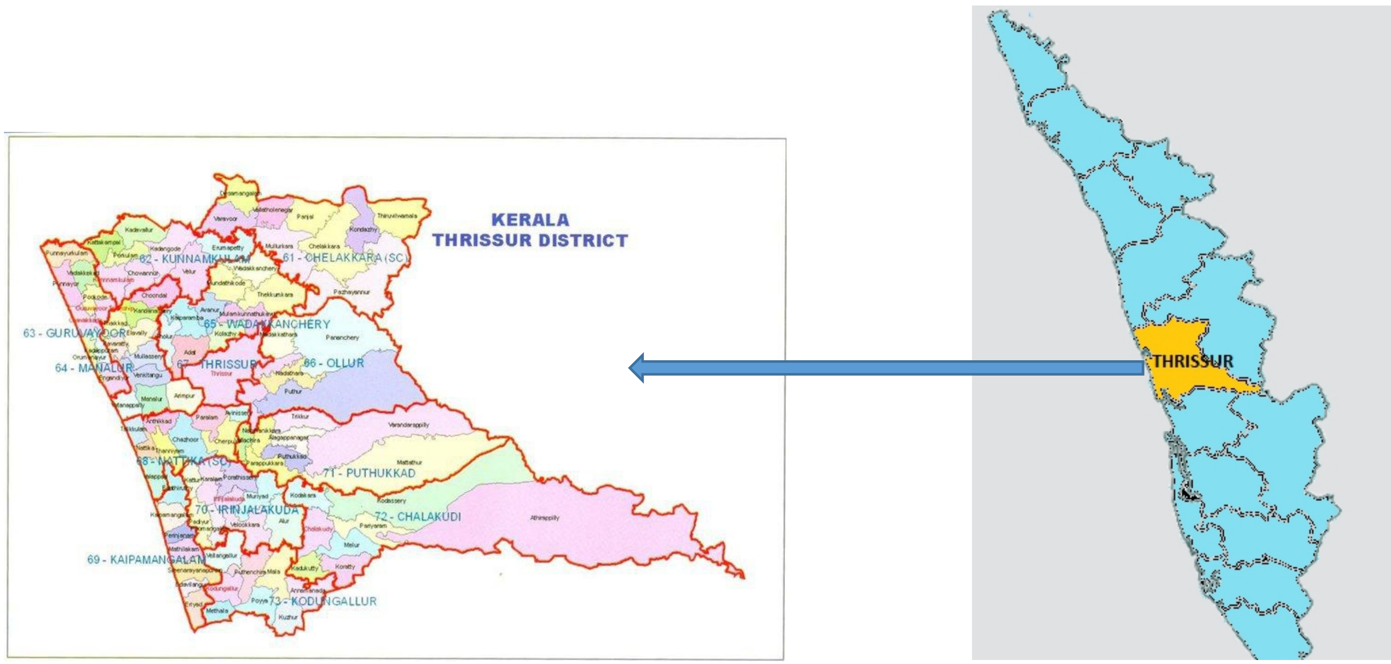


Fig. 3.1. Location of study

3.3. Data collection

The study was based on both primary and secondary data. The primary data included the socio-economic information of farmers, cropping pattern and production, sources of water for domestic purpose and irrigation, and perceptions and economic burden for adaptive strategies to water crisis. The primary data was collected from respondents through the method of personal interview using pretested structured interview schedule as well as direct observation. A pilot survey was conducted initially to test and finalise the schedule. The following institutions/ organisations has helped in various stages of data collection.

1. Department of Agricultural Development and Farmers Welfare, Government of Kerala (Respective Krishibhavans)
2. Farmers' Organisations

The secondary data was gathered from government publications, data maintained by the departments of government and other similar sources.

3.4. Analytical design

The data was analysed employing the basic statistical tools of averages and percentages as well as specific analytical approaches of regression analysis, scaling technique and Shannon-Wiener diversity index.

3.4.1. Estimation of cost of cultivation and irrigation

The estimation of cost of cultivation was based on the approach by CACP, but the paid out costs only were considered for the study. Following Diwakara and Chandrakanth (2007), the total cost of irrigation is comprised of amortised value of fixed costs and variable costs.

$$\text{Total cost of irrigation} = \text{Amortised cost of irrigation} + \text{Variable cost of irrigation}$$

$$
\begin{aligned}
\text{Total cost of irrigation (Rs./ ha)} \\
&= [\text{The amortised cost of digging the well} \\
&+ \text{amortised cost of water lifting} \\
&+ \text{amortised cost of irrigation structures} \\
&+ \text{annual cost of operation and maintenance} \\
&+ \text{annual electricity cost} + \text{annual labour cost}] \\
&\div \text{Gross irrigated area (ha)}
\end{aligned}
$$

Amortisation is the calculation of annual cost of cash outlay for an investment which yield a benefit for a number of years. A cash outlay grows over time due to the compounding of interest charges or opportunity cost of capital. The rate of growth of cash outlay depends on interest rate and economic life/ number of years the equipment is being used.

Amortised cost of irrigation is given by the formula,

$$\text{Amortised cost} = (\text{Compound cost of investment}) \times \frac{(1+i)^{AL} * i}{(1+i)^{AL} - 1}$$

$$
\begin{aligned}
\text{Compounded cost of investment} \\
&= \text{Historical investment} \times (1 + \mathrm{i})^{2018 - year\ of\ investment}
\end{aligned}
$$

The average functioning years of open wells in the sample farms of each BP was taken as their respective economic life. The economic life of dug wells in the study area was decided by estimating their average life for each BP using the formula:

$$Y_W = \sum_{i=1}^{n} \frac{2018 - y_i}{n}$$

Where Y_W is the economic life of dug wells, y_i is the year of digging the existing well in i^{th} farm and n is the total number of wells in the study area.

The estimated average functional life of dug wells in Chavakkad, Thalikulam and Mathilakam BPs were 32, 36, 43 years respectively whereas in Kodungallur Municipality the average functional life of wells was 41 years.

Average functional Life (AL) of irrigation equipment like pumpsets were considered as 15 years. Based on the material of construction of storage and building structures, economic life was taken as 20 years (for concrete). The working life (economic life) was fixed in consultation with expert in the field of irrigation engineering.

The annual rate of increase in cost of digging a new well was reckoned as the discount rate and it was calculated for each BP based on the primary data on investment for digging wells. The annual rate of increase in cost of digging wells in the sample farms was calculated as per following steps:

1. The cost of digging well incurred by farms was arranged in chronological order for each BP.

2. If there was more than one well in one BP in a particular year, average of the cost of digging those wells were reckoned as the cost of digging a well during that year.

3. The rate of increase in cost over the years was calculated using the formula:

$$i_{ow} = \frac{C_l - C_f}{C_l * (Y_f - Y_i)} * 100$$

where i_{ow} is the rate of increase in annual cost of digging one open well, C_l is the cost of digging one open well during the last year in the chronological order, C_f is the cost of digging an open well during the foremost year in the order. Y_l and Y_f are corresponding years (Seenath, 2017).

3.4.2. Crop Diversity Index

The Shannon-Weiner Index is the most commonly used diversity indicator in plant communities, and it takes a value of zero when there is only one species in a community, and a maximum value when all species are present in equal abundance.

The following equation used for this study, looks at the diversity of those species in the sample farm that are grown on an annual or perennial basis. Only cultivar species are considered in the study.

$$H = -\sum_{i=1}^{n}(p_i * \ln p_i)$$

Where H is the Shannon-Weiner diversity index, the proportion of species *i* relative to the total number of species is calculated and multiplied by the natural logarithm of this proportion. The resulting product is summed across species and multiplied by -1.

3.4.3. Regression analysis

Regression equation is the quantitative expression of relationship between a dependent variable and one or more independent variable(s). To assess the major factors that influence household water consumption, regression analysis with multiple linear form was employed as expressed below:

$$Y_i = \beta_0 + \beta_1 D_1 + \beta_2 D_2 + \beta_3 X_1 + \beta_4 X_2 + \beta_5 X_3 + \beta_6 X_4 + \beta_7 X_5 + u_i$$

Where Y_i is the average volume of water for household consumption in summer season (liters)

X_1 is the volume of available water in well in the summer (liters/ well) (calculated from well diameter and depth of water table during summer)

X_2 is the crop diversity index

X_3 is the family size (number)

X_4 is the number of irrigations per year

X_5 is the agricultural income (Rs./ annum)

X_6 is the source of water (Dummy variable)

D_1 and D_2 that described three levels *i.e*. respondents with only well, both well and pond, and well, pond and public water supply. The levels of dummy variable are as follows:

1. D_1=0, D_2=0 if the observation is from only well
2. D_1=1, D_2=0 if the observation is from both well and pond
3. D_1=0, D_2=1 if the observation is from well, pond and public water supply

In general, if a qualitative variables has m levels, then (m-1) dummy variables are required and each of them takes value 0 and 1.

β_0 = constant term

β = coefficient

u_i = error term

Further, the multiple linear form of the relationship was estimated using area irrigated in the sample farm as dependent variable as detailed below:

$$Y_i = \beta_0 + \beta_1 D_1 + \beta_2 D_2 + \beta_3 X_1 + \beta_4 X_2 + \beta_4 X_3 + u_i$$

Where Y_i is the area irrigated in the sample farms (ha)

X_1 is the volume of available water in wells in the summer (liters/well)

X_2 is the experience in agriculture (years)

X_3 is the agricultural income (Rs./annum/ha)

X_4 is the source of water (Dummy variable)

D_1 and D_2 that described three levels *i.e*. respondents with only well, both well and pond, and well, pond and public water supply. The levels of dummy variable are as follows:

1. D_1=0, D_2=0 if the observation is from only well
2. D_1=1, D_2=0 if the observation is from both well and pond

3. D_1=0, D_2=1 if the observation is from well, pond and public water supply

In general, if a qualitative variables has m levels, then (m-1) dummy variables are required and each of them takes value 0 and 1.

β_0 = constant term

β = coefficient

u_i = error term

An attempt was made to identify the factors that influence the adaptation behavior of the respondents by employing the logistic regression model. The dependent variable, which is dichotomous, is grouped as those who adopted at least one among the four strategies and who did not follow any of them. The strategies are digging new ponds, installation of more efficient pumpset, roof water harvesting and filtering of water. The logistic regression equation is expressed as follows:

$$logit\ (p_i) = \ln\left(\frac{p_i}{1-p_i}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \mu_i$$

Where p_i = the probability of adapting any strategy or not adapting any strategy

0= if the sample farmer did not adapt any strategy

1= if the sample farmer adapted any one strategy

X_1 is education (code given to each level: 1- primary, 2- upto 10^{th}, 3- higher secondary, 4- graduate)

X_2 is the experience in agriculture (years)

X_3 is the crop diversity index

X_4 is the volume of available water in wells in the summer (liters/ well)

β_0 = constant term

β = coefficient

u_i = error term

3.4.4. Perception on water crisis

According to Bhatia (1965), perception is a response to stimuli interpreting the sensory input. The major processes are those of hearing, seeing and smelling. Theodorson and Theodorson (1970) defined perception as the selection, organisation and interpretation by an individual of specific stimuli in a situation according to prior learning activities, interests and experiences.

Perception of respondents on extent of water scarcity was measured using a Likert scale method that consists of five statements. The extent of agreement or disagreement to a statement was recorded as Strongly Agree (SA), Agree (A), Neutral (N), Disagree (D) and Strongly Disagree (SD) (Table 3.3).

Table 3.3. Scale to measure perception of respondents on water crisis

Sl. No	**Statements**	**Options**
1.	There are changes in the agricultural production in the farm over the years	SA / A / N/ D / SD
2.	There is a shortage of water for irrigation in the peak summer season	SA / A / N/ D / SD
3.	Deterioration of water quality is observed in the locality	SA / A / N/ D / SD
4.	Changes in the available water quantity and quality significantly affects the household consumption pattern	SA / A / N/ D / SD
5.	Decrease in water quantity and quality are the major reason for yield reduction in the farm	SA / A / N/ D / SD

*SA- Strongly Agree, A-Agree, N- Neutral, D-Disagree, SD- Strongly Disagree

The respondents were asked to state their extent of agreement or disagreement for each statement and a score of one to five was given for strongly agree, agree, neutral, disagree and strongly disagree respectively. In the case of negative statement, the scoring was reversed. Scores for each of the respondent was obtained by summation of scores for all five statements.

