FINAL REPORT

Documentation and analysis of farmers' practices on water management for plantation crops in Kerala

Indian National Committee on Irrigation and Drainage

(Ministry of Water Resources)
New Delhi

Centre for Water Resources Development and Management
Kozhikode – 673 571, Kerala

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Development and Management (CWRDM)

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2. Institution : Centre for Water Resources Development and Management (CWRDM)
Kunnamangalam – 673 571, Kozhikode, Kerala

3. Principal Investigator : Dr. E. J. Joseph
Scientist – F & Head
Water Management (Agriculture) Division
CWRDM, Kozhikode – 673 571, Kerala

4. Co-Investigators : 1) Dr. K. Madhava Chandran
Scientist-E2
Water Management (Agriculture) Division
CWRDM, Kozhikode – 673 571, Kerala

2) Dr. George Chackacherry
Scientist E2 & Head
CWRDM Sub-Centre, Neyyattinkara – P.O
Thiruvananthapuram

5. Project Staff : 1) Shri. M. Saidalavi *(upto March 2006)*
2) Shri. K. T. Vivek *(upto December 2005)*
3) Ms.L.Beena George *(Aug. 2006 to Dec. 2006)*

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Dr. E. J. Joseph	Dr. K. Madhava Chandran	Dr. George Chackacherry
Principal Investigator	Co-Investigator	Co-Investigator

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1. INTRODUCTION

Kerala State experiences a humid tropical climate characterized by heavy rainfall during monsoon season and high temperature during summer. The climate is warm and humid almost throughout the year. Located in the Western Ghats region, Kerala has highly undulating terrain that accelerates surface runoff, soil erosion and leaching of nutrients from the soil during the rainy season. However, nature has provided good forest cover in this region, which in spite of serving as a repository of biodiversity, protects the soil from adverse impacts of heavy rainfall and high temperature, adds soil fertility through biomass recycling and maintains hydrologic regime. Kerala is gifted with nature's bounty of water resources, with rivers and rivulets interconnecting backwaters and canals, several lakes and ponds, springs, and extensive wetlands and rice fields.

Compared to other humid tropical regions in the world, Kerala has more rainfall, higher population density and greater percentage of area under agriculture. The population in different districts of Kerala has increased by 4 to 28 times during the last century. This has led to fragmentation of land holdings, high rate of deforestation, and large-scale human settlement in ecologically sensitive areas. Many of the natural ecosystems have given way to various agricultural ecosystems that predominantly consists of perennial crops like coconut, rubber, arecanut, coffee, tea, cardamom, black pepper, cashew, cocoa, various tree spices etc. in the uplands and rice, pulses, vegetables, tapioca, yams, banana etc. in the valleys. The socioeconomic situation in the State necessitates farmers to practice agriculture even in steep areas having more than 100 per cent slope. In Kerala, the farmers live in houses located in their farm holdings, which together is called homesteads. Homestead farming system is widely adopted wherein, the average size of operational land holding is only 0.24 ha. Ninety five per cent of the land holdings are marginal (<1 ha) and 3 per cent are small (1 to 2 ha). These two categories together constitute 75 per cent of the agricultural area in the State.

The rapidly increasing population, undulating topography, heavy and unevenly distributed rainfall, deforestation, large-scale reclamation of rice fields, unscientific agricultural practices, pollution, climatic vagaries etc. are threats to environmental sustainability that aggravate land degradation and water scarcity in the region. With the erosion of top soil and organic matter, the water holding capacity of Kerala soils is low, causing soil moisture stress for the crops during the summer season extending from December to May. The perennial vegetation, which covers majority of the area in the State, survives during this drought situation by their physiological and morphological adaptations. Though Kerala is a place of evergreen land cover throughout the year, in reality, the crops are suffering from physiological drought, resulting in poor growth and low productivity. Thus, Kerala's problem of agricultural drought is unique.

Kerala makes significant contribution to the cash crop requirements and foreign exchange earnings of the country. Since majority of the agricultural area (75 per cent) in the State is formed by marginal and small land holdings, with only about 12 per cent area contributed by holdings of 2 to 4 ha size and hardly 13 per cent area contributed by big holdings above 4 ha, crop production and productivity can be improved by adopting suitable strategies in homestead farming. Adoption of sustainable farming practices in the homesteads is highly important not only from the crop production point of view, but also for maintaining the ecological balance in the region for the conservation of land, water and other natural resources. If managed properly, these homesteads have the potential to be good productive units that ensure maximum economic returns by adopting subsidiary income generative activities, recycling of bio resources, conservation of ecology and agrobiodiversity, and efficient use of water and energy. There are many success stories of sustainable homestead farming across Kerala.

In a State with 3000 mm of mean annual rainfall, many of the water-related problems are due to the lack of proper awareness and seriousness among the people in adopting suitable water management measures. However, many of the farmers in Kerala have traditionally evolved various agronomic practices, which help in conserving soil and water resources. Unfortunately, some of these traditional wisdom and practices are disappearing due to the influx of modern technologies and changes in the social set up and life style of people. It is required to create awareness on the significance of many of these traditional practices for the conservation of land and water resources in this ecologically fragile zone. Also, there exists enough scope for dissemination of this knowledge to similar agro-climatic conditions elsewhere. It was in this background that the project on "Documentation and analysis of farmers' practices on water management for plantation crops in Kerala" was undertaken by the Centre for Water Resources Development and Management, Kozhikode, Kerala with the financial support from Indian National Committee on Irrigation and Drainage, New Delhi.

1.1. Objectives

The objectives of the project were:

- to analyze the agricultural scenario in the State in the perspective of various agro-ecological and socio-economic factors
- to study the extent of adoption of improved water management practices for different plantation crops
- to document the information on various traditional practices of water management for plantation crops, giving suitable scientific explanation, and to study the socioeconomic factors influencing agricultural water management.

***

2. METHODOLOGY

The available literature on various water related agro-ecological and socio-economic factors pertaining to Kerala and other related geographical locations were collected from various secondary sources. Based on this, the agricultural scenario in the State was analyzed for highlighting the relevance of sustainable agricultural water management in this humid tropical zone. In order to document the water management practices adopted for various plantation crops, a sample of progressive farmers from the State was drawn covering different agro-ecological zones, crops and sizes of operational holdings. For this, the list of progressive farmers, who were screened during previous years by the State Agriculture Department and the Malayala Manorama Co. Ltd. for selection to various awards/ recognitions, was collected. List of progressive farmers was also collected from Spices Board, Coconut Development Board, Coffee Board and Rubber Board. Apart from these, promising farmers were also identified with the help of local libraries, local self governing departments, non-Governmental organizations, and mass communication media. About 1000 addresses of such farmers were obtained. A brief resume on the water management practices followed by these farmers was collected by sending a short questionnaire to them. Based on this, field visits were conducted to about 250 selected farms under diverse types of plantation and spice crops in different agro-climatic zones of Kerala. Personal interviews using a detailed questionnaire were done with 91 farmers. The list of farmers covered in personal interview is given in Appendix 1.

2.1. Information Collected

Information on the following aspects was collected from each selected farmer during the field visit and interview using the detailed questionnaire (Appendix 2).

- Location
- Family and education
- Land holding and amenities
- Land fertility
- Cropping system and cropping pattern
- Other subsidiary income generative activities
- Irrigation methods and practices followed
- Capital and operating cost of irrigation system
- Quantity of water applied and irrigation interval adopted
- Impact of irrigation on crops
- Cultivation practices followed
- Soil and water conservation measures adopted and their merits and limitations
- Cost of cultivation of various crops

- Income from crops
- Recognitions received
- Extension advisory services obtained
- Farm credits, if any

The areas of water management covered for data collection include:

- Mechanical and agronomic measures of soil and water conservation
- Development of water resources and rainwater harvesting
- Irrigation, and
- Drainage

An attempt has been made to explain the scientific principles behind some of the traditional practices of water management. A narrative account of the information collected during the field survey is given under Section 3.4. For each practice, the following details were described.

- Method
- Benefits
- Limitations
- Applicability
- Researchable components

The important practices adopted by farmers were also videographed during field visits. The widely adopted soil and water management practices like post-monsoon tillage and cover cropping were evaluated under farmers' field condition. The details of this trial are described in section 3.5.

***

3. RESULTS AND DISCUSSION

3.1. Agricultural Scenario in Kerala and the Relevance of Sustainable Water Management

3.1.1. Location

Kerala State, a narrow strip of land situated on the southwest coast of Indian Peninsula, lies between 8º18' to 12º48'N latitude and 74º52' to 77º22'E longitude. The State is bordered all along its east and west by Western Ghats and Lakshadweep Sea respectively. The width of land in between the eastern and western borders ranges from 15 to 120 km. The State having a long coastal line of about 590 km is divided into 14 revenue districts, out of which 9 districts have coastal line. The total geographical area of the State is 38863 sq km, which is about 1.18 per cent of the size of India. This area supports a human population of 3.34 crores (2.76 per cent of the country's population), giving rise to a population density of 859 per sq km against the national average of 368 per sq km.

Figure 3.1.1. Map of Kerala

3.1.2. Physiography

The State has three distinct parallel physiographic zones; the highland (above 75 m from the mean sea level), the midland (between 7.5 and 75 m above mean sea level), and the lowland (below 7.5 m from the mean sea level). Out of the total geographical area of the State, 10.24 per cent constitutes lowland, 41.76 per cent midland and 48 per cent highland regions (KSLUB, 1995). Within the 120 km width of the State, the elevation falls from 2,694 m above MSL (on Anamudi peak of Western Ghats) to 5 m below MSL (in Kuttanad region of Ernakulam, Kottayam and Alapuzha districts). The area-altitude analysis reveals that almost 42 per cent of the total geographical area is located above 100 m contour. The rolling topography in the State contributes to a series of big and small watersheds called *elas* having plain valleys that are mostly wetlands, surrounded by highly sloping garden lands. This characteristic terrain and the natural forest vegetation in the region help in alleviating the problems of floods and droughts to a great extent.

The various terrain conditions in the State have slope ranging from <5 to >35 per cent and relief ranging from <10 m to >300 m. The moderately rolling undulating terrains have slopes ranging from 15 to 25 per cent and are intensively cultivated. The highly undulating terrain represents foot hill zones with slope up to 35 per cent. The hilly area represents the hills of Western Ghats, with more than 35 per cent slope and relatively high relief (KSLUB, 1995). The above classes of land terrain that spread over the entire State are intensively used mainly for cultivation of perennial crops. These areas are affected by deforestation, high surface runoff, soil erosion, leaching of nutrients and generally have the presence of clay laterite interface in the soil profile.

3.1.3. Climate

Kerala experiences a humid tropical climate, characterized by the presence of heavy rainfall, high relative humidity, abundant sunshine and high ambient temperature. The atmosphere is warm and humid throughout the year. The micro climate in different parts of the State is influenced by proximity to the sea, altitude, landform and type of vegetation in and around the area. The rain-shadow regions (eastern side of Western Ghats) have dry climate.