RESULTS AND DISCUSSION

Chapter IV

RESULTS AND DISCUSSION

4.1. Socio-economic profile of sample respondents

Socio-economic characteristics gives an idea about the background information of respondents and provides a better understanding of the farms as well as rural farming scenario. The distribution of sample respondents with respect to age, gender, family size, education and experience are presented in Table 4.1. These characteristics contributes to the capacity for implementing better decisions in the farms. Most of the respondents in the study area were above the age of 56 years. In Kerala, the average age of the farmers is above 50 years (Kannan, 2011 and Seenath, 2013). The general pattern was similar in the study area as well *i.e.* 31 per cent of farmers were in the age group of 56-65 years. Most of the respondents were males while the male-female ratio in the state is more in favour of females.

Kerala stands first among the Indian states and Union territories in educational status with literacy level of 93.91 per cent (GOI, 2011) and the average literacy rate of Thrissur district is 95.08 per cent. This was reflected in the sample profile also. Even though all the farmers were literates, most of them (35 per cent) are having only primary education. About 27 per cent of the farmers have studied up to matriculation level and there were only 11 per cent of graduate respondents. Since the farmers are well educated, adoption of modern technologies and scientific approaches can be easier, that benefits to their farming and further development of the whole society.

It has been reported that the farming efficiency is influenced by farming experience, level of education and extension contacts (Kalirajan and Shand, 1985; Ali and Flinn, 1989; Weir, 1999). The improved knowledge of farming has been gained through experience over years. Most of the farmers (41 per cent) were having experience of more than 25 years. However, farming experience of most of the respondents in Chavakkad as well as Thalikulam BPs were only less than 10 years.

Table 4.1. Socio-economic profile of the respondent farmers (in numbers)

Sl. No.	Particulars	Chavakkad	Thalikulam	Mathilakam	Kodungallur	Total
I.	**Age profile (years)**					
1	45 and Below	8 (27)	6 (20)	2 (7)	6 (20)	22 (18)
2	46-55	9 (30)	11 (37)	6 (20)	8 (27)	34 (28)
3	56-65	11 (36)	6 (20)	14 (46)	6 (20)	37 (31)
4	66 and Above	2 (7)	7 (23)	8 (27)	10 (33)	27 (23)
5	Total	30 (100)	30 (100)	30 (100)	30 (100)	120 (100)
II.	**Gender wise classification**					
1	Male	22 (73)	22 (73)	24 (80)	26 (87)	94 (78)
2	Female	8 (27)	8 (27)	6 (20)	4 (13)	26 (22)
	Total	30 (100)	30 (100)	30 (100)	30 (100)	120 (100)

Sl. No.	Particulars	Chavakkad	Thalikulam	Mathilakam	Kodungallur	Total
III. Education status of farmers						
1	Primary	6 (20)	10 (33)	12 (40)	14 (47)	42 (35)
2	Up to 10th grade	10 (33)	3 (10)	12 (40)	7 (23)	32 (27)
3	Higher Secondary	10 (33)	11 (37)	5 (17)	6 (20)	32 (27)
4	Graduate	4 (14)	6 (20)	1 (3)	3 (10)	14 (11)
	Total	30 (100)	30 (100)	30 (100)	30 (100)	120 (100)
IV. Farming experience (years)						
1	< 10 years	13 (43)	13 (43)	3 (10)	8 (27)	37 (31)
2	11-25 years	7 (24)	7 (24)	11 (37)	9 (30)	34 (28)
3	>25 years	10 (33)	10 (33)	16 (53)	13 (43)	49 (41)
	Total	30 (100)	30 (100)	30 (100)	30 (100)	120 (100)

Sl. No.	Particulars	Chavakkad	Thalikulam	Mathilakam	Kodungallur	Total
V. Family size (number)						
1	2-4	21 (70)	20 (67)	19 (63)	21 (70)	81 (68)
2	5-10	9 (30)	10 (33)	11 (37)	9 (30)	39 (32)
	Total	30 (100)	30 (100)	30 (100)	30 (100)	120 (100)

Figures in parenthesis show the percentage to the total

Average family size remains almost similar in the Block Panchayaths/ Municipality at an average of four members. Majority of respondents (68 per cent) belongs to small family with 2-4 members which clearly depicts the limited scope of employing family labour in agriculture.

Table 4.2. Average annual income of respondents in the study area (%)

Sl. No.	Income group (Rs./ annum/ household)	Chavakkad	Kodungallur	Thalikulam	Mathilakam	Average
1	25000-50000	3	10	13	3	7
2	50000-75000	33	20	17	23	23
3	75000- 1 Lakh	3	17	20	10	13
4	1 Lakh- 2 Lakh	44	36	30	40	38
5	>2 Lakh	17	17	20	24	19
6	Average agricultural income (Rs./annum/ household)	125907	116747	120998	139360	125347

Details of average annual income of the respondents are given in Table 4.2. Most of the surveyed households (38 per cent) fall under annual income group of Rupees 1 Lakh to 2 Lakh. The households in Mathilakam BP were having the highest average annual income (Rs. 1, 39, 360/- per annum per household) while those in Kodungallur Municipality has the lowest.

4.1.1. Land holding size

Table 4.3 provides details regarding the size of land holdings among respondents. The farmers were classified in to four size classes *viz*., marginal (<1 ha), small (1-2 ha), medium (2-10 ha) and large (>10 ha) farmers (GoK, 2014a). Majority of respondents were under size class of <1 ha (marginal farmers) land holdings. There was no large farmer (>10 ha) in the study area. The percentage distribution of respondents under marginal, small and medium classes in Thalikulam BP was 83, 13 and 4 per cent respectively while in Kodungallur Municipality it was 74, 13, and 13 per cent respectively. The average land holding size of Thalikulam BP (0.6 ha) was the lowest among the study area and it was 22 per cent less than that of Kodungallur Municipality (0.77 ha). The average land holding size of Chavakkad and Mathilakam BPs was 0.76 and 0.71 ha respectively. The average land holding size of all the three BPs and Municipality were more than that of the state average land holding size (0.22 ha) (GOI, 2011).

Table 4.3. Classification of sample farmers according to land holding size (% of farmers)

Sl. No.	Land holding size class	Chavakkad	Kodungallur	Thalikulam	Mathilakam	Average
1	Marginal (<1 ha)	70	74	83	77	76
2	Small (1-2 ha)	20	13	13	17	16
3	Medium (2-10 ha)	10	13	4	6	8
4	Large (>10 ha)	0	0	0	0	0
	Average land holding size (ha)	0.76	0.77	0.60	0.71	0.69

4.1.2. Cropping pattern and Diversity

The cropping pattern in the study area follows the state pattern of coconut being the major crop. The proportion of coconut in the farm was highest in Kodungallur (72 per cent) and Mathilakam (67 per cent) (Table 4.4). The coastal tracts of Kerala is dominated by coconut with arecanut and banana as intercrops. Coconut occupies 30 per cent of total cropped area in the state (GoK, 2017), while the proportion is much higher in coastal areas.

The water use in agriculture is predominantly determined by the level of crop diversity in farms and the proportion of irrigated crops. The crop diversity index in the farms was calculated employing Shannon-Wiener index which looks at the diversity of those species in the sample farm that are grown on an annual or perennial basis. Thomas and Kurian (2013) reported highest diversity index in Wayanad using Shannon-Wiener biodiversity index.

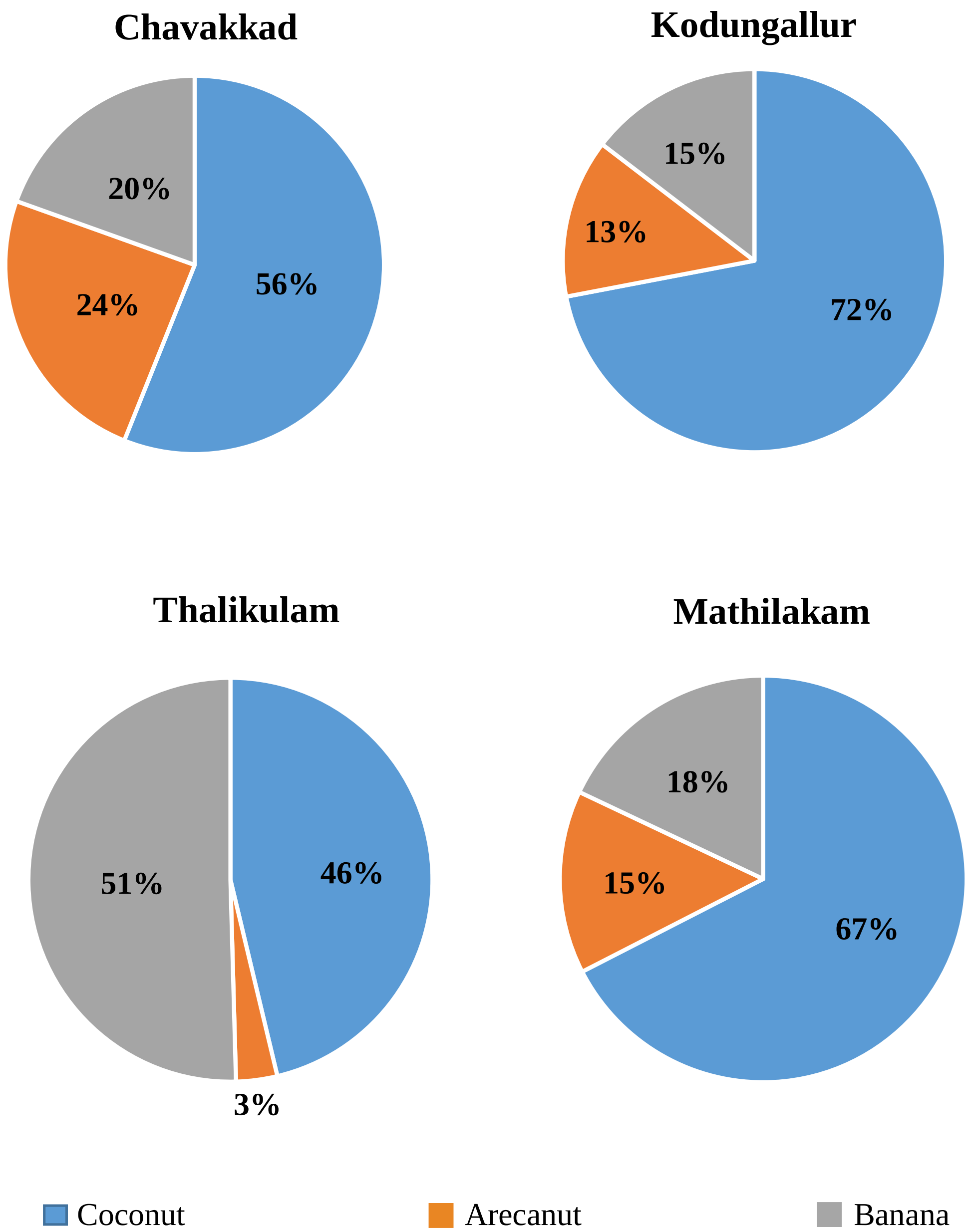
In the study area, the highest crop diversity index was recorded in the homesteads of Mathilakam BP (0.37) followed by those in Chavakkad and Kodungallur (0.36 and 0.34 respectively). The diversity index was lowest in Thalikulam BP (0.31) perhaps due to the lowest holding size where the presence of other trees and plant species might have restricted the presence of crop cultivation. Thomas and Kurian (2013) also reported that biodiversity was influenced by holding size. In a research report on Kerala homegardens, the medium and large gardens have the biodiversity at 0.97 and 0.81 respectively and it was presumed that any homegarden with land size more than 1.0 ha is more an agricultural field or plantation, and therefore, will have lower species richness and diversity (Sankar and Chandrashekara, 2002).

Generally, homesteads of Kerala are reported to have very high biodiversity with the presence of trees, shrubs and other plant species. However, the Shannon-Weiner diversity index of sample farms in the study areas of coastal zones was lower, as cultivated species only are considered here. It was reported that the biodiversity could be varied in homegardens within regions, within and between districts as well (Thomas and Kurian, 2013). The diversity index of sample farms in selected blocks are given in Table 4.4.

Table 4.4. Cropping pattern (%) and diversity index of the sample farms

Sl. No.	Particulars	Chavakkad	Kodungallur	Thalikulam	Mathilakam	Average
1	Coconut	56	72	46	67	60
2	Arecanut	24	13	3	15	14
3	Banana	20	15	51	18	26
4	Crop Diversity Index	0.36	0.34	0.31	0.37	0.35

Fig. 4.1. Pie- Diagram showing major crops in the study area



4.2. Water resources, scarcity and awareness level

In 2020, the world's population is anticipated to reach 7.9 billion which is double than that of 1990. This is a major threat to the available water resources (UN, 2004). Rapid increase in population and subsequent increased demand for water in agriculture, domestic, and industrial fields are the major reasons for ‘water crisis’. The impact of global warming reports also reveals severe threats with more pronounced droughts and progressively extreme floods (IPCC, 2001). It was reported that certain water dependent regions (*e.g.* major farming areas, or large population centres) would experience more water scarcity, while others become more humid due to high climatic variations (EC, 2007). With the existing climate change scenario, by 2030, water scarcity would affect in some arid and semi-arid places (UNESCO, 2018) where 700 million people worldwide could be displaced by intense water scarcity (GWI, 2013). A third of the world’s groundwater systems are already in distress (Richey *et al.*, 2015) and nearly half the global population are living in potential water scarce areas which could increase to 4.8-5.7 billion in 2050 (Burek *et al*., 2016). According to recent studies, more than 2 billion people live in countries experiencing high water stress (UN, 2018).

Kerala state is richly endowed with abundant surface water resources such as rivers, lakes, ponds and also having an average annual rainfall about 3000 mm. The total annual ground water availability in the state has been computed as 6.62 Billion Cubic Meter (BCM) and the net ground water availability is 6.03 BCM. The main source of water is rainfall which contributes about 82 per cent of the total annual replenishable resources and dug wells are the major ground water structure in Kerala. Despite rich endowments of water resources, availability of water in Kerala is dwindling and inadequate for the growing population. The per capita water availability in the state has shown fivefold decrease, while it is only fourfold decrease at national level (CGWB, 2012).

Kerala has two monsoon seasons, South West monsoon (June to September) and North East monsoon (October to November). About 85 per cent of the annual rainfall is received during the monsoon period between June and November and the remaining 15 per cent as summer showers in the post-monsoon period between December and May (Jayasankar and Babu, 2017). There are high seasonal and spatial differences in the distribution of rainfall. The average rainfall of the state is 2943 mm/year, with high variability. The trend in monsoon shows annual rainfall as of declining nature from the past 60 years (Rao, 2008). The decreasing trend in South West monsoon over Kerala was observed by other researchers too (Soman *et. al*., 1988; Sathyamoorthy, 2005; Guhathakurta and Rajeevan, 2007). It was reported that five states in India including Kerala faced water shortages due to rainfall deficiency in monsoon during 2016. The declining trend in precipitation was evident across the state with a significant decline of more than 20 per cent in the northern parts of Kerala during 1951 to 2017, and in 2015, Kerala has experienced a drought-like situation also (Mishra and Shah, 2018).

Even though the rivers and other water bodies in the state are mainly fed during rainfall, most of them get dried-up in the summer months. In the previous decade, Kerala has experienced more rainfall deficit years than surplus years except 2018. The total water demand during the summer months was about 21.4 km^3, whereas the available supply was only 14.3 km^3, posting a deficit of about 7.1 km^3 (GoK, 2013a), and it has resulted in acute water stress in the state during summer months. Indian Network for Climate Change Assessment (INCCA, 2010) also pointed out reduced rainfall (along with increased atmospheric temperature and flooding) as the major climate change scenarios for the Western Ghats and Kerala in the next 20 years. The number of rainy days is most likely to decrease along the entire Western Coast, including the Western Ghats.

Due to erratic monsoon, increase in temperature, high runoff and increased water demand, the state has reached the status of severe water scarcity (CGWB, 2016). Considering the peculiarities of soil, topography and socio-economic aspects, the groundwater potential of the state is very low as compared to many other states in the country. The replenishable water resources of the state was estimated as 70.17 km^3, of which about 42.67 km^3 is put to beneficial uses. Among that 34.77 km^3 is surface flow and rest is replenishable ground flow (Lathika, 2010). The reports shows that the net annual ground water availability for Kerala during 2009 has reduced to 3.22 per cent compared to 2004 and the annual ground water draft for all uses was also reduced by 3.80 per cent during the same period (GOI, 2011).

The recent report on the status of ground water in the state is a matter of concern. The rate of decline in water level of Groundwater Monitoring Wells (GMWs) is increasing over the years. During 1980-2005, only 8.5 per cent of wells were showing declining trend while it was 13 per cent in 1996-2005 period (Varma, 2017). Table 4.5 represents state-wise water level fluctuation (2016 pre-decadal mean). During the period, water level in 44 per cent of observational wells in the state show decline. The decadal trend on ground water level for the pre-monsoon period, reported a declining trend in 44 per cent of the total monitored wells (CGWB, 2016).

Table. 4.5. State-wise water level fluctuation from January 2016 to decadal mean [January (2006 to 2015)]

Sl. No.	**Name of State/UT**	**No. of wells analysed**	**Rise**		**Fall**	
			No.	**%**	**No.**	**%**
1	Andhra Pradesh	764	300	39	460	60
2	Arunachal Pradesh	13	9	69	4	31
3	Assam	195	125	64	70	36
4	Bihar	462	102	22	359	78
5	Chandigarh	13	4	31	9	69
6	Chhattisgarh	584	123	21	461	79

7	Dadar & Nagar Haveli	12	1	8	11	92
8	Daman & Diu	11	3	27	8	73
9	Delhi	114	39	34	75	66
10	Goa	40	15	38	25	63
11	Gujarat	798	261	33	536	67
12	Haryana	106	47	44	59	56
13	Himachal Pradesh	94	42	45	52	55
14	Jammu & Kashmir	205	125	61	80	39
15	Jharkhand	198	47	24	150	76
16	Karnataka	1351	542	40	808	60
17	**Kerala**	1302	717	**55**	572	**44**
18	Madhya Pradesh	1301	378	29	923	71
19	Maharashtra	1503	388	26	1112	74
20	Meghalaya	18	7	39	10	56
21	Odisha	1251	462	37	787	63
22	Pondicherry	7	5	71	2	29
23	Punjab	236	70	30	165	70
24	Rajasthan	851	384	45	466	55
25	Tamil Nadu	459	300	65	159	35
26	Telangana	557	63	11	492	88
27	Tripura	18	10	56	8	44
28	Uttar Pradesh	773	87	11	686	89
29	Uttarakhand	44	11	25	33	75
	TOTAL	3955	4904	35	9268	65

(Source: CGWB, 2016)

The studies conducted in the water scarcity regions in Kerala reveals that the drought frequencies and intensity has increased in the previous decades (Rao, *et. al.*, 2009) and declining trend in the ground water levels of wells was reported from 30 cm to 3 meters over a period of 5 years in the state (KSDMA, 2016). The analysis of decadal water level trend during 1996-2005 also reported a decline of more than 0.1 m/ year for pre-monsoon in 13 per cent of monitoring wells and 30 per cent for post-monsoon season in Kerala (CGWB, 2005 and Shaji *et. al.*, 2009). A recent report submitted by Central Groundwater Board showed a decline in water table in 94 per cent of observational wells during 2017 to 2018 in Thrissur district alone [CGWB, 2018].

The domestic needs and irrigation requirements of the respondents in Kerala is met through the groundwater resources and wells play a significant role in both sectors. The same is the case in the study area. The drinking and other domestic water supply needs are supplemented by public water supply to houses or public taps of Kerala Water Authority. Apart from these resources, during water scarcity periods where existing water sources either dry partially or completely, several respondents depends upon neighbour's private wells also. For irrigation purpose, ponds are major water source.

4.2.1. Water resources for domestic sector

In Kerala, 80 per cent of rural households depend on traditional groundwater systems, 10-15 per cent on piped water supply systems, and 5 per cent use traditional surface and other systems (GoK, 2017) for domestic purposes. In the study area, the major water sources for domestic purpose are own dug wells, house connection of Kerala Water Authority, common public supply taps, and neighbour's private wells. In Thrissur district alone, 70 per cent of the domestic water source is open dug wells. In the study area also dug wells are the major source followed by public water supply. The dependence on public water connections (home as well as common) are limited in the study area as the water release is not continuous and assured. The percentage of dependence of households on various water sources across seasons are given in Table 4.6.

Most of the households depends on own dug wells for major part of the year. In Chavakkad BP, 93 per cent households depend on own dug wells and only 7 per cent were depending on public water supply in the rainy season. As the season advances to summer, the water level gradually declines and dependence of water sources changes. By summer, only 20 per cent households could depend on dug wells, since most of the wells dry up either completely or partially or due to poor water quality in Chavakkad BP. In Thalikulam, the situation is comparatively better where 44 per cent households manage to get water from own wells.

Public taps forms an important source of water, from December onwards and dependence reaches peak during March-May. During the period, 30 per cent households each in Kodungallur Municipality and Thalikulam BP depends on the same. The dependence was found higher in Chavakkad BP (40 per cent) and least in Mathilakam BP (27 per cent). The dependence on common public taps was based on the regularity in water supply. Some of the households depend on the neighbour’s private wells as well.

Table 4.6. Water sources for domestic purpose in the study area

Sl. No		June – August					September – November					December – February					March - May				
		Chavakad	**Kodungallur**	**Thalikulam**	**Mathilakam**	**Average**	**Chavakad**	**Kodungallur**	**Thalikulam**	**Mathilakam**	**Average**	**Chavakad**	**Kodungallur**	**Thalikulam**	**Mathilakam**	**Average**	**Chavakad**	**Kodungallur**	**Thalikulam**	**Mathilakam**	**Average**
1	Own dug well	28 (93)	21 (70)	26 (87)	17 (57)	92 (77)	27 (90)	21 (70)	26 (87)	17 (57)	91 (76)	16 (54)	14 (47)	19 (64)	12 (40)	61 (51)	6 (20)	6 (20)	13 (44)	7 (23)	32 (27)
2	Public water supply/ house connection	2 (7)	9 (30)	4 (13)	13 (43)	28 (23)	3 (10)	9 (30)	4 (13)	13 (43)	29 (24)	4 (13)	9 (30)	4 (13)	13 (43)	30 (25)	4 (13)	9 (30)	4 (13)	13 (43)	30 (25)
3	Common public taps	-	-	-	-	-	-	-	-	-	-	9 (30)	7 (23)	7 (23)	5 (17)	28 (23)	12 (40)	9 (30)	9 (30)	8 (27)	38 (32)
4	Neigbour's well	-	-	-	-	-	-	-	-	-	-	1 (3)	-	-	-	1 (1)	8 (27)	6 (20)	4 (13)	2 (7)	20 (16)

Figures in parenthesis show the percentage

4.2.1.1. Open well characteristics

The major source of water for the domestic purpose in the study area are open dug wells. The number of open wells in the state is estimated roughly as one well for every eight to ten person, implying the highest well density in the world (George, 2016). The well density is reported as around 200 wells per sq.km in coastal areas, while it is 150 wells per sq.km and 70 wells per sq.km respectively in mid land and high land region (CWRDM, 1995).

The characteristics of the dug wells in the sample farms is furnished in Table 4.7. The well density was highest in Thalikulam BP (163 wells/km^2) followed by Chavakkad BP (132 wells/km^2) and Kodungallur Municipality (91 wells/km^2). The least well density was observed in the Mathilakam BP (76 wells/km^2). The open well density in Kodungallur region was 17 per cent more than Mathilakam BP and 31 per cent less than that of Chavakkad BP. But in all cases it was lower than that reported by CWRDM (200/$km^{2)}$ in 1995. This may be due to filling up of wells, due to higher pressure on land resources.