Rainfall

The rainfall received in different parts of the State show high temporal and spatial variability. The mean annual rainfall of the State is around 3000 mm, out of which about 85 per cent is received during the two monsoon seasons that fall between the months of June and November. The south-west monsoon that extends from June to September and the north-east monsoon during October-December contribute to 70 per cent and 15 per cent of the annual rainfall respectively (Figure 3.1.2). The remaining 15% of the rainfall is received during the winter and summer seasons (January to May). Though the northern districts receive more annual rainfall than the southern districts, the temporal distribution of rainfall is highly uneven in the north. The northern region, especially

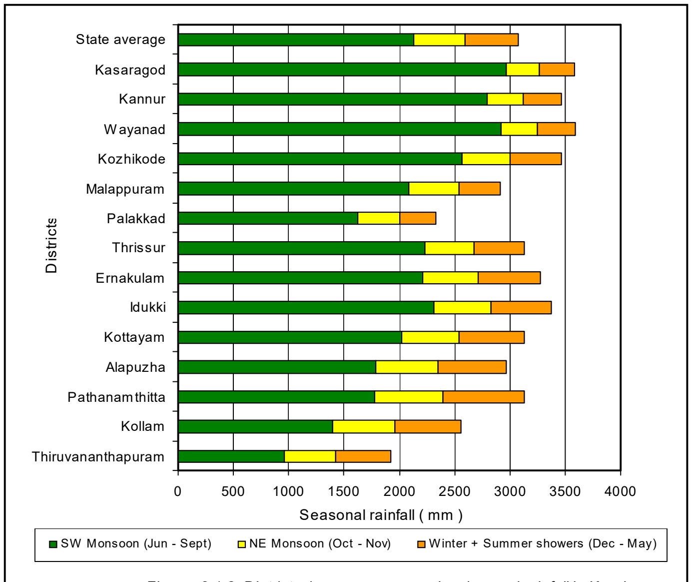

Figure- 3.1.2. District-wise mean seasonal and annual rainfall in Kerala

Kasaragod, Kannur, Wayanad and Kozhikode districts receive very heavy and highly intense south-west monsoon. But, north-east monsoon is less and summer showers are scanty in the north (Figure 3.1.3). The temporal distribution of rainfall becomes more even towards the south with better rainfall during the period from October to May and hence, the southern region is less drought-prone.

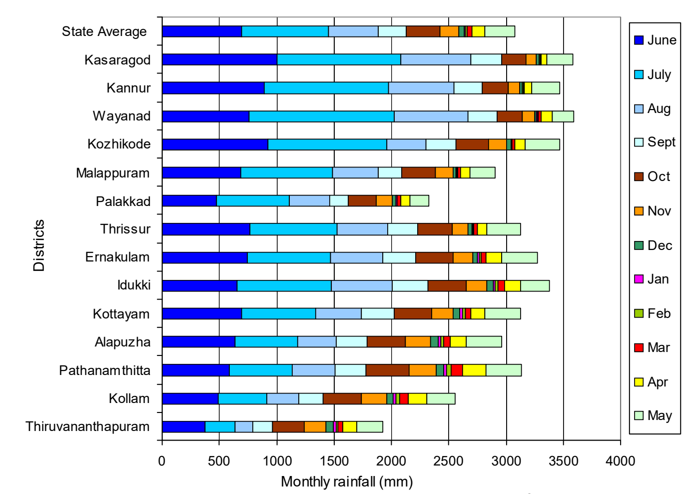

Figure- 3.1.3. District-wise mean monthly and annual rainfall in Kerala

The rainfall variability within a district or a geographical location is less in the coastal regions and more towards the inland. For instance, the inland districts of Wayanad, Palakkad, Idukki and Pathanamthitta exhibit very high spatial variability in rainfall (Figure 3.1.4).

In Kerala, the high rainfall, coupled with the undulating topography accelerates the processes of surface runoff, soil erosion and leaching of nutrients from the soil. However, nature has provided a thick blanket of wet evergreen, semi-evergreen and wet deciduous forests, which protects the soil from strong solar radiation and intense rainfall, enriches fertility of soil through biomass recycling, maintains hydrologic regime in the area, and serves as a repository of biodiversity. The high rainfall and cloudiness in the region lowers evapotranspiration, which restricts nutrient uptake in plants during the monsoon period. Heavy rainfall and low solar radiation during the monsoon period, and very low rainfall and high solar radiation during summer are climatic constraints for agriculture in Kerala.

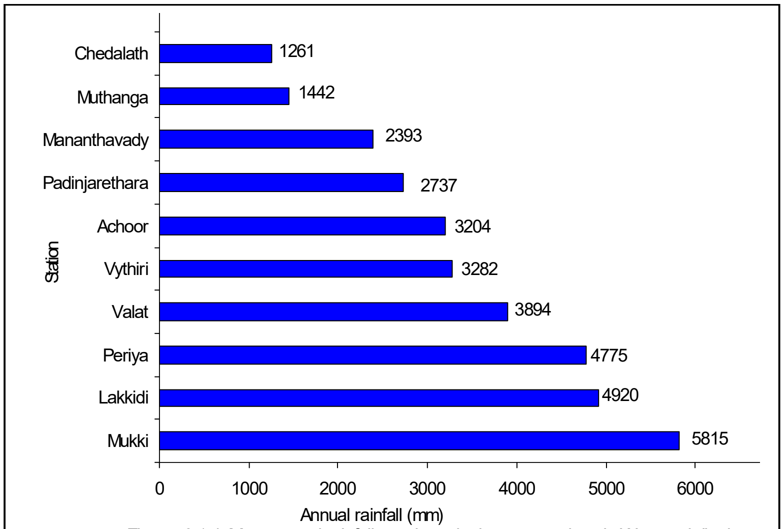

Figure- 3.1.4. Mean annual rainfall at selected raingauge stations in Wayanad district

Temperature

The annual average ambient temperature over Kerala is 27.5ºC. There is spatial variation in annual mean temperature ranging from 25.5 to 27.5ºC in the coastal belt, 27.5 to 29.5ºC in the central regions and 17.5 to 21.5ºC in the hilly areas. The mean maximum temperature is about 33ºC during the hottest period (March-April) and 28.5ºC in July. The temperature rises up to 40ºC in Palakkad district during March-April. The diurnal variation in temperature is only about 5.3ºC during the peak monsoon period (July to August), which increases to the tune of 8.5ºC to 9.5ºC during December to March period. The surface of the earth gets heated up during the day and cools during the night, causing significant diurnal changes in the top layers of soil. The diurnal variations in soil temperature is high (27.5 to 44.4ºC) at the surface, while it is low (31.2 to 40ºC) at relatively deeper soil layers (15 cm and more).

Relative humidity

During the monsoon season, mean maximum and minimum relative humidity values in Kerala are 95 per cent and 70 per cent respectively. The diurnal variation in relative humidity is low (10 to 20 per cent) during monsoon months and high (25 to 40 per cent) during December and January. The minimum relative humidity is significantly low during December-January period when it ranges between 45 and 60 per cent. High relative humidity during the monsoon season results in the incidence of many diseases for crop plants.

3.1.4. Land and soil

With the extensive removal of natural forest cover, the land and soil in most parts of the State are exposed to intense weathering and subjected to accelerated degradation due to erosion of top soil and organic matter. The average sediment yield from the Western ghats region of Kerala is estimated as 15 to 20 tonnes/ha/yr (CWRDM, 1992). Laterite, one of the most important products of weathering, is widely distributed over Kerala, particularly in the northern region. The soils are low in pH and base saturation. The soils, in general, are poor and deficient in almost all the macro and micro nutrients. However, even under these impoverished soil conditions, the average consumption of fertilizers in the State during the period from 1995-96 to 2004-06 is only 65.6 kg per ha as against 85.2 kg per ha in India.

Apart from high rainfall, intense solar radiation and undulating topography, the major causes of land degradation are deforestation, extension of agriculture to highly sloping areas, unscientific cultivation practices, inadequate coverage of soil conservation measures etc. It is estimated that about 9.5 lakh ha of land area in the State is prone to moderate to severe soil erosion. The loss of fine-textured top soil and organic matter leaves behind larger soil particles and gravel that decreases the water holding capacity of the soil.

3.1.5. Water resources

Kerala is gifted with 44 rivers of small and medium category, interconnecting backwaters and canals, several lakes and ponds, streams, springs, wells and extensive wetlands and rice fields. Both natural forests and wetland rice fields serve as natural means of rainwater harvesting and groundwater recharge. The narrow valleys in the region receive sediments and water from the surrounding slopes and retain them for a longer time thereby increasing the intake opportunity time. The loose sediments retain water and help in groundwater recharge.

3.1.6. Agro-ecological zones

Based on different levels of parameters such as altitude, rainfall, soil type and topography, the State has been delineated into 13 agro-ecological zones taking Block Panchayat as the unit for delineation (KAU, 2007). The wide range of agro-climatic conditions prevailing in the State facilitates the cultivation of various crops ranging from semi arid to temperate crops.

3.1.7. Biological diversity

Kerala represents an epitome of biodiversity profile of the Western Ghats in India. The State is endowed with diverse types of ecosystems, each supporting unique assemblage of biological communities, with an impressive array of species and genetic diversity. There are three hotspots of endemic centres in Kerala – Agasthyamala, Anamalai High Ranges and Silent Valley-Wayanad. The State contains 95 per cent of the flowering plants and 90 per cent of the vertebrate fauna of the Western Ghats.

Kerala is also very rich in agrobiodiversity. Many wild relatives and landraces of cultivated crops exist in the region. The Silent Valley and Wayanad areas are repository of genetic diversity in black pepper and turmeric. In addition to wild forms of *Piper nigrum* (black pepper), a rich genetic stock of 17 other species of *Piper* have been found in the forests of Western Ghats. Similarly, besides *Curcuma longa* (turmeric), 23 other species of *Curcuma* also occur in the region. In the case of ginger and cardamom also, a rich collection of wild relatives exists in the forests of Western Ghats (SPB, 2007).

3.1.8. Land use changes

The Western Ghat region, like other parts of the tropics, has undergone significant land use transformation. In Kerala, the population density in different districts has increased by 4 to 28 times during the last century. This high demographic pressure has led to increased deforestation and large scale human settlement in ecologically fragile areas. The forest cover in Kerala, which was more than 40 per cent of the total geographical area during the pre-independence period, has decreased to about 28 per cent now. The natural forest coverage is reported to be below 10 per cent. A sudden decrease in forest cover took place during the period 1940 to 1950 because of the steps taken by the Government to lease out cultivable areas within the forest reserves for food production in order to tide over the food-shortage and poverty during and after World War II (1940s). Thus, many of the natural ecosystems were gradually replaced by different agricultural ecosystems.

Presently, the net sown area in the State is 20,88,955 ha, which is 54 per cent of the total geographical area (DoES, 2009). Though the net sown area has increased by about 25 per cent during the period from 1952 to 2008, it is showing a declining trend in recent years. About 22 per cent of the total area is currently cultivated more than once, contributing to a cropping intensity of 139 per cent, which is slightly above the national average of 135 per cent. However, this high cropping intensity in the State is attributed more to the specific land use pattern characterized by the predominance of plantation crops under high density mixed cropping than the effect of irrigation.

During the 28 years from 1980 to 2008, area under crops like coconut, rubber, arecanut, coffee, black pepper, banana, etc. recorded increase (some of them showing marginal decrease in recent years), while cashew, tea, cardamom, rice etc. showed a reduction in area. Rice cultivation, which maintains standing water in the field and facilitates groundwater recharge, has shown decrease in area by 69 per cent over the past 28 years. The present gross cultivated area under rice is only 2,34,265 ha. The large scale reclamation of lowland paddy fields, which started throughout Kerala in 1980s is still being continued. Many of these reclaimed areas are converted into coconut and arecanut plantations, banana orchards etc. Since these introduced crops are sensitive to water stagnation, facilities for quick drainage are created in the lowlands. In the drought-prone districts of Palakkad and Wayanad, the area under banana, arecanut and coconut have shown significant increase mainly at the expense of rice farming. The crop shift in favour of commercial crops is primarily due to the low profit and the high cost of production of food crops. Even with high wages, there is extreme shortage of farm labourers, especially during peak seasons of work. In many of the lowland regions, where extensive conversion to banana cultivation has taken place, pollution of fresh water bodies due to the indiscriminate use of pesticides is becoming a serious problem. In Kottayam and Ernakulam districts, rubber has come up in vast areas, which are devastated by the root wilt disease of coconut. The area under rubber has highly increased in Idukki, Palakkad and Kannur districts also. Rubber has become the second important crop in the State's agriculture after coconut, relegating rice to the third position. Some of these land use changes, especially the extensive reclamation of paddy fields, can have serious environmental consequences that increase water scarcity and incidence of drought in the region.