The average depth of wells in the study area was 4.9 meters from the ground level with a diameter of 1.88 meters. The average depth was highest in Chavakkad BP (5.02 m) which is 9 per cent more than that of Mathilakam BP (4.59 m). The average diameter as well as average age of dug wells were also highest for Chavakkad BP (2.09 m and 16 years respectively). Generally, average diameter was ranged from 1-2 meters. In Kerala, the dug wells are with maximum depth of about 10 to 15 meters and have a diameter of about 1 to 2 meters in coastal region and 2 to 6 meters in the midland and high land regions (CGWB, 2012).

Table 4.7. Particulars of wells in the study area

Sl. no.	Particulars	Chavakkad	Kodungallur	Thalikulam	Mathilakam	Average
1	Open well density (Number of wells per sq.km)	132	91	163	76	116
2	Average depth of the open wells (mbgl))	5.02	4.90	4.96	4.59	4.90
3	Average diameter of the open wells (m)	2.09	1.83	1.85	1.59	1.87
4	Average age of the open wells (years)	16	14	16	8	14

*mbgl - meters below ground level

Table 4.8. represents average water level in the wells of sample farms expressed as meters below ground level (mbgl). It was measured during field visits (April-May) by measuring the distance from the ground surface to the water in the well. The data on well water level during the other two periods were obtained from the respondents by personal interview, based on their observations. The average well water level during summer months was almost similar in Chavakkad and Mathilakam BPs (4.39 mbgl and 4.40 mbgl respectively) and it was highest for Thalikulam region (4.79 mbgl).

The water level during March-May was 59 per cent lower than that of rainy season in Thalikulam BP while it was 54 and 57 per cent lower in Kodungallur and Mathilakam regions respectively (Table 4.8). The highest percentage deviation in well water level in the study area was observed in Kodungallur region (142 per cent) and lowest in Chavakkad region (97 per cent). It was reported that in coastal plains of Kerala, the water level generally ranges from less than 1 to 6 mbgl and the depth of water table is influenced by weather variables like rainfall, area under water intensive crops and maximum temperature (Balasubramanian, 2013).

Table 4.8. Seasonal water level in open wells in the study area

Sl. No.	Particulars	Chavakkad	Kodungallur	Thalikulam	Mathilakam	Average
1	Well water level from ground during June-July (mbgl)	2.23	2.11	1.98	1.88	2.05
2	Well water level from ground during October-November (mbgl)	4.36	2.82	3.63	3.40	3.55
3	Well water level from ground during March-May (mbgl)	4.39	4.54	4.79	4.40	4.33
4	Percentage deviation of water level in summer months compared to the rainy season (%)	97	115	142	134	124

The average volume of water stored in open dug wells of the respondent households were calculated through direct measurement of the water level (from ground level), and the diameter of the well. The details of water level during different months were gathered from the respondents. Based on the information, the volume of water in the well at different points of time was estimated and is presented in Table 4.9.

Table 4.9. Average water volume in the sample wells (liters/well)

Sl. no.	Particulars	Chavakkad	Kodungallur	Thalikulam	Mathilakam	Average
1	June-September	13706	10420	11007	8016	10787
2	October-February	9553	6523	6766	5130	6993
3	March-May	5435	3701	3913	3200	4062

The volume of water storage in the wells varied considerably where the volume was high for Chavakkad BP (13706 liters/ well) in monsoon season which nearly halved to 5435 liters/ well during the summer months. However it is higher in Chavakkad followed by Thalikulam and Kodungallur regions (5435, 3913 and 3701 liters/ well respectively). The average water volume in the wells was lowest in Mathilakam BP *i.e.* about 8016 liters/ well during monsoon season and 3200 liters/ well in summer season.

The extent of decline in water storage of wells was estimated by subtracting the volume of water in the wells during the irrigation months in comparison to that of rainy months when it is maximum (Table 4.10). Volume of water storage in the wells was found to decline by an average of 35 per cent during October-February, and 62 per cent during peak summer in the study area. It was observed that the water storage declined drastically in both Kodungallur and Thalikulam regions.

Table 4.10. Extent of decline in water storage (liters/ well)

Sl. No.	Particulars	Chavakkad	Kodungallur	Thalikulam	Mathilakam	Average
1	June-September.	-	-	-	-	-
2	October-February	4153(30.00)	3897(37.39)	4241(38.53)	2886(36.00)	3794(35.17)
3	March-May	8271(60.34)	6719(64.48)	7094(64.44)	4816(60.07)	6725(62.34)

Figures in the parenthesis shows percentage

4.2.1.2. Household water consumption

Domestic water consumption is largely dependent upon the socio-economic status and water availability of the region. The factors like the traditional and cultural habit of very high consumption of water, high literacy rate, and health care awareness (high Human Development Index) could be considered as the major factors that decide domestic water consumption. It was reported that the water demand in domestic sector in the state has higher growth rate than that of population (Devi *et al*., 2015). However, per capita water availability in Kerala reports a continuous decline over the years. The normal minimum available water per person per year was estimated as 1000 m^3, anything below this, is considered as a water scarce situation (UNICEF, 2013).

The usual practice for meeting the daily water requirements is to pump water to the overhead tank. Hence, average water consumption of households in the study area was calculated by assessing the frequency of pumping and filling the overhead tanks and tank capacity, during normal periods as well as summer season. Table 4.11 details the domestic water consumption status.

Table 4.11. Average household water consumption (liters per day)

Sl. No.	BPs/ Municipality	June-August		September-November		December-February		March-May	
		Water use/HH	Per capita water use	Water use/HH	Per capita water use	Water use/HH	Per capita water use	Water use/HH	Per capita water use
1	Chavakkad	793	194	731	181	679	168	649	161
2	Kodungallur	703	169	669	163	653	159	625	153
3	Thalikulam	729	178	683	167	661	163	604	149
4	Mathilakam	718	169	701	166	654	156	628	150
	Average	736	177	696	169	662	161	627	153

**HH - Household*

This information was primarily gathered from the women members of the households who manage the domestic water needs. The household level average consumption varies according to the difference in family size. The average family size was found to be 2 to 4 members. The household level average water consumption was estimated to be highest in Chavakkad BP (793 liters/day) during June-August months and lowest in Kodungallur Municipality (703 liters/day). In summer months, the lowest average household water consumption was reported in Thalikulam BP (604 liters/day). The decline in average household consumption was noticed to be more in Chavakkad BP. On a per capita basis, the average consumption in summer months was estimated highest in Chavakkad region (161 liters/day) and lowest in Thalikulam BP (149 liters/day). This variation is mainly on account of the difference in family size.

4.2.1.3. Factors affecting household water consumption

As per Central Ground Water Authority (2016), the suggested per capita water use is 150-200 liters per day. The per capita consumption status showed sharp reduction in Chavakkad BP. The factors influencing the household water consumption level was analysed employing the linear regression model. The dependent variable was taken as the volume of water for household consumption (liters/day) during summer period. The independent variables like number of water sources (1- only well; 2- well and pond; 3- well, pond and public source), volume of available water in summer in the well (the main water source for domestic purpose), crop diversity index, family size, number of irrigations per year and agricultural income were considered for the analysis (Table 4.12). As expected, family size is the strongest variable that influences household water consumption. The available water in the well during summer season also prompt the members to regulate water use. The own dug well is the major source of domestic water consumption and traditional behaviour in the state is to depend on open wells in homesteads for drinking water. The result also implies that the crop diversity index (proxy for irrigation decision)

Table 4.12. Factors affecting household water consumption

Sl. No.	Particulars		Coefficients	Standard Error	t Stat	p-value
	Intercept		461.8	76.01	6.07	0.00001***
1	Number of water sources	Well and pond	-13.00	20.62	-0.63	0.52
2		Well, pond and public water supply	-28.38	20.68	-1.37	0.17
3	Volume of available water in well in the summer (Liters/well)		0.01	0.004	2.20	0.02 **
4	Crop diversity index		1100	707.9	1.55	0.12
5	Family size (number)		41.64	8.61	4.83	0.00004***
6	Number of irrigations per year		-0.21	0.36	-0.60	0.54
7	Agricultural income (Rs./annum)		0.0001	0.0002	0.73	0.46
	R^2		0.265			
	Adjusted R^2		0.212			

***significance at 1% level **significance at 5% level * significance at 10% level do not influence the household water consumption. This might be due to two reasons- irrigation water source in the area include ponds also and there are nearly four sources for water. Thus the alternate irrigation source ensure the water availability while pond water is not used for domestic consumption. It is very important that the water availability be improved through appropriate water harvesting methods. The particular model was tested for multicollinearity using VIF test and obtained a VIF value of 1.03, which shows non multicollinearity or stability of the model. The model confined with an R^2 value of 0.265 per cent.

4.2.2. Irrigation water use: water sources for irrigation purpose across seasons

Water is a critical input in agriculture having a determining impact on the yield. India has 18 per cent of world population, having 4 per cent of world's fresh water, out of which 80 per cent is used in agriculture. Globally, about 40 per cent of irrigation water is supplied from groundwater and in India, groundwater irrigation covers more than half of the total irrigated area (around 42 million ha). Currently, irrigation consumes about 84 per cent of total available water where industrial and domestic sectors consume about 12 per cent and 4 per cent of total accessible water respectively (CGWB, 2016). Domestic sector gets the priority in water allocation and hence during scarcity situations the irrigation water allocation is skewed. However, irrigation remains the dominant user of water, "per drop more crop" is an imperative.

In Kerala, groundwater is the major irrigation source and the state has a wide network of rivers, streams and springs spread over the entire area. The annual replenishable groundwater of Kerala has been computed as 6.7 Billion Cubic Meters (BCM) in March 2011, and rainfall accounts for about 82 per cent of the annual groundwater recharge (GOI, 2011). However, out of the net area sown in the state, only 18.74 per cent is irrigated. Coconut is the major irrigated crop which accounts for about 35 per cent, followed by paddy (29 per cent), banana (10 per cent) and arecanut (7 per cent). Ground water (open wells) meet 33 per cent of total irrigated area (GoK, 2017).

In the study area, respondents mainly depend upon the traditional water sources especially ponds and open dug wells. The irrigation water availability in the study area was measured in different periods, viz. September-November, December-February and March-May. The irrigation starts usually in September-November months, mainly dependent on the extent of rainfall. Majority of the farmers (77 per cent) irrigate from own dug wells except in Mathilakam BP (47 per cent) (Table 4.13).

In Mathilakam region, farmers generally use ponds as a major irrigation source in all the seasons. As the summer advances, as much as two-third households across the study area shift the irrigation dependence to ponds. In Kodungallur Municipality, 97 per cent households depend on ponds as the dug wells dry up or the water become saline. Likewise the shift was also observed in Thalikulam (77 per cent) and Chavakkad BPs (73 per cent) (Table 4.13).

Table 4.13. Sources of irrigation water in the study area (% of farms)

Sl. No.	BPs/ Municipality	June-August		September-November		December-February		March-May	
		Own dug well	Pond	Own dug well	Pond	Own dug well	Pond	Own dug well	Pond
1	Chavakkad	-	-	23 (77)	7 (23)	14 (47)	16 (53)	8 (27)	22 (73)
2	Kodungallur	-	-	18 (60)	12 (40)	13 (43)	17 (57)	1 (3)	29 (97)
3	Thalikulam	-	-	19 (63)	11 (37)	16 (53)	14 (47)	7 (23)	23 (77)
4	Mathilakam	-	-	14 (47)	16 (53)	13 (43)	17 (57)	10 (33)	20 (67)
	Total	-	-	74 (62)	46 (38)	56 (47)	64 (53)	26 (22)	94 (78)

Figures in the parenthesis shows percentage

4.2.2.1. Characteristics of ponds in the study area

Ponds are very common in the coastal belts as well as low-lying areas in the state which are chiefly used for bathing, washing and irrigation purpose. The usual depth of the pond was 2.5-3 meters (Chakrapani, 2014). The characteristics of the ponds in the sample farms are furnished in Table 4.14. The ponds in Thalikulam BP (3.02 m) was deeper by 14 per cent than that of Mathilakam BP (2.60 m). Average diameter of the ponds was observed highest in Mathilakam BP (13.11 m) and lowest in Kodungallur region (10.76 m). In Kodungallur region, the average age of the ponds was found higher (57 years) compared to other study areas and the lowest average age was observed in Chavakkad region (26 years). The average age was noted as 36 years. It is evident that the ponds were very common in the coastal areas and wells were dug only recently.

Table 4.14. Particulars of ponds in the study area

Sl. No.	Particulars	Chavakkad	Kodungallur	Thalikulam	Mathilakam	Average
1	Average depth of the ponds (mbgl)	2.52	2.45	3.02	2.60	2.64
2	Average diameter of the ponds (m)	11.50	10.76	12.02	13.11	11.84
3	Average age of the ponds (years)	26	57	30	31	36

*mbgl- meters below ground level

4.2.2.2. Irrigation methods

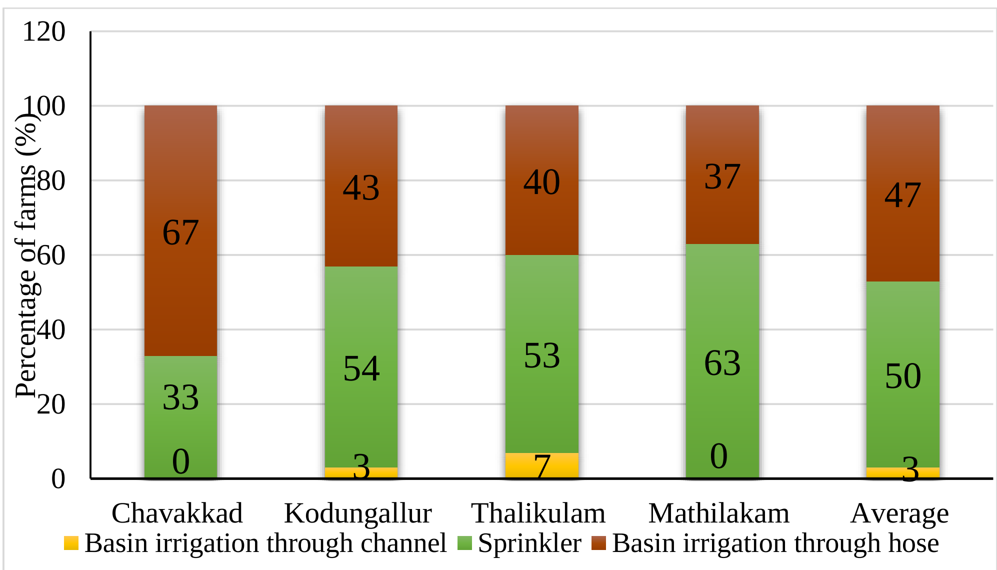
The irrigation methods has a great influence on water use efficiency and area irrigated. Basin irrigation method using hose or through channels and sprinkler irrigation are the major irrigation methods in the study area. Table 4.15 and Fig 4.2 describes different irrigation methods followed by the farmers in the study area. The sprinkler irrigation system was seen popular in Mathilakam (63 per cent) compared to other areas. These systems are more efficient than basin irrigation, however, they are more costly to install and operate because of the need for pressurized water. Sprinkler irrigation system was promoted with subsidy support. Around 54 per cent households in Kodungallur and 53 per cent in Thalikulam regions adopted sprinkler system and the least was in Chavakkad (33 per cent). The sprinkler irrigation method is labour saving, major drawback being the higher weed growth.

In Chavakkad BP, basin irrigation was the prominent irrigation method (67 per cent). Though the method is cheap, it is usually highly inefficient. Farmers use synthetic hoses and poly propylene pipes for the transmission of water to the basins of crops which helps to reduce conveyance and transmission losses. Few of them conveyed water to the basins through earthen channels along the field. The soil being sandy in the coastal areas, the percolation loss may be higher. It was reported that, only less than 10% of the water is taken up by the plant in surface irrigation systems such as basin irrigation (UNEP, 2008).

Table 4.15. Irrigation methods among sample farms (% of farms)

Sl. No.	Irrigation method	Chavakkad	Kodungallur	Thalikulam	Mathilakam
1	Basin irrigation through channel	0	3	7	0
2	Sprinkler	33	54	53	63
3	Basin irrigation through hose	67	43	40	37
	Total	100	100	100	100

Fig.4.2. Major irrigation methods in the study area (% of farms)



4.2.2.3. Interval of irrigation

Table 4.16. gives the information regarding the distribution of farms according to the interval of irrigation during the irrigation months (December to March). Homesteads of the study area generally cultivate coconut for household needs as well as for economic sustainability. The general cropping pattern of the study area (Table 4.4)

followed cultivation of coconut (60 per cent) as major crop along with arecanut (14 per cent) and banana (26 per cent). Around 33 per cent of the farms in Thalikulam BP were irrigating on alternate days making interval as one day (*i.e.* 4 days per week), where in Chavakkad 20 per cent of households followed the same. But in Kodungallur Municipality (10 per cent) and Mathilakam BP (63 per cent), number of irrigation was only 2-3 per week. Quite a substantial number of farms followed an irrigation schedule of once in 10 days during the peak summer months, often as a life saving method.

Table 4.16. Distribution of farms based on interval of irrigation (%)

Sl.No.	Interval of irrigation	Chavakkad		Kodungallur		Thalikulam		Mathilakam	
		Dec-Feb	March-May	Dec-Feb	March-May	Dec-Feb	March-May	Dec-Feb	March-May
1	1 day	20	10	10	10	33	11	17	-
2	2 days	27	-	30	3	23	3	20	-
3	3 days	50	23	60	13	44	33	63	33
4	One week	3	40	-	37	-	20	-	40
5	10 days	-	27	-	37	-	33	-	27
	Total	100	100	100	100	100	100	100	100

4.2.3. Cost of cultivation and irrigation investments

4.2.3.1. Investments in irrigation

The largest component of ground water use in India is the water extracted for irrigation by the means of canals, tanks and wells. Wells, provide about 61.6 per cent of water for irrigation, followed by canals with 24.5 per cent (Suhag, R., 2016). Since groundwater is extracted/ pumped by farmers freely along with free electricity connection, farmers think that irrigation has less expenditure. But it is crucial to properly account for the cost of irrigation as an input in the cost of cultivation.

The major crops irrigated in the study area are coconut, arecanut and banana by basin irrigation method with hose as well as channels and also with sprinkler irrigation. Hence the major components of irrigation cost are the costs for fixed assets such as structures and equipment used for water draft and storage (well, motor pumpsets, pump house and storage structures) and variable costs like operation and maintenance cost (Table 4.17). The fixed cost of irrigation includes amortised investment on well digging, pumpsets, pump houses, irrigation systems and other structures where the amortised cost is modestly influenced by the discount rate that indicate the rate of growth of nominal investment in irrigation wells (Chandrakanth and Patil, 2019). The items under variable cost includes labour cost and repair and maintenance cost.

Among the three BPs, the cost of irrigation was highest in Thalikulam BP (Rs. 41,569/ ha/ year) and a major share of the cost were the amortised cost of wells and other assets (fixed cost till drafting) and labour cost. Higher well density and low holding size resulted in high fixed cost of irrigation. The number of wells per hectare was highest in Thalikulam which was the major reason for high fixed cost. The labour cost for irrigation was also highest in Thalikulam (Rs. 3,709/ ha/ year), obviously due to the unfavourable economies of scale. The lowest irrigation cost was among the farms in Chavakkad BP where amortised cost of fixed assets was also the lowest (Rs. 17,996/ ha/ year).

Table 4.17. Cost of irrigation in farms of the study area (Rs./ ha/ year)

Particulars/ Items	Chavakkad	Kodungallur	Thalikulam	Mathilakam	Average
A. Fixed costs					
Amortised fixed cost (well, pump set, pump house and storage structures)	17996	23463	32093	29476	25757
B. Variable costs					
1.Labour cost	3194	2740	3709	2715	3089
2. Other variable costs	1023	959	1029	684	924
Total variable cost	4217	3699	4738	3399	4013
Total cost	26430	30861	41569	36274	33783

4.2.3.2. Cost of cultivation of major crops

It is relevant to understand the proportion of irrigation cost as a component in total cost of cultivation of major crops in the farm (Fig. 4.3). Coconut is the major crop cultivated in the region along with arecanut and banana as intercrops. The cost of irrigation and cost of labour were two major cost components (Table 4.18) in the total cost of cultivation of crops in the study area. Most of the previous studies have reported labour cost as the main component in crop production in the state. In Kerala, the percentage share of labour costs in the per hectare cost of paddy cultivation was reported to be around 65 per cent and in coconut crop it was about 50 per cent (Thomas, 2002). The wage rate in Kerala is higher than any state in the country by a factor of 2.5 (GoK, 2017) where the average daily wage rate of male and female agricultural workers in rural Kerala was Rs. 659/- and 443/- respectively, compared to the national average of Rs. 265/- and 207/-. However, irrigation cost constituted the highest proportion in this study pushing up the costs by 45 per cent, on an average. The cost of irrigation component in the study area was high compared to cost of cultivation reports by GoK (only Rs.207/- for land tax and irrigation cess), as the estimated cost for irrigation in the sample farms in the study area included fixed and variable components.

Table. 4.18. Cost of cultivation of crops in the irrigated farms (Rs./ha/year)

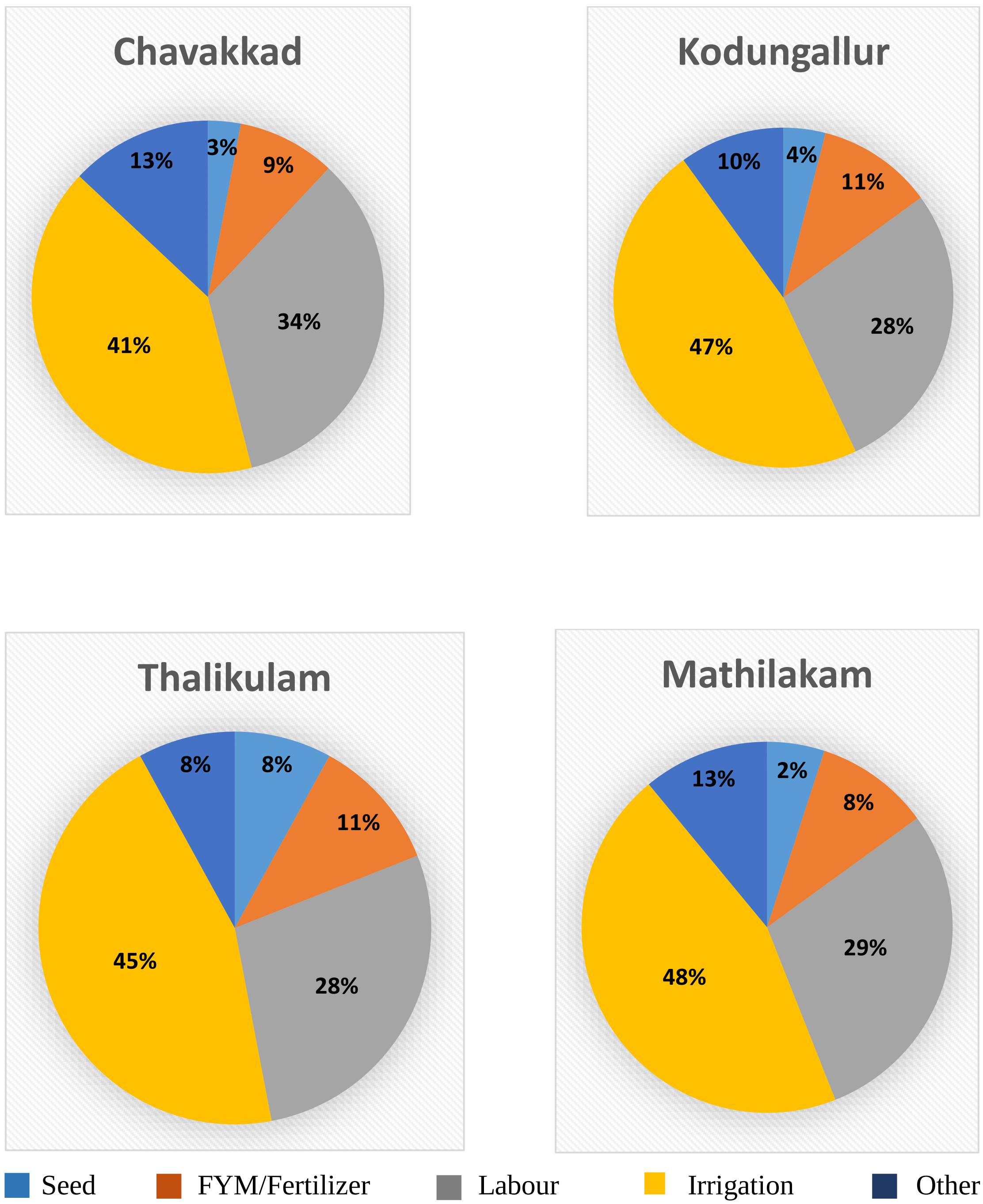
Items	Chavakkad	Kodungallur	Thalikulam	Mathilakam	Average
Seed	1870 (3)	2644 (4)	7655 (8)	1804 (2)	3493 (5)
FYM/Fertilizer	5170 (9)	6796 (11)	9937 (11)	6638 (8)	7135 (10)
Labour	21368 (34)	18460 (28)	25948 (28)	21171 (29)	21737 (30)
Irrigation	26430 (41)	30861 (47)	41569 (45)	36274 (48)	33783 (45)
Others	8840 (13)	6294 (10)	7261 (8)	9836 (13)	8057 (10)
Total cost	63678	65055	92370	75723	74894
Returns	131222	141646	194074	140538	151870
Net returns	67544	76591	101704	64815	76976