3.1.9. Land holding

The high population pressure in the State has resulted in high rate of fragmentation of land holdings. According to the Agricultural Census of 2000-01, there are 66.57 lakhs of operational holdings in the State and the average size of holding is only 0.24 ha, as against the national average of 1.41 ha. Ninety five per cent of the holdings are marginal (< 1 ha) and 3 per cent are small (between 1 and 2 ha). The small and marginal holdings together cover about 75 per cent of the agricultural area in the State. Only about 12 per cent agricultural area is contributed by holdings of 2 to 4 ha size and hardly 13 per cent area is contributed by big holdings above 4 ha size (SPB, 2009). Therefore, farming in Kerala is mainly of subsistence nature. Agriculture is practiced even in steep areas having slope of more than 100 per cent. People are compelled to cultivate some of the soil erosion promoting crops like tapioca, yams, ginger, turmeric etc. also on slopes because of their pressing economic needs. The crop productivity in these small and marginal holdings is generally low due to poor crop management. This is an important factor behind the overall low productivity of crops in the State.

Unlike in other parts of the country, a staggered settlement pattern is prevalent throughout Kerala, wherein, the farmers live in houses located in their farm holdings itself. These farm holdings containing a house surrounded by various crops are known as homesteads or home gardens. Open wells and ponds are the main water sources in most of the homesteads. Animal husbandry and other subsidiary income generative activities also form part of most of the homesteads. Coconut is an integral component of the homestead farming system almost throughout Kerala. Since these homesteads have the potential to be good productive units, the crop production and productivity in the State can be improved by adopting appropriate strategies in homestead farming. The adoption of various conservation and management practices in the homesteads is highly important for the sustainability of land, water and other natural resources in the region.

3.1.10. State income from agriculture

Presently, agriculture in Kerala is almost in a stagnant stage. The contribution of agriculture alone to State income was only about 13.5 per cent during 2006-07. The percentage contribution of the primary sector (agriculture and allied sectors, forestry and logging, fishing, and mining and quarrying) to State income came down from 56 per cent in 1960-61 to about 16.8 per cent in 2006-07, while the contribution of secondary and tertiary sectors have gone up from 15 to 23.9 per cent and 29 to 59.3 per cent respectively. The percentage share of agriculture has been on the decline while the other sectors registered higher rates of growth. The sector-wise annual growth rates of primary, secondary and tertiary sectors of gross state domestic product (GSDP) at current prices during 2006-07 are about 12.24, 17.71 and 15.51 per cent respectively (SPB, 2009).

3.1.11. Crops

Agriculture in Kerala has predominance of perennial crops like coconut, rubber, arecanut, black pepper, cardamom, coffee, tea, cocoa, tree spices etc. that are mainly cultivated in the uplands/ garden lands. Rice, vegetables, pulses, tapioca, yams, banana etc. occupy the valleys. While rubber, tea, coffee and cardamom are mostly grown under mono cropping system, coconut, arecanut, black pepper etc. are grown either under mono cropping or mixed cropping system. Crops like tea, coffee, cardamom and black pepper are cultivated in the high range areas. Kerala State makes significant contribution to the cash crop and foreign exchange requirements of the country.

Coconut is the major crop in the State, which occupies 42 per cent of the net sown area, followed by rubber with 22 per cent of the area. Crops like arecanut, cashew, coffee, tea and cardamom cover 5, 3.8, 4, 1.2 and 1.9 per cent of the net sown area respectively. Black pepper, grown under both mono cropped and mixed cropped situations, constitutes 8 per cent of the gross cropped area. Nutmeg and cocoa are grown as intercrops in coconut or arecanut gardens and form 0.4 and 0.3 per cent of the gross cropped area respectively. Many of the fruit crops like banana, pineapple, mango, jack etc. and tuber / root crops like tapioca, yams etc., vegetables and pulses are either intercropped in coconut gardens or grown as mono crop in lowland or upland conditions. The area under rice is only 9.6 per cent of the gross cropped area. The food crops comprising of rice, pulses, millets and tapioca occupy hardly 12.5 per cent of the gross cropped area.

Area and productivity of principal crops

The net area and gross area under cultivation during 2008-09 was 2088955 ha, and 2694943 ha respectively (DoES, 2009). Area, production and productivity of some of the major crops are either static or show a declining trend. The problem is very complex and is governed by a variety of factors including market fluctuations. The area and productivity of the major crops in the State over the years are given in Tables 3.1.1 and 3.1.2.

Kerala's share in area as well as production of coconut in the country is declining over time. It has declined from 57 per cent in 1991-92 to 43 per cent in 2007-08, while the share of area of the crops in Karnataka and Tamil Nadu together increased from 29 per cent in 1992-93 to 41 per cent in 2007-08. The productivity of 6889 nuts per ha in

Kerala is lower than that of other major coconut producing States. For instance, the coconut productivity in Andhra Pradesh and Tamil Nadu in the year 2006-07 was 12629 and 14495 nuts per ha respectively.

Kerala accounts for 98 per cent of the area and production of black pepper in India. The productivity of 231 kg per ha of black pepper in Kerala is very low compared to that of Vietnam (1300 kg per ha), Thailand (4300 kg per ha) and Malaysia (2000 kg per ha). Though the area under cardamom has come down since 1980-81, there was a steady increase in its productivity and hence, the share of Kerala in national production has gone up from 28 per cent in 1992-93 to about 75 per cent in 2007-08. In cashew, Kerala's share in area in the country has come down from 23 per cent in 1987-88 to 6 per cent in 2008-09 and the share in production has come down from 31 per cent to 6 per cent during the same period. Maharashtra has become the leading producer of cashew in India with a share of 32 per cent of production during 2008-09. The cashew yield in Kerala is showing a declining trend over the years. The area and productivity of rubber is showing a promising trend. Kerala accounts for 81 per cent of the rubber growing area in the country. Although the area under coffee has registered increase in Kerala during the last two decades, the productivity remains below the national level of 860 kg per ha (SPB, 2009).

Table 3.1.1. Area under major crops in Kerala over the years *(lakh ha)*

Crops \ Year	1952-53	60-61	70-71	80-81	90-91	2000-01	07-08	08-09
Rice	7.42	7.79	8.75	8.02	5.59	3.47	2.29	2.34
Coconut	4.3	5.01	7.19	6.51	8.70	9.26	8.19	7.88
Rubber	0.63	1.23	1.79	2.38	4.11	4.74	5.12	5.17
Arecanut	0.60	0.54	0.86	0.61	0.65	0.87	1.00	0.97
Black pepper	0.79	0.99	1.17	1.08	1.68	2.02	1.76	1.54
Cardamom	0.25	0.28	0.47	0.56	0.44	0.41	0.40	0.42
Coffee	0.12	0.17	0.32	0.58	0.75	0.85	0.84	0.85
Tea	0.45	0.38	0.37	0.36	0.35	0.37	0.36	0.37
Cashew	0.35	0.54	1.02	1.41	1.15	0.92	0.58	0.53

Table 3.1.2. Productivity of major crops in Kerala over the years *(kg/ha)*

Year / Crops	1952-53	60-61	70-71	80-81	90-91	2000-01	07-08	08-09
Rice	973	1371	1477	1587	1942	2162	2308	2520
Coconut*	6919	6430	5536	4618	5289	5980	6889	7384
Rubber	308	387	439	590	747	1222	1471	1514
Arecanut	485	622	648	770	880	1007	1077	1288
Black pepper	287	271	213	264	277	301	239	231
Cardamom	48	45	26	55	79	184	177	206
Coffee	406	442	430	634	279	833	578	675
Tea	671	1073	1103	1402	1751	1876	1432	1415
Cashew	1547	1558	1122	580	888	718	898	800

* *Nos. per ha*

3.1.12. Water scarcity and crop production

With majority of the area under perennial vegetation, Kerala is a place of evergreen vegetation covering the land surface throughout the year. The gravity of the recurring agricultural drought situation in Kerala is difficult to be understood because of the perennial greenery in the State. Due to the erosion of top soil and organic matter, the water holding capacity of Kerala soils is on the decline, causing a condition of soil moisture stress for the crops during the summer season extending from December to May. Though perennial crops sustain drought damages because of their physiological and morphological adaptations, they suffer from physiological drought during the long summer season, often resulting in poor growth and low productivity of the crops. In case of severe prolonged drought resulting in the total drying up of crop plants, the damage will be devastating, since most of these perennial crops have a long juvenile / immature period ranging from 3 to 8 years.

Though mild water stress is conducive to initiate reproductive phase in most of the plants, extreme drought conditions affect their productivity. In coconut and arecanut, the flowering phase is continuous throughout the year and so, water stress at any time of the year will affect the productivity of these crops. The maximum effect of a drought on coconut yield is reported to be seen between 8 and 12 months after the occurrence of a drought. However, since the bud-to-nut period in the case of coconut is about 44 months, the effect of a drought will be manifested in yield for about 3 to 4 years. In the case of pepper, drought condition during April-May will severely affect spike formation and yield. For cashew plantation, drought during October-November period severely affects flowering and nut production. The productivity of cardamom will be affected by drought during January-May, which coincides with panicle initiation stage of the crop. Arecanut and nutmeg are crops, which are highly sensitive to water deficit. In crops like cocoa, coffee, tea, rubber etc. also, drought affects the productivity.

Evapotranspiration

The average reference crop evapotranspiration (ET_0) in different districts ranges from 3.3 to 4.4 mm/day during rainy season and 3.8 to 5.4 mm/day during summer season. In Palakkad and Punalur region, ET_0 rises to about 6.2 mm/day during the month of March (Table 3.1.3) (CWRDM, 1990).

Crop water deficit

Under normal climatic conditions, the water deficit for coconut was estimated to range from 73 mm in Alappuzha district to 445 mm in Wayanad district. The water deficit for arecanut in Wayanad and Kasargod districts was found to be about 640 mm. Between the two high range districts of Wayanad and Idukki, the water deficit for black pepper, coffee, tea and cardamom was higher in Wayanad district than Idukki district. The water deficit for these crops ranges from 598 to 719 mm in Wayanad and 265 to 364 mm in Idukki (Table 3.1.4) (Varadan, 1996). When the north-east monsoon is below normal and/ or summer showers fail, the water deficit will be still higher. Hence, soil moisture stress during summer season is one of the major limiting factors for higher productivity of various crops in the State. With more than one-third of the annual rainfall returned back to the atmosphere as evaporation and transpiration under normal conditions, the deficit is expected to increase under conditions of climate change and increase in atmospheric temperature.

Since most of the plantation crops are grown under rain fed conditions, the influence of water deficit can be assessed from the rainfall pattern. The moisture stress period in summer ranges from 14 to 15 weeks in southern parts and 18 to 21 weeks in northern parts of the State. In order to increase the crop productivity, production and net returns of the farmers in the State, the crop water deficit has to be replenished by increasing soil moisture storage through the improvement of the soil structure, enrichment of soil organic matter, mulching, *in situ* harvesting and conservation of rainwater, and supplementary irrigation.