Figures in the parenthesis shows percentage

Among the study area, the estimated cost of cultivation was highest for Thalikulam BP (Rs. 92,370/ha/year) and least for Chavakkad (Rs. 63,678/ha/year). The percentage share of irrigation cost in total cost of cultivation was highest for Mathilakam (48 per cent) and lowest for Chavakkad (41 per cent). Generally, the cost of cultivation reported by Directorate of Economics and Statistics/ CACP is an average of both rainfed and irrigated situations leading to omission of huge investment made by farmers in groundwater irrigation system (Patil, 2015). Similar observations of discounting irrigation cost in cost of cultivation studies by Directorate of Economics and Statistics/ CACP were made by other authors also (Chandrakanth, 2015; Rohith *et al*., 2015). However, as per GoK reports, the cost of cultivation of coconut per hectare was estimated as Rs. 61,429/- excluding interest on fixed capital, land value and value of household labour (DES, 2017).

The cropping pattern in the study area shows around 60 per cent of cultivation is under coconut crop followed by banana (26 per cent) and arecanut (14 per cent) and the returns per hectare of cropped area in the study area was estimated to Rs. 1,51,870/ ha/ year. It was highest for Thalikulam BP (Rs. 1, 94,074/ ha/ year) followed by Kodungallur Municipality (Rs. 1, 41,646/ ha/ year). This was due to increased crop diversity in Thalikulam BP and more returns from banana cultivation compared to other regions. But the net returns was lowest in Mathilakam BP (Rs. 64,815/ ha/ year), obviously due to the adverse economies of scale (Table 4.18).

Fig.4.3. Pie-Diagram showing cost of irrigation as major share of total cost of cultivation



4.2.4. Factors affecting the area irrigated in sample farms

The decision to irrigate the farm, under a water stressed situation is influenced by many factors such as agronomic, economic and social. The coconut based farming systems are intercropped with banana and arecanut where banana crop is highly sensitive to water stress and is grown as irrigated crop. However, the irrigation decision (area irrigated) is hypothesized to be mainly influenced by number of water sources (1- only well; 2- well and pond; 3- well, pond and public source), volume of available water in summer in the wells, farming experience and agricultural income. The results of the linear regression model fitted, is furnished in Table 4.19. Agricultural income and number of water sources, were proved to be the major determinants of irrigation decision as per the fitted model. Most of these farmers belonged to marginal category which reflect their relatively scarce resource position. Thus agricultural income form a major source of income for them. It is interesting to note that, more number of water sources restrict the irrigated area. Obviously public water connection is availed, when there is water shortage. So more water sources, especially the public water supply connection, is an indication of water scarcity either due to quantitative or qualitative reasons, and is mainly for domestic consumption. However, agricultural income is exerting a strong influence on irrigation decision, among the resource poor farmers.

Table 4.19. Results of the analysis to identify variables that influence irrigation decision

Sl. No.	Particulars		Coefficients	Standard Error	t Stat	p-value
	Intercept		0.15	0.09	1.71	0.08
1	Number of water sources	Well and pond	-0.15	0.06	-2.39	0.01**
		Well, pond and public water supply	-0.21	0.06	-3.21	0.001***
2	Volume of available water in wells in the summer (Litres/well)		0.00001	0.01	0.12	0.90
3	Experience in Agriculture (Years)		0.002	0.001	1.61	0.10
4	Agricultural income (Rs./annum)		0.005	0.0004	12.99	<0.000002 ***
	R^2		0.648			
	Adjusted R^2		0.633			

*******significance at 1% level **significance at 5% level * significance at 10% level

4.2.5. Perception of respondents on water crisis and impact on agriculture

Water crisis has a greatest relevance on agriculture since it accounts for 70 per cent of global freshwater withdrawals. It affects severely on both rainfed and irrigated agriculture and results into significant reduction in crop production (FAO, 2011). The food and agricultural production in Australia was found to decrease substantially after the drought in 2007 (Goesch *et al.*, 2007). The rural people in the semi-arid tropics were also affected with reduced crop and livestock yields as a result of droughts and climate change (IPCC, 2007). In India, the occurrence of drought years has significantly increased, where there have been five droughts already in the past 16 years led to the below average crop yields and it was predicted to increase during 2020 to 2049 (Dhawan, 2017).

This study tried to understand the perception of respondents on the awareness of water scarcity and its impact on agricultural sector in the study area. The responses of the farmers are given in Table 4.20. It has been observed that majority of the respondents experienced a reduction in agricultural yield over the years and half of them attribute this to water scarcity. Two third of them underline the severity of water scarcity. Regarding the deterioration of available water quality, 30.8 per cent respondents strongly opined with the decline in water quality levels and 40.9 per cent respondents endorsed it. Likewise, close to 60 per cent respondents strongly agreed/agreed with the perception that the decline in both water quantity and quality lead to reduction in agricultural yield, while 15 per cent had a neutral opinion.

Table 4.20. Perception of respondents on water crisis and impact on agriculture (% of respondents)

Sl. No.	Statements	SA	A	N	DA	SDA
1.	There are changes in the agricultural production in the farm over the years	30	24.2	17.5	28.3	-
2.	There is a shortage of water for irrigation in the peak summer season	35	25	8.3	27.5	4.2
3.	Deterioration of water quality observed in the locality	30.8	40.9	6.7	10.8	10.8
4.	Changes in the available water quantity and quality significantly affects the household consumption pattern	35	25	15	25	-
5.	Decrease in water quantity and quality are the major reason for yield reduction in the farm	20	32.5	20	22.5	5

4.2.6. Perception of respondents on water quality in summer season

Increased pollution and continuously decreasing water level leads to a decline in water quality, which is a major concern around the world. Increased water demand as well as inadequate sanitation facilities are the key reasons for unsafe drinking water that consumed by almost 900 million people worldwide and up to five million people are dying every year from water-related illness. The deterioration of water quality may therefore make scarcity worse, particularly in developing countries and it has an adverse impact on the resource poor people. It was reported that poor people are forced to have water that unfit for human consumption which eventually results in several health problems (Mayers *et al.*, 2009).

The respondents' perception on water quality during peak summer season is given in the Table 4.21. As the summer advances, the color of water changes to yellowish brown to reddish in many parts of the study area. The problem was more prevalent in the areas which are far away from the coastal shore of Chavakkad (53 per cent), Thalikulam (47 per cent) and Mathilakam (40 per cent) regions. Comparatively, the problem was least observed in Kodungallur Municipality. Salinity of water is another problem faced by the farmers in the study area. Salinity due to the sea water intrusion was reported to be very common in coastal lands and backwater lagoons of Kerala (Chakrapani, 2014). The salinity issues was observed higher in Kodungallur regions among the study area. Bhoominathan *et al.* (2012) also reported incidence of salinity in the Kodungallur region due to saltwater intrusion.

In Mathilakam BP, 33 per cent farmers who lives near to the coastal area face salinity issues that is 60 per cent more than the coastal areas of Chavakkad BP. Hardness of water is another quality issue reported across the area and the problem was observed higher near the sea coast of Chavakkad BP (27 per cent). Aquatic weed problems (especially *Eichhornia* and *Salvinia sp*.) was also reported.

Microbial contamination is another problem. Several water borne diseases like diarrhoea, dysentery, typhoid, worm infestations and infectious hepatitis are reported due to water contamination (Kunhikannan and Aravindan, 2000). Faecal contamination also contributed to poor groundwater quality (Harikumar and Chandran, 2013). Quality of water not only poses risk to human wellbeing, it also affects the crop yield through irrigation water. The assessment of microbial contamination is beyond the scope of this study.

Table 4.21. Respondents' perception on water quality in summer season (% of respondents)

Sl.No.	Quality aspects	Chavakkad		Kodungallur		Thalikulam		Mathilakam		Average	
		Away from sea coast	Near the sea coast	Away from sea coast	Near the sea coast	Away from sea coast	Near the sea coast	Away from sea coast	Near the sea coast	Away from sea coast	Near the sea coast
1	Colour change	53	40	27	20	47	40	40	20	42	30
2	Odour	14	-	13	-	13	13	27	13	15	7
3	Salinity	13	6	27	47	13	13	13	33	20	25
4	Hardness	20	27	13	13	7	20	7	20	12	17
5	Aquatic weeds	-	27	20	20	20	14	13	14	13	18
	Total	100	100	100	100	100	100	100	100	100	100

4.3. Adaptation strategies

Adaptation refers to particular adjustments in a system to better cope with external stress. It is the potential or ability of a system to adjust to exposures in order to regulate damages, take advantage of opportunities or cope with effects (Yohe and Tol, 2002; Fussel and Klein, 2006; Adger *et al*., 2007). According to IPCC (2007), adaptation is an adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.

The adaptation strategies are considered as a process involving the socio-economic and policy environments, producers' perceptions, and elements of decision making on the perspective of vulnerability (Luo and Lin, 1999). The farmers' perceptions on the water scarcity situations as well as adaptation strategies are more important. In India, groundwater recharge was the centric adaptation strategy as a precaution for the future water crisis, by constructing several groundwater recharge structures (Shah, 2009). Digging of new wells, deepening of existing wells, adoption of efficient irrigation methods and dependence on water markets are the most common adaptation strategies adapted by the farmers to cope with water scarcity situations (Nagaraj *et al*., 2003).

The farmers' immediate responses to water crisis in the study area are furnished in Table 4.22. The behavioral response at micro level were basically to increase the water availability (extraction) or decrease the consumption (conservation) or a combination. Due to the shortage of water in the peak summer seasons along with difficulty in water harvesting from traditional water sources, farmers opted for water extraction practices like digging new ponds, installation of more efficient pumpsets and roof water harvesting. Quality issues especially for domestic use are addressed by installing water filters.

4.3.1. Adaptation strategies by the respondent farmers

4.3.1.1. Digging new ponds

Ponds used to be one of the water source in the coastal region owing to the shallow water table in the area. As scarcity increases, there is a tendency to dig more ponds especially in Kodungallur and Chavakkad (11 per cent each) regions. Digging new ponds of an average size of 3 meter depth and 10 meter diameter could be done with an investment around Rs. 13,400/- per pond. It is an average initial investment to dig a new pond in the study area. The cost for digging new ponds was observed higher in Kodungallur region (Rs. 14,000/-) followed by Chavakkad (Rs.13,500/-). It was observed lowest in Chavakkad (Rs.12,000/-). The cost for new pond construction in Mathilakam BP was 11 per cent less than the cost incurred in Chavakkad (Table 4.22). Varghese (2012) studied water scarcity and adaptations among farmers in Wayanad district of Kerala and reported that measures for improving supply of water were digging new wells, water conservation strategies and exploring alternate sources of water. It was reported that there could be decrease in household welfare due to increasing irrigation expenses.