Table 3.1.3. Reference crop evapotranspiration (ET_0) in different districts of Kerala

District / Month	Reference crop evapotranspiration (mm/day)											
	Jan -uary	Febr- uary	March	April	May	June	July	August	Septe- mber	Octo -ber	Nove- mber	Dece- mber
Thiruvananthapuram	4.2	4.5	4.7	4.5	4.2	3.7	3.7	3.9	4.0	3.9	3.8	4.0
Kollam	5.2	5.8	6.2	5.9	5.3	4.1	4.1	4.3	4.6	4.7	4.4	4.6
Alappuzha	4.2	4.4	4.6	4.5	4.1	3.7	3.6	3.6	3.7	3.7	3.7	4.0
Pathanamthitta	3.9	4.3	4.9	4.8	4.0	3.4	3.0	3.3	3.6	3.7	3.9	3.8
Kottayam	4.4	4.8	5.3	5.5	5.5	4.2	4.3	4.4	4.5	4.5	4.1	4.1
Idukki	3.8	4.5	4.9	4.7	4.0	3.2	2.7	3.2	3.5	3.6	3.8	3.7
Ernakulam	3.7	3.7	3.8	3.9	3.8	3.5	3.2	3.2	3.1	3.4	3.3	3.5
Thrissur	4.6	5.2	5.3	5.4	5.8	3.8	4.3	4.3	4.7	4.5	4.5	4.2
Palakkad	4.6	5.5	6.2	5.7	4.9	3.8	3.6	3.7	4.2	4.1	4.2	4.2
Malappuram	4.2	4.4	4.5	4.7	4.4	3.9	3.4	3.5	3.9	4.1	4.0	4.0
Kozhikkode	4.2	4.4	4.6	4.5	4.4	3.8	3.4	3.6	3.8	3.9	3.9	4.0
Wayanad	4.0	4.6	5.1	5.1	4.7	3.0	3.2	3.4	4.0	3.8	3.8	3.9
Kannur	4.1	4.3	4.5	4.5	4.5	3.5	3.6	3.5	3.8	4.0	4.0	4.0
Kasaragod	4.2	4.7	5.1	4.9	4.5	4.5	4.3	4.4	4.4	4.3	4.2	4.2

Source: CWRDM (1990)

Table 3.1.4. Crop water requirement, effective rainfall and crop water deficit during October-May period for major upland crops in different districts of Kerala.

Crop \ Dist.	Para-meter	TVM	KLM	ALP	PTA	KTM	IDI	EKM	TSR	PKD	MPM	KKD	WYD	KNR	KSD
Coconut	WR	771	941	756	760	875	753	663	895	899	782	751	789	766	835
	ER	628	722	683	605	697	577	540	545	487	583	492	344	439	441
	WD	143	219	73	155	178	176	123	350	412	199	259	445	327	394
Arecanut	WR	-	-	-	-	-	-	-	-	-	-	-	996	-	1038
	ER	-	-	-	-	-	-	-	-	-	-	-	355	-	399
	WD	-	-	-	-	-	-	-	-	-	-	-	641	-	639
Cocoa	WR	-	-	1005	-	1171	998	886	-	-	-	-	-	-	-
	ER	-	-	850	-	726	643	622	-	-	-	-	-	-	-
	WD	-	-	155	-	445	355	264	-	-	-	-	-	-	-
Pepper	WR	-	-	-	-	-	1006	-	-	-	-	-	1071	-	-
	ER	-	-	-	-	-	648	-	-	-	-	-	352	-	-
	WD	-	-	-	-	-	358	-	-	-	-	-	719	-	-
Cardamom	WR	-	-	-	-	-	999	-	-	-	-	-	1051	-	-
	ER	-	-	-	-	-	666	-	-	-	-	-	353	-	-
	WD	-	-	-	-	-	333	-	-	-	-	-	698	-	-
Tea	WR	-	-	-	-	-	1008	-	-	-	-	-	1082	-	-
	ER	-	-	-	-	-	644	-	-	-	-	-	396	-	-
	WD	-	-	-	-	-	364	-	-	-	-	-	686	-	-
Coffee	WR	-	-	-	-	-	910	-	-	-	-	-	948	-	-
	ER	-	-	-	-	-	645	-	-	-	-	-	350	-	-
	WD	-	-	-	-	-	265	-	-	-	-	-	598	-	-

WR - Water requirement (mm), ER - Effective rainfall (mm), WD - Water deficit (mm), TVM - Thiruvananthapuram, KLM - Kollam, ALP - Alappuzha, PTA - Pathanamthitta, KTM - Kottayam, IDI - Idukki, EKM - Ernakulam, TSR - Thrissur, PKD - Palakkad, MPM - Malappuram, KKD - Kozhikkode, WYD - Wayanad, KNR - Kannur, KSD - Kasaragod

Source: Varadan (1996)

3.1.13. Irrigation

There are 18 completed and 5 ongoing irrigation projects in Kerala. Out of the 18 completed projects, 13 have storage and 5 are barrages. The estimated irrigation potential of Kerala is 16 lakh ha, but there are several constraints to achieve this target. So far, all the completed projects together have about 2.92 lakh ha of net and 5.51 lakh ha of gross ayacut area. The net and gross irrigated areas from all sources in the State during 2008-09 are 3.99 lakh ha and 4.58 lakh ha, which constitute 19% and 17% of the net sown area and gross sown area respectively (Table 3.1.5) (DoES, 2009). The proportion of net irrigated area to net sown area fluctuates around 18 per cent since the year 2000. The gross irrigated area has also been fluctuating around 16 per cent during the period.

Though the productivity of irrigated rice has increased, the emphasis of irrigation projects, except Kallada and Neyyar projects, towards supply of water mainly for rice has become unrealistic in Kerala due to the major shift in cropping pattern. However, tree crops in the plains and downhill side of the irrigation canal system get indirect benefit through groundwater recharge and moisture replenishment in the soil profile. The open wells and ponds on the downhill side and adjoining areas of the canals have become perennial sources of water for domestic use and also for irrigation of tree crops in some of the homesteads.

Table 3.1.5. Net area and gross area under irrigation (2008-09)

Sl. No.	Irrigated area (ha)			
	Irrigation source	Net area (ha)	Crop	Gross area (ha)
1	Govt. canal	95956	Rice	169024
2	Private canal	6318	Tubers	10293
3	Govt. tanks	1476	Vegetables	19238
4	Private tanks	38276	Coconut	157199
5	Govt. wells	387	Arecanut	33626
6	Private wells	132925	Cloves	135
7	Minor irrigation	9163	Nutmeg	7821
8	Other sources	96393	Other spices	7369
9	Tube wells	18359	Banana	34888
10			Betel vine	399
11			Sugarcane	2976
12			Other crops	15270
	Net total	399253	Gross total	458238

Source: DoES (2009)

The major source of irrigation is private wells, which irrigate 27 per cent of the net irrigated area, followed by government canals (26 per cent), private tanks (11 per cent), tube wells (4 per cent), minor lift irrigation (2 per cent) and private canals (1.2 per cent). Rice is the major irrigated crop, which accounts for about 40 per cent of the gross irrigated area in the State. Crops like coconut, arecanut, banana and vegetables contribute to 35, 8, 7 and 3 per cent respectively of the total gross irrigated area. The irrigated area under rice, coconut, arecanut and banana accounts for 63, 17.5, 34 and 51 per cent of the cultivated area of these crops in the State. There is decline in the area of rice under almost all the irrigation projects and it is more pronounced in the case of summer season crop. Irrigated rice fields have been gradually replaced by coconut, arecanut and banana on account of the irrigation facilities available. Coconut, arecanut, banana and other horticultural crops would yield better under irrigated conditions. However, the major coconut growing district of Kozhikode has only about 2 per cent of the coconut area under irrigation. The two other major coconut growing districts, viz., Malappuram and Kannur also have only 11 and 12 per cent of the corresponding coconut area under irrigation. Meanwhile, in Thrissur, Kasargod and Palakkad districts, about 60, 43 and 36 per cent respectively of the coconut-growing areas are irrigated. In the case of arecanut, 80 per cent of the arecanut growing area in the major arecanut growing district of Kasaragod is irrigated. In Thrissur and Malappuram districts, about 87 and 29 per cent of their respective arecanut cropped area is irrigated.

The expansion of irrigated area in plantation crops is limited by various factors such a non-availability of perennial sources of water in many of the plantation tracts situated on slopes, high capital cost for development of irrigation facilities, high cost of labour, shortage of farm labourers, fragmentation of holdings, market fluctuations etc.

3.1.14. Kerala and other humid tropical regions in the world

About 20 per cent of the land area in the world is experiencing humid tropical climate. Humid and sub humid tropics include Amazon basin in South America, Central America, Southern Mexico, Caribbean Islands, Congo basin, Mozambique, Kenya, Madagascar, Guinea

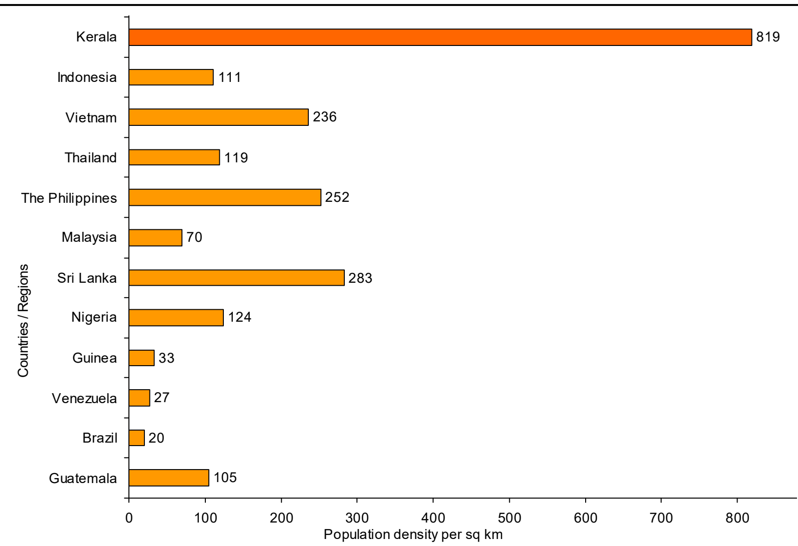

Figure 3.1.5. Density of population in selected humid tropical countries/ regions

Source: 1) World Resources Institute (2005); 2) Census Report (2001) coast of Africa, the peninsular and large islands of south east Asia, parts of Indian sub continent, North east Australia, New Guinea and the Hawaiian islands in Pacific ocean. Kerala is one of the most densely populated regions in the humid tropics, which naturally is subjected to overexploitation of natural resources and related environmental problems (Figure 3.1.5).

The average annual rainfall received in Kerala is also of the highest order (Figure 3.1.6). But, unlike in certain other humid tropical regions like Malaysia, Brazil and Sri Lanka, Kerala experiences water scarcity and drought during the long summer season mainly due to the uneven distribution of rainfall (Table 3.1.6). In countries like Malaysia, Brazil and Sri Lanka, rainfall is spread evenly throughout the year. As evident from Table 3.1.6 there are very few regions in the world, which receive such heavy rainfall as that of Kerala during continuous two or three months in a year. In fact, the northern districts of Kasaragod, Kannur, Wayanad and Kozhikode in Kerala receive about 2000 mm of total rainfall during June and July (Figure 3.1.3). This reveals the intensity of the soil erosive force acting on Kerala soils.

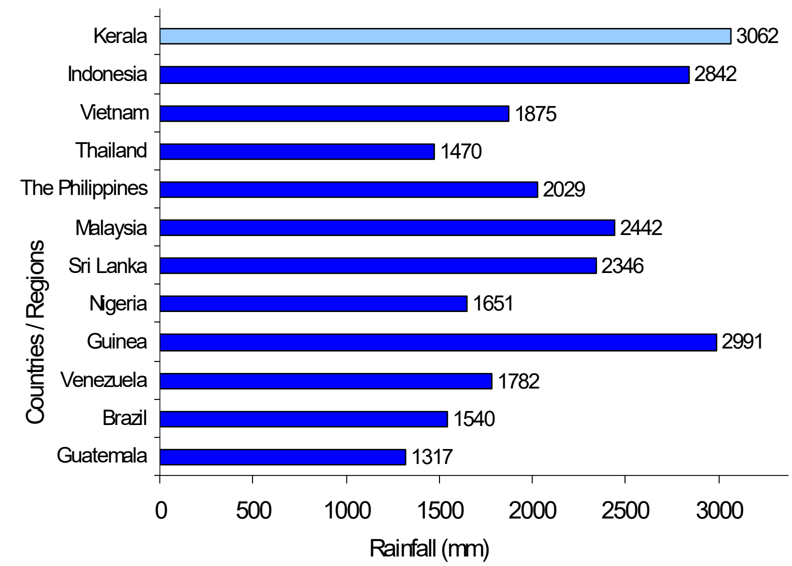

Figure 3.1.6. Mean annual rainfall in selected humid tropical countries / regions

Source: 1) John E. Oliver (1987); 2) Farm Information Bureau (2007)

The percentage of cropped area (55 per cent) in Kerala is the highest among humid tropical regions (Table 3.1.7). As the humid tropical regions are ecologically sensitive areas, long-term intensive agriculture will upset the ecological balance of this fragile zone, if sustainable agricultural practices are not adopted. The type of crops cultivated in most of the humid tropical regions of the world show similarity. The crops are mainly perennial with a predominance of tree crops. The average fertilizer use is high in regions like Vietnam, Malaysia and Sri Lanka. Vietnam, Sri Lanka and Thailand have high percentage of irrigated area to gross cropped area.

Table 3.1.6. Mean monthly rainfall (mm) in selected humid tropical countries / regions

Country / Region Month	Malaysia (Kuala Lumpur)*	Brazil*	Sri Lanka (Colombo)*	Guatemala (Guatemala City)*	Vietnam*	Guinea*	Kerala#
January	158	187	89	8	18	6	14
February	201	180	69	3	17	5	17
March	259	187	147	13	38	17	39
April	292	160	231	31	67	47	112
May	224	127	372	152	163	146	256
June	130	101	224	274	307	403	691
July	99	75	135	203	309	798	760
August	162	63	109	198	328	700	433
September	218	69	160	231	295	512	247
October	249	104	348	173	179	269	288
November	259	122	315	23	90	78	163
December	191	165	147	8	64	10	42
Total	2442	1540	2346	1317	1875	2991	3062

Source: * John E. Oliver (1987); # DoES (2009)

Table 3.1.7. Agricultural indicators in selected countries / regions in the humid tropics.

Country/ Region	Contribution of agriculture to GDP (%)	Cropped area to total land area (%)	Irrigated area to gross cropped area (%)	Average fertilizer use (kg/ha)	Major cultivated crops
Guatemala*	22	18	6.8	107.6	Coffee, banana, cotton, tobacco, cardamom
Brazil*	6	8	4.4	102.9	Coffee, cocoa, tobacco, soybeans
Venezuela*	3	4	16.9	88.0	Coffee, cocoa, banana, maize, rice
Guinea*	24	6	6.2	2.1	Tapioca, sugarcane, banana, coffee
Nigeria*	37	36	0.7	7.1	Cocoa, Oil palm, cotton, rubber
Sri Lanka*	20	30	33.3	127.7	Tea, rubber, coconut, rice
Malaysia	9	23	4.8	149.1	Rubber, Oil palm, black pepper, coconut, coffee, tea, cocoa, rice
The Philippines*	15	36	14.5	73.4	Coconut, banana, pineapple, rice, maize, tobacco
Thailand*	9	38	25.6	92.0	Rice, coconut, tobacco, cotton
Vietnam*	23	27	33.7	225.9	Rice, sugarcane, coffee, maize, tea, black pepper

Indonesia*	17	19	14.3	78.5	Rice, tobacco, coffee, rubber, coconut, oil palm, black pepper, tea, tapioca, sugarcane
Kerala#	12.7	55	15.2	65.6	Coconut, rubber, rice, arecanut, pepper, cardamom, tea, coffee, cashew, banana, pineapple, etc

Source: * World Resources Institute (2005); # DoES (2009)

3.1.15. Traditional agricultural calendar in Kerala

Since olden days, agriculture in Kerala is traditionally dependant on rainfall. Sowing / planting and all other intercultural activities were very much connected with different *njaattuvelas* to take maximum advantage of rainfall and soil moisture. A calendar year is divided into 27 specific periods known as *njaattuvela*. These 27 *njaattuvelas* are known by the names of 27 stars. *Aswathi njaattuvela,* which starts on *Medam* 1 (April 14) is the first and *Revathi njaattuvela,* which ends on *Meenam* 30 (April 13) is the last *njaattuvela*. Twenty seven *njaattuvelas* and their duration are given in Table 3.1.8.

Table 3.1.8 Different *njaattuvelas* and their duration

Sl. No	Name of *njaattuvela*	Malayalam calendar - month & dates	Gregorian calendar – month & dates
1	*Aswathi*	*Medam 1-14*	April 14 -27
2	*Bharani*	*Medam 14-28*	April 27 – May 10
3	*Kaarthika*	*Medam 28 – Edavam 10*	May 10 - 24
4	*Rohini*	*Edavam 10 - 24*	May 24 - June 7
5	*Makeeram*	*Edavam 24 – Mithunam 7*	June 7 - 21
6	*Thiruvathira*	*Mithunam 7 - 21*	June 21 – July 5
7	*Poornatham*	*Mithunam 21 – Karkkidam 3*	July 5 - 18
8	*Pooyam*	*Karkkidam 3 - 17*	July 18 - August 2
9	*Aayiliam*	*Karkkidam 17 - 31*	August 2 – 16
10	*Makam*	*Karkkidam 31 – Chingam 14*	August 16 - 30
11	*Pooram*	*Chingam 14 -28*	August 30 – September 13
12	*Uthram*	*Chingam 28 – Kanni 10*	September 13 - 26
13	*Atham*	*Kanni 10 - 24*	September 26 – October 10
14	*Chithira*	*Kanni 24 – Thulam 7*	October 10 - 23
15	*Chothi*	*Thulam 7 - 21*	October 23 – November 6
16	*Visaakham*	*Thulam 21 – Vrichikam 4*	November 6 – 19
17	*Anizham*	*Vrichikam 4 - 17*	November 19 – December 2
18	*Thrukkotta*	*Vrichikam 17 – 30*	December 2 -15
19	*Moolam*	*Vrichikam 30 – Dhanu 13*	December 15 - 28
20	*Pooraadam*	*Dhanu 13 -26*	December 28 – January 10

21	*Uthradam*	*Dhanu 26 – Makaram 11*	January 10 – 23
22	*Thiruvonam*	*Makaram 11 - 24*	January 23 – February 5
23	*Avittam*	*Makaram 24 – Kumbham 7*	February 5 – 18
24	*Chathayam*	*Kumbham 7 - 20*	February 18 – March 4
25	*Pooruruttaathi*	*Kumbham 20 – Meenam 3*	March 4 - 17
26	*Uthruttaathi*	*Meenam 3 -17*	March 17 – 30
27	*Revathi*	*Meenam 17 - 30*	March 30 – April 13

Thiruvaathira njaattuvela extends for 15 days. All the other *njaattuvelas* are about 13½ days each. Out of the 27 *njaattuvelas*, good rainfall is expected during 10 *njaattuvelas*. Major portion of the rainfall during south-west monsoon is spread over seven *njaattuvelas* from *Kaarthika* to *Aayiliam*. *Thiruvathira, Punartham, Pooyam* and *Aayilliam njaattuvelas* are agriculturally very important *njaattuvelas*.

During the *Thiruvaathira njaattuvela* it will be wet and dry for 7½ days each. If the beginning of the *njaattuvela* is dry, it is expected to have continuous rainfall towards the end. Heavy rainfall is usually expected in *Thuruvathira njaattuvela* and *Pooyam njaattuvela*. During *Poornatham njaattuvela* there will be sufficient rainfall and sunlight. During *Aayiliam njaattuvela* the rainfall intensity will be high. It is said that the intensity of rainfall is highest during *Atham njaattuvela. Aswathi* and *Bharani njaattuvelas* are characterized by intermittent rainfall called *puthumazha. Kaarthika njaattuvela* is usually dry.

3.1.16. Conclusion

The foregoing account gives a glance of the agro-ecological scenario of Kerala. It shows that productivity of most of the crops in the State is very low. This may be attributed to climatic, topographical, pedological and socio economic features of the State. High rainfall coupled with undulating topography causes high rate of erosion of topsoil and organic matter, and leaching of nutrients from the soil. Crops are cultivated on soils thus impoverished with respect to their chemical (mainly macro and micro nutrient status) and physical (mainly water holding capacity) properties. Crops often become vulnerable to the recurring incidence of drought and soil moisture stress. High humidity during most part of the year and cloudiness during the monsoon season are also limitations to many crops for proper nutrient uptake and growth. Fragmentation of landholdings and subsistent nature of farming often limit the efficient and economic use of farm inputs. In addition to these, the increasingly high cost of production, scarcity of labour and low price of produce in the recent past are making many farmers to abstain from intensive and extensive agriculture that produce more.

The water demand for various sectors is rapidly increasing due to increase in population and many changes in the socioeconomic front. The predicted global climate change and atmospheric warming is also expected to increase the atmospheric evaporative demand. Thus, there is likelihood of the water scarcity situation getting worsened in future. In this context, scientific water management is highly essential for the sustainability of ecosystem and environment. In Kerala, a high percentage (55 per cent) of geographical area is under agriculture, mainly because of the high population density of 859 per sq km. The people live in staggered settlements known as homesteads and mainly follow homestead farming system. With an average landholding size of 0.24 ha and a total of 62.99 lakh operational holdings in the State, even extremely sloping lands are put under agriculture. Almost all big and small watersheds in cultivated areas are inhabited by people. Therefore, the judicious management of soil and water in each homestead under every watershed can only ensure the sustainability of water resources and agriculture in the region. This will in turn increase the productivity of different crops and net return of farmers.

Thus, documentation of sustainable agricultural water management practices adopted by farmers will be useful for propagation / dissemination among other farmers, which will ultimately help in the conservation of land and water resources in Kerala and similar areas in the humid tropics.

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3.2. Socio-Economic Profile of the Progressive Farmers

During personal interview with 91 progressive farmers, information on their socio-economic profile was collected. The details are given below.

Tables 3.2.1 shows that about 43 per cent of the farmers interviewed have less than 2 ha of land and they belong to either marginal or small category. Medium and large farmers, who possess more than 2 ha of land, together constitute about 57 per cent of the respondents. Only about 5 per cent of the farmers interviewed have landholding above 25 ha. However, farmers in all categories are found to follow fairly good water management practices and intensive agriculture.