4.3.1.2. Installation of more efficient pumpset

Electric motors are simple, economical and requires low maintenance. The farms in the study area generally use pumpsets with electric motors for the extraction of water. Motor pumpset helps to improve efficiency in groundwater draft and irrigating water over a range of cultivated area in an efficient manner. Nowadays, Bureau of Energy Efficiency is recommending BEE Star-rated pumps as the right move for efficient consumption of electricity. These pumps helps in energy and cost savings. Hence, installing efficient motor pumpset for water draft was practiced as an adaptation strategy by the farmers in the study area. It was widely adopted by the farmers in Mathilakam BP (72 per cent) followed by Thalikulam (56 per cent). In Chavakkad BP, 33 per cent farmers purchased new motor pumps during the years

2005-2018 and a few farms in Kodungallur region (18 per cent) went for the installation of efficient pumpset as an adaptation strategy. Seenath (2016) reported that 63 per cent farms in Chittur BP in Palakkad used compressor cum motor as an adaptive strategy for improving the supply of groundwater.

The cost for this adaptation strategy in the study area was observed higher in Kodungallur municipaliy (Rs. 8733/-) and lower in Thalikulam BP (Rs. 6289/-). The cost incurred in Mathilakam BP (Rs.8256/-) was 8 per cent more in comparison to the Chavakkad BP (Rs.7625/-). However, it was reported that such measures are capital intensive causing financial burden on farmers (Vaidyanathan, 2013).

Table 4.22. Adaptation strategies adopted by respondent farmers

Sl. no	Adaptation strategies	Chavakkad		Kodungallur		Thalikulam		Mathilakam		Average	
		% of farmers	**Actual cost (Rs./unit)**	**% of farmers**	**Actual cost (Rs./unit)**	**% of farmers**	**Actual cost (Rs./unit)**	**% of farmers**	**Actual cost (Rs./unit)**	**% of farmers**	**Actual cost (Rs./unit)**
1	Digging new ponds	11	13500	11	14000	0	0	8	12000	8	13400
2	Installation of efficient pumpset	33	7625	18	8733	56	6289	72	8256	43	7446
3	Roof water harvesting	45	12600	24	12950	24	15625	14	14150	28	13522
4	Filtering of water for domestic purpose	11	15250	47	17125	18	12500	8	15500	22	15750

4.3.1.3. Roof water harvesting

The water conservation measures like roof water harvesting were adopted on a limited extent in the study area. It would improve groundwater availability by enhancing the recharge. In this water conservation method, the roof water was collected in polythene/polypropylene tanks installed near open wells using PVC pipes. The collected water was allowed to drain through a layer of pebbles and a layer of sand to get it purified, and was directed to open wells. Generally, these structures were installed with the technical and financial support from Local Self Governments (LSGDs) and National Bank for Agricultural and Rural Development (NABARD).

In Chavakkad BP, about half of the respondents (45 per cent) adopted roof water harvesting and in Thalikulam, it was 24 per cent. Only 14 per cent of respondents adopted this adaptation strategy in Mathilakam BP. In Kodungallur, roof water harvesting method was more preferred rather than construction of new ponds or installation of efficient pumpset. This can be directly attributed to poor water quality (salinity, colour change) of the groundwater. The situation in Kodungallur Municipality was found to be very grave as far as water quality is considered, due to saline water intrusion in this region.

Some of the farms were allowing harvested rainwater to be stored in a pit taken near open well to facilitate artificial recharge. Farmers could not claim subsidy on such conservation pits since pits are constructed without following the prescribed standards. The average adaptation cost for roof water harvesting was approximately Rs.13, 522/- the highest being in Thalikulam BP (Rs. 15, 625/-) and least in Chavakkad BP (Rs.12, 600/-). It was observed that the average cost for roof water harvesting in Mathilakam region (Rs.14, 150/-) was 9 per cent higher than the average cost of the same in Kodungallur region (Rs.12, 950/-). It is apparent that the water conservation measures are more sustainable and less capital intensive than measures for intensive water extraction.

4.3.1.4. Filtering of water

Water filtration systems are helpful for making the available water free from dirt, debris, heavy metals, micro-organisms, and chemicals. Filtering of water was considered as the only option left to the respondents for getting potable water. Generally households of the study area adopted a whole house water filter system which is known as point-of-entry, or POE filter, installed at a single point that connects directly to the main water supply line and acts as a central filtration system for the whole house. Water filters were installed in 47 per cent households in Kodungallur Municipality while in Mathilakam BP it was only 8 per cent. On an average, this adaptation strategy was adopted by 11 per cent households in Chavakkad, 47 per cent in Kodungallur and 18 per cent in Thalikulam BP. Installing a whole house water filtration system became a necessity in the Kodungallur region due to the presence of high salt content in the water. The adaptation cost for installing a water filter was calculated higher in Kodungallur Municipality (Rs.17, 125 per unit) followed by Chavakkad BP (Rs.15, 250 per unit). It was least observed in Thalikulam BP (Rs.12, 500 per unit).

4.3.2. Factors affecting the adaptation

Households' adaptation behavior to water stress conditions are influenced by many factors like awareness, financial aspects and technical feasibility. An attempt was made to identify influence of these factors by employing the logistic regression model (Table 4.23). The dependent variable, which is dichotomous is grouped as those who adopted atleast one among the four strategies (1) and who did not follow any of them (0). The independent variables were education level, farming experience, crop diversity index and water availability in the wells in summer. The farming experience was proved to be the only significant variable that favoured the decision to adapt any of the four methods. The Odds ratio (1.03) shows that an increase in experience by one year results in 1.03 times more chance to opt for the adoption of any of the strategies. However this analysis is constrained by adequate sample size to separately address the agricultural and domestic adaptation strategies.

Table 4.23. Factors influencing adaptation strategies

Sl. No.	Particulars		Coefficients	Standard Error	t Stat	p-value	Odds ratio
	Intercept		-1.28	0.75	-1.70	0.08	0.27
1	Education (code given to each level)	Upto 10th grade	0.28	0.51	0.55	0.58	1.32
		Higher secondary	0.35	0.55	0.63	0.52	1.41
		graduate	0.12	0.71	0.18	0.85	1.13
2	Experience in agriculture (Years)		0.03	0.01	2.67	0.007 ***	1.03
3	Crop diversity index		0.76	11.25	0.06	0.94	2.14
4	Volume of available water in wells in the summer (Liters/well)		0.0001	0.0001	1.28	0.19	1.0001

*******significance at 1% level ******significance at 5% level *significance at 10% level

SUMMARY AND CONCLUSIONS

Chapter V

SUMMARY AND CONCLUSIONS

Water scarcity as well as declining water quality, became a major threat in several parts of the world, due to overuse or contamination of sources. Rapid increase in population and subsequent increased demand for water in agriculture, domestic, and industrial fields are the major reasons for 'water crisis'. The impacts of water scarcity in coastal ecosystem are both qualitative and quantitative in dimensions. The study on 'Water crisis in coastal areas: domestic adaptation strategies and impact on agriculture sector' was undertaken in this background in coastal areas of Thrissur district in Kerala. The main objectives of the study were to analyse the dimensions of water scarcity and the level of understanding of the same among coastal communities and to identify the strategies to address the issue. Further, economic burden on households were identified and the impact of scarcity on agriculture sector was also analysed.

In this study, two stage random sampling was used for sample selection from three Block Panchayats and one Municipality in the coastal areas of Thrissur district. All the wards (under the Grama Panchayaths/Municipality) were categorised in to two categories based on distance from sea. From each category, three wards were selected randomly, from these wards, five households each were randomly chosen making total sample of 120 respondents. Primary data regarding socio-economic aspects, cropping pattern and production, sources of water for domestic purpose and irrigation, perceptions and economic burden for adaptive strategies to water crisis were collected from the sample farms by personal interview method using pre-tested structured interview schedule and through direct observation. The secondary data was gathered from various government publications, data maintained by departments of the government and other similar sources. Statistical tools like descriptive analysis, regression analysis, scaling technique and Shannon-Wiener diversity index were employed for the analysis of the data.

The average age of the sample respondents in the study area was 56 years with an average level of education of seven years. Majority farmers (41 per cent) have more than 25 years of farming experience. Most of the households (81 per cent) were small sized, the average family size being 2-4 members. Majority of the respondents (76 per cent) were under marginal holding size group possessing a land area of less than 1 hectare. The average landholding size was maximum in Kodungallur (0.77 ha) and the minimum in Thalikulam (0.60 ha), the average being 0.69 hectares.

The cropping pattern in the study area follows the state pattern, coconut being the major crop. However, the proportion of coconut was higher than state average to the tune of 6 per cent. Arecanut and banana are the major intercrops in the area and crop diversity index was estimated at an average of 0.35. Crop diversity was observed lowest in Thalikulam BP where the holding size was comparably lower which might have restricted the cultivation of other crops. The highest crop diversity index was recorded in the homesteads of Mathilakam BP (0.37) followed by those in Chavakkad and Kodungallur (0.36 and 0.34 respectively).

The major water sources in the study area are own dug wells. Apart from that public water supply/ house connection, common public taps and neighbours' private wells are the major water sources for domestic purpose. Ponds are also very common in the coastal areas. There is season wise difference in the level of dependence on water sources for domestic purpose. During June-August period, dug wells form the major source (77 per cent) followed by public water supply/house connection (23 per cent). As the season advances to summer, dependence on dug wells reduced (20 per cent), since most of the wells dry up either completely or partially or the water quality is poor. Public taps are source of water during summer months. In Chavakkad BP, 40 per cent of the respondents depended on public taps. Some of the households depend on the neighbour's private wells also.

The average well density in the study area was 116/ Km^2 and it was lower than the reported average density of wells in the coastal areas of Kerala (200/ Km^2). The well density was higher in Thalikulam (163/ Km^2) and lowest in Mathilakam (76/ Km^2). The average depth of dug wells was 4.90 meters below ground level and the wells in the Chavakkad area was deepest (5.02 mbgl). The average diameter as well as average age of dug wells was found to be 1.88 m and 14 years respectively. The average diameter of wells ranged from 1-2 meters.

The well water level during summer months was at 4.55 meters below ground level and it was highest in Thalikulam region (4.79 mbgl). The average water storage in the wells during monsoon season was at 10787 liters/ well that reduced by 62 per cent to 4042 liters/ well in summer months. The average storage in the wells was lowest in Mathilakam BP i.e. about 8016 liters/ well during monsoon season and 3200 liters/ well in summer season. The volume of water storage in the wells declined by an average of 30-38 per cent during October-February, and 60-64 per cent during peak summer. The water storage decline was more in both Kodungallur and Thalikulam BPs.

The average household water use varied across regions and seasons and it was 680 liters/ day on an average. The per capita average water consumption was estimated at 165 liters/ day. The factors influencing the household water consumption level was analysed employing linear regression model. Volume of available well water and number of family members triggered the household water consumption. The area seeks appropriate water harvesting methods and structures to improve the water scarce condition prevailing in the area.

The respondents mainly depend upon the traditional water sources especially ponds and dug wells for irrigation. Majority of the farmers (77 per cent) irrigate from own dug wells except in Mathilakam BP (47 per cent). As the summer advances, as much as two-third of households across the study area shift the dependence for irrigation to ponds. A large shift was observed in Kodungallur region where 97 per cent households depend on ponds in summer months as the dug wells dry up or the water is saline. The average age of the ponds was 30 years with an average depth of 2.63 mbgl (meters below ground level) and 11.93 m diameter.

Sprinkler irrigation was the major irrigation method in the study area except in Chavakkad where basin irrigation was more popular. Most of the farms are irrigated (40 per cent) at an interval of 3 days where 15 per cent of the farms followed an irrigation schedule of once in 10 days, during the peak summer months, often as a life saving method. The decision to irrigate the farm is negatively influenced by number of water sources and agricultural income which was confirmed by linear regression analysis. Based on the linear regression analysis, it was revealed that increase in accessibility to water sources like pond and public water supply negatively influence the decision making in area irrigated because of the water scarcity for domestic purpose prevailing in the area. Farmers may utilise water sources for domestic purpose rather than going for irrigation.