Table 3.2.1. Size of operational land holdings of farmers.

Size of holding	% of farmers
Less than 1 ha	12.2
1.1 to 2 ha	31.1
2.1 to 5 ha	32.2
5.1 to 25 ha	18.8
More than 25 ha	5.5

All the farmers are literate and about 75 per cent of them have education from lower primary to higher secondary school level. About 22 per cent of the respondents are graduates. It was interesting to find that one of the respondents is a practicing medical doctor, who is also engaged in agriculture (Table 3.2.2).

Table 3.2.2. Educational status of farmers.

Educational status	% of farmers
Lower Primary education	6.7
Upper Primary education	15.5
Secondary School education	37.8
Higher Secondary education	15.5
Diploma education	2.2
Under Graduation education	21.2
MBBS education	1.1

As shown in Table 3.2.3, only 4 per cent of the respondents are youths with less than 35 years of age. The youth and middle aged groups together constitute about 23 per cent of the total farmers interviewed. A major section of farmers (52 per cent) are between 50 and 65 years of age. About 24 per cent farmers are above 65 years of age.

Table 3.2.3. Age of farmers.

Age group	% of farmers
30-35	4.4
36-40	7.8
41-45	6.7
46-50	4.4
51-55	16.7
56-60	17.8
61-65	17.8
66-70	8.9
71-75	7.8
76-80	5.5
81-85	2.2

Table 3.2.4 shows that almost all the respondents are affluent, possessing many of the basic amenities. Many of them possess a car, jeep or a motor cycle. Some of them (11 per cent) have a tractor or a tiller. Almost 97 per cent of the farmers have a television and 84 per cent have a refrigerator in their house. Thirty nine per cent have washing machine. Two houses are found to be not electrified. Communication facilities like telephone are present in almost 91 per cent of the households. All of the farmers have pukka houses ranging from tile roof buildings to bungalows. Eighty eight per cent of the farmers are subscribers of newspaper, with some of them subscribing more than one newspaper and even English newspaper. About 50 per cent of the farmers are subscribers of agricultural magazines also. Almost 81 per cent of them possess pump sets, either electric or diesel operated. Open well forms the chief source of water (90 per cent), followed by farm pond (43 per cent) and bore well (10 per cent). Some farmers have both open well and farm pond.

Agriculture is the primary occupation of the respondents for 81 per cent of the cases. Nineteen per cent of the respondents have other primary occupations (Table 3.2.5).

Table 3.2.4. Amenities of farmers.

Particulars	% of farmers
Car	27.7
Jeep	17.7
Motorcycle	27.7
Tractor	8.8
Tiller	2.2
Electricity	97.7

Television	96.6
Refrigerator	84.4
Washing machine	38.8
Land phone	91.1
Mobile phone	17.7
Tile roof house	33.3
Concrete roof house	35.5
Two storied house	17.7
Bungalow	13.3
Subscribing newspapers	87.7
Subscribing both English & Malayalam news papers	5.5
Subscribing two or more Malayalam newspapers	14.4
Agricultural magazines	50.0
Pump sets	81.1
Electric	67.7
Diesel	13.3
Open well	90
Farm pond	43.3
Bore well	10.0

Table 3.2.5. Primary occupation of farmers.

Primary occupation	% of farmers
Farming	81
Others	19

Apart from agriculture, many farmers are engaged in various subsidiary income generative activities like dairying, goat farming, poultry farming, pig rearing, apiculture, pisciculture, sericulture and rabbit rearing (Table 3.2.6).

Table 3.2.6. Number of farmers engaged in other subsidiary occupations.

	% of farmers
Dairying - 1 cow	15.5
-do- - 2 to 3 cows	24.4
-do- - more than 3 cows	22.2
Goat farming	10.0

Pig rearing	5.5
Apiculture	3.3
Poultry farming	1.1
Pisciculture	13.3
Sericulture	20.0
Rabbit rearing	1.1

About 52 per cent of the farmers have taken loans from banks / co-operative societies with 44.4 per cent availing from Nationalized Banks (Table 3.2.7).

Table 3.2.7. Financial liability of farmers.

Institution	% of farmers
From Co- Operative Bank / Society	7.7
From Nationalized Bank	44.4

The socio-economic profile of the progressive farmers selected for interview shows high degree of variability with regard to their educational status, landholding size, crops cultivated, amenities, income generative activities etc. In about 5 per cent of the cases the farm is managed by women. However, irrespective of these differences, most of the farmers are found to follow many traditional water management practices that conserve land, water and bioresources. It was observed that these farmers are getting 3 to 4 times the average yield reported in the state for most of the crops.

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3.3. Innovativeness of Farmers in Irrigation Management and Soil and Water Conservation

Rainwater conservation and irrigation of crops during the summer season are two important water management practices relevant for Kerala. Hence, since the farmers considered under this study are progressive, it was decided to study their innovativeness with respect to irrigation management of crops and soil and water conservation in their landholdings. For this, data collected using questionnaire was analyzed. The details are given below.

3.3.1. Irrigation management by farmers

3.3.1.1. Irrigating farmers

Table 3.3.1 shows the percentage proportion of irrigating farmers under different crops. Only those crops having 25 per cent and more of irrigating farmers have been considered. It may be seen from the table that 92 per cent of Cardamom farmers and 71 per cent of Coconut farmers irrigate their crop, while only 26 per cent of Pepper farmers practice irrigation.

Table 3.3.1. Irrigating farmers

Crop	Irrigating farmers (%)*
Coconut	71
Arecanut	45
Coffee	52
Cardamom	92
Black Pepper	26

* Percentage of total

The Package of Practices Recommendations of Crops (KAU, 2007) provides details of agronomic practices including irrigation for different crops cultivated in Kerala. This is the State recommendation for crops. Centre for Water Resources Development and Management (CWRDM) had also empirically worked out the irrigation schedule for various crops cultivated in the State (Varadan, 1996). An attempt has been made in the present study to compare the irrigation management practices adopted by farmers with the State recommendation and CWRDM schedule in order to establish their scientific basis and accordingly, analyze innovativeness of the farmers.

The quantity of water for different crops was computed on per day basis from the State recommendation as well as the CWRDM schedule. Data was collected from the farmers using a questionnaire on the irrigation interval and quantity of water applied for different crops. From this, the quantity of water being used by farmers for various crops (on per day basis) was calculated. Based on this, farmers irrigating @ 80 per cent and more of the state recommendation / CWRDM schedule were considered as "very innovative", those irrigating @ 50 to 79 per cent of state recommendation / CWRDM schedule as "innovative" and farmers irrigating @ less than 50 per cent of state recommendation / CWRDM schedule as "non innovative" (Satadal Das Gupta, 1989). Farmers irrigating @ more than 100 per cent of state recommendation / CWRDM schedule were also considered as "non-innovative", since applying more water is a waste, without any additional influence on the crop. The irrigation interval adopted by farmers was also compared with the State recommendation and CWRDM schedule for different crops.

Data was also collected from farmers on area under irrigation, method of irrigation, year of start of irrigation and continuation of irrigation to work out scores for these components of irrigation and to quantify irrigation index. The crop-wise analysis of data is given below.

3.3.1.2. Quantity of irrigation water used

Coconut: For coconut, the quantity of water computed based on the State level recommendation and CWRDM schedule for the crop work out to 175 litres per tree per day and 47 litres per tree per day respectively. Table 3.3.2 shows that 16.7 per cent of coconut farmers irrigate in the range of 56 to 80 per cent of the State recommendation, while 21.4 per cent irrigate in the range of 50 to 96 per cent of CWRDM schedule.

Considering the State irrigation recommendation, it may be made out from Table 3.3.2 that 2.4 per cent farmers are "very innovative", 14.3 per cent of farmers "innovative" and 83.3 per cent "non innovative" (64.3 per cent irrigating less than 50 per cent of state recommendation plus 19 per cent irrigating more than 100 per cent of state recommendation). With regard to CWRDM irrigation schedule, Table 3.3.2 reveals that 7.1 per cent farmers are "very innovative", 14.3 per cent are "innovative" and 78.6 per cent are "non innovative" (33.3 per cent farmers with less than 50 per cent, and 45.3 per cent farmers with more than 100 per cent of State recommendation). Hence, a very high proportion of coconut farmers are non-innovative with regard to the quantity of water used.

Table 3.3.2. Quantity of irrigation water used by Coconut farmers

Quantity of water/day/plant (litres)	Quantity of water/day/plant (%)*	Farmers (%)	Quantity of water/day/plant (litres)	Quantity of water/day/plant (%)**	Farmers (%)
5.25	3	7.14	5.17	11	7.14
7.00	4	4.76	6.11	13	2.38
8.75	5	2.38	7.05	15	2.38
10.50	6	4.76	8.46	18	2.38
12.25	7	4.76	10.34	22	4.76
15.75	9	4.76	11.28	24	2.38
17.50	10	4.76	12.22	26	2.38
24.50	14	4.76	14.57	31	2.38
26.25	15	4.76	15.51	33	2.38
33.25	19	4.76	16.45	35	4.76
40.25	23	2.38	23.50	50	4.76
45.50	26	2.38	24.44	52	2.38
47.25	27	2.38	25.38	54	2.38
50.75	29	2.38	31.49	67	4.76
61.25	35	2.38	39.01	83	2.38
84.00	48	4.76	42.77	91	2.38
98.00	56	4.76	45.12	96	2.38
101.50	58	2.38	48.88	104	2.38
105.00	60	2.38	59.22	126	2.38
124.25	71	2.38	80.84	172	4.76
138.25	79	2.38	94.00	200	4.76
140.00	80	2.38	96.82	206	2.38
239.75	137	2.38	100.11	213	2.38
267.75	153	2.38	119.38	254	2.38
343.00	196	2.38	131.60	280	2.38
357.00	204	2.38	133.95	285	2.38
507.50	290	2.38	229.83	489	2.38
560.00	320	2.38	256.62	546	2.38
666.75	381	2.38	328.06	698	2.38
1338.75	765	2.38	341.22	726	2.38
			485.04	1032	2.38
			536.27	1141	2.38
			638.73	1359	2.38
	Total	100	1283.10	2730	2.38
				Total	100
	Categorization of farmers	*Farmers (%)*		*Categorization of farmers*	*Farmers (%)*
	Very innovative	2.40		Very innovative	7.10
	Innovative	14.30		Innovative	14.30
	Non-innovative	83.30		Non-innovative	78.60
	Total	100		Total	100

* expressed as percentage of per day quantity computed from the State recommendation for the crop

** expressed as percentage of per day quantity computed from CWRDM schedule for the crop

Arecanut: In the case of arecanut, the per day quantity of water computed based on the state level recommendation for the crop (33 litres / plant / day) is the same as the one computed using CWRDM irrigation schedule. It may be seen from Table 3.3.3 that 18.75 per cent of arecanut farmers have an irrigation rate (expressed in litres / pant / day) above 50 per cent (in the range of 57 to 89 per cent) of State recommendation / CWRDM schedule. Accordingly, it can be inferred from Table 3.3.3 that only 6.3 per cent of farmers are "very innovative", 12.5 per cent are "innovative" and 81.2 per cent are "non innovative" (47 per cent "non innovative" due to irrigation at less than 50 per cent of state recommendation / CWRDM schedule and 34.2 per cent farmers with irrigation rate above 100 per cent of state recommendation / CWRDM schedule). In short, as in the case of coconut, a very high proportion of arecanut farmers are also not innovative in water use for the crop.

Table 3.3.3. Quantity of irrigation water used by Arecanut farmers

Quantity of water/day/plant (litres)	Quantity of water/day/plant (%)*	Farmers (%)
1.00	3	6.25
2.00	6	9.40
7.59	23	3.12
7.92	24	3.12
8.58	26	3.12
9.57	29	3.12
10.23	31	9.40
11.22	34	3.12
12.21	37	3.12
14.19	43	3.12
18.81	57	6.27
22.77	69	3.12
23.43	71	3.12
26.40	80	3.12
29.37	89	3.12
49.17	149	3.12
57.42	174	3.12
59.40	180	3.12
74.58	226	3.12
82.83	251	3.12
86.79	263	3.12
94.38	286	3.12
99.00	300	3.12
106.59	323	3.12
171.60	520	3.12

687.39	2083	3.12
	Total	100
Categorization of farmers		*Farmers (%)*
Very innovative		6.3
Innovative		12.5
Non-innovative		81.2
Total		100

* expressed as percentage of per day quantity of water computed from the State recommendation / CWRDM schedule for the crop

Coffee: As per CWRDM schedule, the quantity of water for the crop works out to 17 litres per plant per day. There is no state recommendation for Coffee. Table 3.3.4 reveals that 53.7 per cent farmers fall in the "non-innovative" group (38.5 per cent applying less than 50 per cent and 15.2 per cent applying more than 100 per cent of CWRDM schedule). Among the farmers applying different quantities of water, a comparatively high proportion (23.3 per cent farmers) apply water equivalent to 61 per cent of CWRDM irrigation schedule (Table 3.3.4). It can also be inferred from the table that 15.3 per cent farmers are "very innovative" and 31 per cent "innovative", totaling to 46.3 per cent farmers, who have a favourable attitude towards water requirement of the crop. It should also be noted that the number of farmers applying more water than the requirement is less in the case of coffee, when compared to arecanut and coconut, indicating more scientific orientation for coffee farmers.

Under Kerala conditions, crops like coconut and arecanut can give good yield through adoption of *in situ* rainwater conservation measures, without necessarily irrigating the crop during summer season. However, coffee requires irrigation during summer for blossoming, fertilization and berry growth, which contributes to optimum production. The crop is sprinkler irrigated and the firms supplying sprinklers usually advice farmers on the irrigation schedule. This is especially relevant for an energy consuming irrigation technique like sprinkler. Further, based on research findings, Coffee Board also provides information to farmers on irrigation requirement of the crop. All these factors would have contributed to the development of a scientific orientation on quantity of irrigation water among a good proportion of coffee farmers in this study.

Table 3.3.4 Quantity of irrigation water used by Coffee farmers

Quantity of water/day/plant (litres)	Quantity of water/day/plant (%)*	Farmers (%)
0.34	2	7.69
0.85	5	7.69
3.06	18	7.69

4.76	28	7.69
5.10	30	7.69
10.37	61	23.3
12.92	76	7.69
15.47	91	15.3
20.57	121	7.69
51.51	303	7.69
	Total	100
	Categorization of farmers	*Farmers (%)*
	Very innovative	15.3
	Innovative	31.0
	Non-innovative	53.7
	Total	100

* expressed as percentage of per day quantity computed from CWRDM schedule for the crop

Cardamom: Cardamom does not have a state recommendation for irrigation. As per CWRDM schedule, the quantity of water works out to 4 litres per plant per day. Accordingly, it can be made out from Table 3.3.5 that eventhough 70 per cent farmers are "non-innovative", 10 per cent fall in the "very innovative" and 20 per cent in the "innovative" categories. This implies that 30 per cent farmers have a scientific perspective towards irrigation quantity for the crop. It can be observed from Table 3.3.5 that none of the farmers irrigate above 100 per cent of the requirement, indicating their awareness on economizing water consumption. Cardamom is also mainly sprinkler irrigated. Hence, as in the case of coffee, cardamom farmers will be getting scientific advice on irrigation management of the crop from sprinkler firms and agencies like Cardamom Board, which would have motivated many of them to adopt scientific water management.

Table 3.3.5. Quantity of irrigation water used by Cardamom farmers

Quantity of water/day/plant (litres)	Quantity of water/day/plant (%)*	Farmers (%)
0.04	1	10
0.72	18	10
0.96	24	20
1.20	30	10
1.40	35	10
1.64	41	10
2.12	53	10
2.84	71	10

4.00	100	10
	Total	100
	Categorization of farmers	*Farmers (%)*
	Very innovative	10
	Innovative	20
	Non-innovative	70
	Total	100

* expressed as percentage of per day quantity computed from CWRDM schedule for the crop

Black Pepper: The quantity of water computed for the crop is 11 litres per plant per day (state recommendation) and 8 litres per plant per day as per CWRDM schedule. Table 3.3.6 gives details of the quantity of water used by the Black Pepper farmers. Considering the state recommendation, 40 per cent farmers are "innovative", while 40 per cent fall in the "very innovative" category with regard to CWRDM irrigation schedule. Black Pepper is a sensitive crop regarding soil moisture availability. It is also a cash crop. Hence, pepper farmers can be expected to be more innovative than coconut or arecanut farmers to practice irrigation based on crop water requirement.

Table 3.3.6. Quantity of irrigation water used by Pepper farmers

Quantity of water/day/plant (litres)	Quantity of water/day/plant (%)*	Farmers (%)	Quantity of water/day/plant (litres)	Quantity of water/day/plant (%)**	Farmers (%)
7.48	68	40	7.52	94	40
17.93	163	20	18.0	225	20
89.98	818	20	90.0	1125	20
385.0	3500	20	384.96	4812	20
	Total	100		Total	100

* expressed as percentage of per day quantity computed from State recommendation for the crop

** expressed as percentage of per day quantity computed from CWRDM schedule for the crop

3.3.1.3. Irrigation interval adopted

Coconut: For coconut, the state recommendation includes irrigation intervals of 3, 4, 5, 7, 8 and 9 days depending upon soil type and location. It can be made out from Table 3.3.7 that a total of 50 per cent farmers adopt intervals of 3, 4, 7, 8 and 9 days for coconut. But, in this crop, it has been seen that only 16.7 per cent and 21.4 per cent of farmers come within the "very innovative" and "innovative" categories together (considering the state recommendation and CWRDM schedule respectively) as far as quantity of water is concerned.

Arecanut: The irrigation interval recommended for arecanut in the state varies from 3 to 7 days, while the CWRDM schedule shows intervals of 4 and 9 days for different soil types. It can be made out from Table 3.3.7 that a total of 62.5 per cent arecanut farmers adopt irrigation interval in the range of 3 to 7days, which tallies with the state recommendation. However, as already mentioned earlier, only 18.8 per cent of arecanut farmers come within the “very innovative” and “innovative categories” together with regard to the quantity of water used.

Arecanut and coconut are primarily cultivated as homestead crops in Kerala, where water availability is usually insufficient to meet various demands, especially irrigation, which consumes more water than for domestic use. It is also cumbersome for farmers to practice irrigation for these crops, since they are mainly cultivated on undulating terrain. According to Farm Information Bureau (2007), only 17.3 per cent of the gross cropped area under coconut and 34.3 per cent under arecanut are irrigated in Kerala. Further, market value of the produce has been low and more or less stagnant over many years for these crops. These are all factors which will influence a farmer’s decision on adopting irrigation. Even if farmers are irrigating, they may not be in a position to apply the required quantity of water.

Coffee: According to the CWRDM schedule, the irrigation intervals for coffee are 3, 7 and 9 days for different soils. Table 3.3.7 shows that 40 per cent farmers irrigate at 3 day interval, while another 40 per cent irrigate at 7 days interval. It has been already observed that about 46 per cent farmers show innovativeness with regard to the quantity of water applied for the crop. From this, it may be inferred that a good proportion of coffee farmers are interested in scientific irrigation scheduling (quantity and interval). Good market value for the produce and extension support available to coffee farmers could be the factors contributing to this.

Cardamom: According to the CWRDM irrigation schedule, the crop needs irrigation at an interval of 4, 7 and 8 in different types of soils. 10 per cent farmers irrigate at 4 days interval and 20 per cent at 7 days interval (Table 3.3.7), making a total of only 30 per cent farmers irrigating as per CWRDM schedule. It was also seen earlier that 70 per cent of cardamom farmers fall in the “non innovative category” regarding quantity of water use.

Black Pepper: According to the state recommendation, Black Pepper has to be irrigated once in 8 to 10 days. As per CWRDM schedule, irrigation intervals are 5, 10 and 11 days for different soils. It can be seen from Table 3.3.7 that 20 per cent farmers irrigate at 10 days interval, while 40 per cent irrigate at 7 days interval, which is close to the 8 days interval of the state recommendation. Hence, 60 per cent of the pepper farmers may be considered to be enterprising in adoption of irrigation interval. Regarding quantity of water applied, it was observed that 40 per cent farmers are "innovative" with respect to the state recommendation, while 40 per cent are "very innovative" as far as CWRDM irrigation schedule is concerned. Adoption of scientific irrigation scheduling by majority of the farmers may be because pepper is a cash crop, giving higher returns than coconut or arecanut.

Table 3.3.7. Irrigation interval adopted by farmers

Crop	Interval (days)	Farmers (%)	Crop	Interval (days)	Farmers (%)
Arecanut	1	12.60	Coconut	1	16.67
	2	9.40		2	4.77
	3	12.60		3	11.91
	4	18.70		4	14.28
	7	31.20		7	19.05
	8	3.10		8	2.38
	9	3.10		9	2.38
	10	3.10		10	11.90
	15	6.20		15	11.90
	Total	100		20	2.38
				30	2.38
				Total	100
Black Pepper	5	20.0	Cardamom	1	20.0
	7	40.0		2	20.0
	10	20.0		3	20.0
	30	20.0		4	10.0
	Total	100		7	20.0
				30	10.0
				Total	100
Coffee	1	20.0			
	3	40.0			
	7	40.0			
	Total	100			

3.3.1.4. Irrigation methods adopted

Table 3.3.8 shows the irrigation methods adopted by farmers for different crops. For arecanut and coconut, majority adopt basin method of surface irrigation. About 26 per cent and 22 per cent farmers respectively adopt sprinkler irrigation for arecanut and coconut. Sprinkler irrigation for a widely spaced crop like coconut, which requires irrigation in the basin area where the active roots are concentrated, leads to wastage of water. Hence, it is an inefficient irrigation method for the crop. None of the farmers have adopted drip irrigation for arecanut, while only 3.3 per cent of farmers have adopted it for coconut (Table 3.3.8), even when financial subsidy is provided by the Agriculture department for promoting drip irrigation.

It can be observed from Table 3.3.8 that for cardamom, pepper and coffee, majority of the farmers adopt sprinkler irrigation (including micro sprinkler in the case of cardamom).