The cost of irrigation involves amortised fixed cost component (well, pump set, pump house and storage structures) and the variable costs (labour and electricity charges). The average amortised costs per hectare was Rs. 29,838/- and it was highest in Thalikulam (Rs. 32,093/-) due to higher cost for constructing wells and other assets. The average cost of cultivation in the study area was estimated as Rs. 74,900/ha/year and irrigation cost was found to be a major component that constitutes 45 per cent on an average. However, returns per hectare cropped area was found higher in Thalikulam (Rs. 1,94,074/ha/year) due to more banana cultivation compared to other areas.

Most of the respondents reported a reduction in agricultural yield over the years and 60 per cent respondents attribute it to water scarcity. The water quality changes in the area was reflected as colour changes, odour and salinity where the colour change of water was more prevalent in the areas far away from the coastal shore of all BPs. However salinity was the predominant factor in Kodungallur (47 per cent). Hardness and aquatic weed infestation is a serious problem in the area. The respondents try to adapt to the situation through various strategies.

Digging new ponds, installation of efficient pump sets, roof water harvesting and filtering of water for domestic purpose are the major adaptation strategies followed by the farmers. The cost for adaptation is an additional burden to the households. Average cost for digging a new pond of 3 meter depth and 10 meter diameter was around Rs. 13, 400/-. Installation of efficient pumpsets was widely adopted by the farms in Mathilakam BP (72 per cent) and average cost was reported at Rs.7446/-. Roof water harvesting was done by 28 per cent of farmers at a cost of Rs.13, 522/- and it was popular in Chavakkad BP (45 per cent). Around 21 per cent of respondents have fixed water filters for domestic purpose with an investment of Rs. 15, 750/-. Installing a whole house water filtration system became a necessity in the Kodungallur region owing to the presence of high salt content in the water.

The factors affecting adaptation behaviour was analysed using logit regression model. The experience in agriculture was found to be the prevalent factor which determines adaptation behavior of the farmers. A unit increase in agricultural experience results 1.03 times improved chances to go for any adaptation strategy to acclimatise with the existing scarce conditions.

Policy suggestions

1. The crop diversity in the coconut based cropping system in the coastal areas can be improved through introduction of more crops like turmeric, ginger and black pepper. The models developed by KAU can be popularised in the area. This may improve the income, making farming more climate resilient and help in risk management.
2. Traditionally wells and ponds are the major water sources in the study area. The urbanization and concurrent higher pressure on land resources seems to have

less well density (116 wells per sq.Km) compared to the state average well density in the coastal areas (200 wells per sq.Km). There should be focused efforts to retain the traditional water sources that helped in water storage and conservative local sources are to be conserved, rather than depending on public water supply. The rain water recharge efforts are to be implemented in a priority basis at Kodungallur and Mathilakam regions where the decline in water quality is highest.

3. The per capita water consumption seems to be less than the prescribed minimum during the summer months. The water availability is to be ensured through water harvesting methods and efficient use pattern.
4. The common irrigation methods (sprinkler and basin) are high water consuming methods. Drip irrigation methods are to be compulsorily popularised in the area. Improving the crop diversity, mulching and husk burial methods are to be popularised.
5. The present irrigation investment amount to Rs. 33,781 per ha per year including amortised fixed cost, constitute 45 per cent of cost of cultivation needs to be reduced.
6. Scientific water quality monitoring system is to be implemented in the area. Presently the water quality changes are noticed by physical or visual characters only. The chemical and biological aspects are to be scientifically monitored and remedial measures to be taken up.
7. Technically enhanced public water distribution system should be implemented. Regularity, water quality and quantity must be standardised to cop up with existing conditions.
8. Scientific awareness campaigns on water harvesting and water conservation should be arranged in the study area.

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Appendices

APPENDIX –I

KERALA AGRICULTURAL UNIVERSITY
COLLEGE OF HORTICULTURE
KAU P. O
Vellanikkara, Thrissur
Department of Agricultural Economics

Water crisis in coastal areas: domestic adaptation strategies and impact on agriculture sector

MSc Programme

The information furnished will be only used for the research purpose and the data will be kept strictly confidential

SURVEY QUESTIONNAIRE

Block/ Municipality: Panchayat:

I. Individual Details

I. Name of the farmer:
II. Age:
III. Address:

IV. Telephone Number:
V. Education of the farmer: ☐

Class	Code
Primary	1
Up to 10th	2
Post Graduate	3
Technical	4
Others	5

a. If code is 1, specify the number of years of schooling:
b. If code is 4, specify the course:

VI. Occupation- Full time/ Part time:
a. If part time, specify main occupation:

VII. No: of years engaged in agriculture:

VIII. Annual household income: ☐

Income	Code
< 25000	1
25000-50000	2
50000-750000	3
750000-100000	4
100000-200000	5
>200000	6

II. Family details

Sl No.	Name	Age	Annual income
1			
2			
3			
4			

III. Cropping pattern (main holding)

Sl. No.	Crop	Number of plants/ area	Area

IV. Water sources details:

<table>
<tr><th rowspan="2">Sl. No.</th><th rowspan="2">Type*</th><th rowspan="2">Year of construction</th><th rowspan="2">Depth from ground (m/ft specify)</th><th rowspan="2">Diameter (m)</th><th rowspan="2">Water quality aspects**</th><th colspan="3">Water availability</th></tr>
<tr><th>June-Sep</th><th>Oct-Feb</th><th>Mar-May</th></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

*1. Dug well 2.Bore well 3. Pond 4.Others (specify)

**1. Colour change (specify), 2.Odour 3. Salinity 4. Hardness 5. Muddy 6. Aquatic weeds 7.Any other (Specify).

V. Domestic Water use pattern

Particulars		**Details**
HP of motor		
Capacity of the tank		
Time taken to fill the tank		
Frequency of filling per day		
Approximate quantity of water consumed per day	Dec- Feb	
	Mar- May	
	June- Aug	
	Sep-Oct	

VI. Irrigation Details

- Time: from …………..to………….(month)

Sl No. & Crop	Irrigation method	No. of labours/ day	Labour charge	Frequency/ week	Energy charges	Total cost

1. Basin 2.Flood 3.Ridge 4.Drip 5.Sprinkler 6.Pitcher pot 7.Manual hose 8.Others (Specify)

VIII. Cost of irrigation

Sl No.	Year of purchase	Fixed cost						Maintenance cost			
		Motor	Building	Storage tank	Materials	Labour cost	Total	Labour time	Material cost	Electricity bill monthly	Total

*1. PVC Pipe 2.GI Pipe 3. Others (specify)

IX. Cost of cultivation of crops grown

Crop	Area	Stage/Operation	Cost of cultivation						
			Seed	Labour	PP chem	Transport	Machine	Others	Total
		Ploughing							
		Planting							
		Fertilizer							
		Weeding							
		Harvesting							
		Others							

X. Production and returns per year

Crop	2017					
	Season/Age	HH consumption	Seed	Other purpose	Sold	Price

XI. Cost of adaptation strategies to overcome water crisis

Description	Year	Area/ capacity	Cost				Invest ment Source	Interest rate	Sub sidy	O/S Amount	Remarks
			Mate rial	Lab our	Others	total					
Pond construction											
Motor change											
Water storage tank/pit											
Rain water harvesting pit											

Roof water harvesting											
New irrigation method											
Filtering											
Crop change											
No cultivation											

A. Did you feel any changes in agricultural production in your land?

Yes : No:

B. What are the coping mechanisms practiced by you?

a. Change in cropping pattern:
b. Change in cropping intensity:
c. Choice of crop:
d. Change in planting time:
e. Depending on water markets:
f. Group farming:
g. Water conservation practices:
h. Limiting farming practices in owned land(Avoiding leased land farming):
i. Leaving agriculture:

C. Do you have any shortage of water for household purpose?

Yes: No:

D. If yes, how long you been experiencing such problems?

a. One year
b. Two years
c. 3-5 years
d. > 5 years

E. During which period of the year you experience such shortage?

a. Summer:
b. All months other than the rainy season:
c. Throughout the year:

F. What would you do to cope with such problems?
   a. Buying water :
   b. Depending on nearby households:
   c. Depending on nearby streams:
   d. Collecting water from distant places:
   e. Rain water harvesting:
   f. Reducing the use of water
   g. Water conservation methods

G. Do you feel any change in the water availability in your locality?

Yes : No:

H. If yes, what type of changes do you feel?
   a. Decrease in the availability
   b. Drying up of natural streams and lakes during summer
   c. Poor quality
   d. Decrease in the water table
   e. Others -specify

I. In your view, what may be the reasons for these changes?
   a. Climate change
   b. Changes in cropping pattern
   c. Conversion of paddy fields for other purposes
   d. Deforestation
   e. Change in land use pattern
   f. Urbanisation
   g. Lack of good management
   h. Others- specify

J. Do you feel any changes in the quality of water?
   a. Yes b. No

K. What are the difficulties you are facing regarding water?
   a. Drinking water problems
   b. Pollution
   c. Diseases
   d. Others

L. If the available water is polluted, signs that indicates the pollution?

a. Odour smell
b. Colour change
c. Diseases
d. Reduction in the number of aquatic organisms
e. Others- specify

M. What sort of adaptation measures would you like adopt to cope with such changes?
   a. Constructing conservation structures
   b. Planting trees
   c. Judicial use of natural reservoirs
   d. Preventing sand mining
   e. Migration
   f. Others: specify

N. Whether you have insured your crops?

Yes: No:

a. If yes, for which crops?

b. How long you have been insuring your crops?

c. Whether you feel it is good for farmers?

ABSTRACT

Water crisis in coastal areas: domestic adaptation strategies and impact on agriculture sector

Abstract

Despite rich endowments of water resources, availability of water in Kerala is dwindling and inadequate for the growing population. Several regions in the state experience seasonal drought like condition, every year. The coastal areas of Kerala become most vulnerable region with respect to water scarcity due to quantitative and qualitative aspects. The study on 'Water crisis in coastal areas: domestic adaptation strategies and impact on agriculture sector' was undertaken in this background in coastal areas of Thrissur district in Kerala. The main objectives of the study were to analyse the dimensions of water scarcity and the level of understanding of the same among coastal communities and to identify the strategies to address the issue. Further, economic burden on households were estimated and the impact of scarcity on agriculture sector was also analysed.

The study was conducted in Chavakkad, Thalikulam, Mathilakam, and Kodungallur regions of Thrissur district by a two stage random sampling of 120 respondents. The study was based on both primary and secondary data and the data was analysed using statistical tools like descriptive analysis, regression analysis, scaling technique and Shannon-Wiener diversity index.

The major water sources in the study area were own sources such as wells, ponds, and public sources like house connections and public taps. Wells are the major source for domestic sector and ponds serve the irrigation purpose. The volume of water in the wells, which was a major water source in the region, declined by an average of 62 per cent by summer season. Thus, the dependence on dug wells for household consumption reduced to 27 per cent, compared to monsoon season (77 per cent). This was also due to the water quality problems,

in certain cases. The water quality issues in the area was reflected as colour change, odour, salinity and hardness. Aquatic weeds was reported as a major threat in the coastal belt. Correspondingly, the average household water consumption level also declined. The volume of water in the well and family size influenced the household consumption.

Coconut based cropping system was prevalent in the study area with arecanut and banana as major intercrops. Ponds were the major source of irrigation water. Most of the farms were irrigated (40 per cent) at an interval of three days. In regions of severe water scarcity, an irrigation schedule of once in ten days (15 per cent of the farms) was followed. The decision to irrigate the farm was significantly influenced by number of water sources and agricultural income. The irrigation investment amounted to ₹33,781 per ha per year which constituted 45 per cent of cost of cultivation while accommodating the fixed cost component. Most of the respondents reported a gradual reduction in agricultural yield over the years and 60 per cent respondents attribute it to water scarcity.

Digging new ponds, installation of efficient pumpsets, roof water harvesting and filtering of water for domestic purpose were the adaptation strategies opted by the farmers to address the water scarcity. Farming experience was proved to be the most influential factor that determined the adaptation behaviour.

The study brings out results that suggest policy interventions for implementing rain water recharge efforts and scientific water quality monitoring system in Kodungallur and Mathilakam regions where water quality problems were more severe. Simultaneously water resource conservation strategies, as well as models developed by KAU for improving crop diversity are to be popularised.