Table 3.3.8. Irrigation methods adopted by farmers

Crop	Farmers (%) adopting irrigation methods						
	Basin	Sprinkler	Micro sprinkler	Drip	Channel	Flood	Total
Coconut	67.5	21.6	Nil	3.3	Nil	7.6	100
Arecanut	49.1	25.7	Nil	Nil	16.2	9.0	100
Coffee	26.9	62.5	Nil	5.2	Nil	5.4	100
Cardamom	46.2	23.1	23.1	7.6	Nil	Nil	100
Black Pepper	28.9	36.5	Nil	7.6	21.2	5.8	100

3.3.1.5. Irrigation adoption index

Irrigation adoption index of farmers was worked out as a composite score of the irrigated area score, irrigation method score, year of start of irrigation score and irrigation continuation score. The methodology adopted for scoring is mentioned below.

a) Score for area irrigated: Irrigated area score for a crop is given as the area irrigated expressed as a fraction of the total cultivated area of the crop. Area score of a farmer is the sum of area scores of all crops cultivated by him. Maximum possible area score for a crop is 1 (100 per cent area irrigated).

b) Score for irrigation method: Score of 2 for adopting improved methods of irrigation (sprinkler, drip, mist etc.). For other irrigation methods, score is 1.

c) Score for year of start of irrigation: The year of start of irrigation of each crop was compartmentalized into groups with equal intervals of 5 years (except the first group for some crops, where it was 6 year interval). The lowest score (1) is given to the latest group of years and the highest score (which depends on the number of groups available for that crop) is given to the earliest group of years for each crop.

d) Score for irrigation continuation: If irrigation is done without interruption, score is 1. Otherwise, the score is 0.

Maximum possible irrigation adoption index = Sum of maximum possible values of irrigation area score, method score, continuation score and year score.

Table 3.3.9 shows crop-wise range of irrigation adoption index of the farmers. It may be made out from the table that 66.7 per cent of coffee farmers have an index within 75 to 100 per cent of the maximum index value. For cardamom, 63.6 per cent farmers have a high index of 66.7 per cent and the remaining farmers have 83.3 per cent of the maximum index value. However, this is not the case with arecanut and coconut, where the proportion of farmers coming within the maximum range of adoption index (21.7 per cent and 6.6 per cent farmers respectively for arecanut and coconut) is less than the proportion falling within the lower ranges of adoption index (Table 3.3.9).

As already explained, adoption index of farmers is a composite score of the area irrigated, method of irrigation adopted, continuation of irrigation and year of start of irrigation. Hence, the trend observed in the case of coconut and arecanut can be attributed to factors such as less area under irrigation, non-adoption of improved irrigation methods, discontinuance of irrigation due to very low market price for produce, and delay in starting irrigation for these crops. Once again, this indicates the difficulty of arecanut and coconut farmers to practice irrigation. This difficulty was also evident with respect to application of the required quantity of water for these crops, wherein, the contributing factors could be non-availability of sufficient water, undulating cropped land etc.

As far as crops like coffee and cardamom are concerned, even if water availability problem exists, sensitivity of these crops to soil moisture deficit during summer would motivate farmers to increase the area under irrigation through adoption of efficient irrigation methods like sprinkler, drip etc., start irrigation early during the life span of the crop and also continue irrigation. This would have contributed to high adoption index values of coffee and cardamom farmers in this study. Comparatively higher profit attainable for these crops than coconut or arecanut will also help the farmers to adopt costly irrigation techniques like sprinkler.

With regard to pepper, since Table 3.3.9 reveals that there is not much variation in the proportion of farmers falling within the three ranges of adoption index, it is not possible to conclude that a significantly higher proportion of pepper farmers have maximum adoption index values. Pepper is mostly cultivated as an intercrop in coconut and arecanut gardens in Kerala, where farmers usually adopt *in situ* soil and water conservation measures to harvest rainwater. Because of this, many of the pepper farmers under this study might not have significantly extended their area under irrigation, adopted improved irrigation methods or continued irrigation for their crop. This would have contributed to the trend on adoption index observed in the case of these farmers.

Table 3.3.9. Crop-wise range of irrigation index of farmers

Crop	Maximum irrigation adoption index	Range of irrigation adoption index of farmers	Range of the adoption index as a % of the maximum index	Farmers (%)
Arecanut	12	1 - 4	8.3 to 33.3	28.3
		5 - 8	41.7 to 66.7	50.0
		8 - 11	66.8 to 91.7	21.7
			Total	100
Coconut	15	3 - 5	20 to 33.3	23.0
		6 - 8	40 to 53.3	37.7
		8 - 11	53.4 to 73.3	32.7
		12 - 15	80 to 100	6.6
			Total	100
Coffee	12	4 – 6	33.3 to 50	33.3
		9 - 12	75 to 100	66.7
			Total	100
Cardamom	6	4	66.7	63.6
		5	83.3	36.4
			Total	100
Black Pepper	12	3 - 5	25 to 41.7	32.4
		6 - 8	50 to 66.7	30.8
		9 - 11	75 to 91.7	36.8
			Total	100

Table 3.3.10 gives details of farmers having high values of irrigation component scores and irrigation adoption index. It is evident from the table that by and large, as the number of crops cultivated increases, the proportion of farmers with high values for the irrigation component scores and irrigation index decreases. This is especially applicable to the data under the column - irrigated area score. Similarly, continuation of irrigation appears to be generally affected when more crops are grown, as evident from the data under the column - irrigation continuation score (Table 3.3.10). This indicates the problems faced by farmers in extending area under irrigation and also in continuing irrigation, when there are many crops under cultivation. This is true in Kerala, where water scarcity has become a major constraint in the farming sector. Hence, adoption of suitable inter-cropping systems which optimize water use and also give better returns to farmers assume significance for sustaining upland farming in the State.

Table 3.3.10. Details of farmers possessing high irrigation component scores and irrigation index

No. of crops cultivated	Irrigated farmers (%) possessing 60% and more of maximum score/index				
	For irrigated area score	For irrigation method score	For year of start of irrigation score	For irrigation continuation score	For irrigation index
1	100	33.3	33.3	100	66.7
2	100	33.3	33.3	100	33.3
3	80	20	nil	60	nil
4	60	nil	20	50	20
5	44.4	7.4	11.1	55	11.5
6	44.4	27.8	5.6	57.1	5.6
7	25	nil	nil	nil	nil

3.3.2. Adoption of soil and water conservation measures

Adoption of soil and water conservation (SWC) measures by farmers in their landholdings was studied with the objective of analyzing their level of innovativeness in rainwater conservation. For this, data was collected from farmers on the number of SWC measures adopted, area of adoption and year of adoption of the measures.

3.3.2.1. Type of soil and water conservation measures adopted

It may be made out from Table 3.3.11 that majority of the farmers (75.3 per cent) adopt circular basin during south-west monsoon, which is the main SWC measure adopted by farmers cultivating coconut, the prominent upland crop of Kerala. Taking basin around each coconut palm with the onset of south west monsoon season is a traditional practice followed for fertilizer application. The basin also helps in rainwater conservation from the southwest and northeast monsoon seasons, which helps to meet the water requirement of the crop to a considerable extent during summer. However, since coconut is a widely spaced crop, adoption of other SWC practices in the interspaces also is necessary for soil conservation. Table 3.3.11 shows that 68.8 per cent farmers are adopting contour bunds, while 59.7 per cent adopt platform terracing. About 35 per cent farmers are adopting trenches/pits and 29 per cent adopt cover cropping.

Table 3.3.11. Soil and water conservation measures adopted by farmers

Measure	Farmers (%)
Circular basin	75.3
Contour bund	68.8
Platform terracing	59.7
Trenches / pits	35.1
Cover cropping	28.6
Vegetative hedges / barriers	9.1
Contour farming	1.3
Strip cropping	1.3

3.3.2.2. Number of soil and water conservation measures adopted

Table 3.3.12 shows the number of SWC measures adopted by farmers. Based on this, their level of innovativeness has been analyzed and shown in the table. As in the case of irrigation management, farmers adopting 80 per cent and more of SWC measures observed in this study were considered as "very innovative", those adopting between 50 and 79 per cent of the measures as "innovative", and farmers adopting less than 50 per cent as 'non-innovative" (Satadal Das Gupta, 1989).

32.5 per cent farmers adopt two SWC measures, 22.1 per cent adopt three measures, while farmers adopting only one SWC measure is proportionately less (Table 3.3.12). Similarly, less than 15 per cent farmers are adopting more than three measures. This implies that even though farmers want to adopt more than one measure in their landholding, they are restrained from adopting the maximum number of measures. This may be attributed to factors such as non availability and high cost of labour and the small sized nature of majority of the land holdings in Kerala.

With respect to the innovativeness of farmers, it can be seen from Table 3.3.12 that farmers are more or less equally divided among the innovative ("very innovative" and "innovative" groups) and non-innovative categories. However, as already mentioned, since only few farmers adopt more number of measures, 14.2 per cent only are "very innovative" (Table 3.3.12).

Table 3.3.12. Number soil and water conservation measures adopted by farmers

No. of measures adopted	Farmers (%)
1	16.9
2	32.5
3	22.1
4	14.3

5	11.7
6	2.5
Total	100
Innovativeness	*Farmers (%)*
Very innovative	14.2
Innovative	36.4
Non-innovative	49.4
Total	100

3.3.2.3. Soil and water conservation adoption index

Scoring was done for the number of SWC measures adopted, area and year of adoption of the measures. From this, the soil and water conservation adoption index was worked out. Only those SWC measures adopted for rainwater conservation were considered. The details of scoring are as follows.

Score for number of SWC measures adopted: Scoring is done based on the number of measures adopted. Score of 1 for one measure, 2 for two measures and so on.

Score for area of adoption of SWC measures: If a measure is adopted in the entire area of the farmer, the score is 1. Accordingly, score is given depending on the proportion of area where SWC measure is adopted. The cumulative area score of different measures is taken when more than one measure is adopted. In the case of SWC measures like basin and cover cropping, only the area of the particular crop where these measures have been adopted is considered for scoring.

Score for year of adoption of SWC measures: The year of adoption is categorized into groups. The earliest group of years is given the maximum score and the last group is given the lowest score for the particular SWC measure.

Soil and water conservation adoption index: The total of the number score, area score and year score is the adoption index of each farmer.

Table 3.3.13 shows the range of scores of farmers (adopting different number of SWC measures) for various components of adoption. Based on the data presented in Table 3.3.13, innovativeness of farmers (adopting different number of measures) with respect to area of adoption, earliness in adoption (year of adoption) and adoption index was analyzed and is shown in Table 3.3.14. From the data presented in this table, the following conclusions may be drawn:

1. On the whole, the percentage of farmers exhibiting innovativeness with regard to area of adoption is increasing with the number of measures adopted, thus reducing the possibilities of soil erosion to the maximum extent.

2. With respect to adoption index, farmers adopting only one measure are found to be non-innovative. However, the proportion of innovative farmers increases with the number of measures adopted. Accordingly, 88.9 per cent, 90.9 per cent, 94.1 per cent and 100 per cent of farmers adopting 3, 4, 5 and 6 measures respectively show innovativeness in adoption index (Table 3.3.14).
3. The trend regarding area of adoption (explained in item 1 above) is not observed for year of adoption (earliness in adoption of measures) in Table 3.3.14. Hence, it may be inferred from the results of the study that the number of measures adopted and area of adoption of the measures are the main factors contributing to innovativeness in adoption index of farmers in this study.

3.3.3. Conclusion

Regarding innovativeness of farmers on irrigation water management, even though a good proportion of coconut and arecanut farmers irrigate at intervals specified in the State recommendation, majority of them are not in a position to apply water according to either the Sate recommendation or the CWRDM irrigation schedule. This may be attributed to factors such as water scarcity, difficulty in adopting irrigation on undulating terrain where they are mostly cultivated, and lack of motivation due to the low market value of the produce of many of these crops in Kerala. The low percentage of irrigated area under coconut and arecanut, as reported by Farm Information Bureau (2007), is a testimony to this. However, the situation is different for crops like coffee and black pepper, where a fairly high proportion of farmers adopt scientific irrigation scheduling with respect to both quantity of water and interval of irrigation.

As far as irrigation methods are concerned, majority of the arecanut and coconut farmers practice basin irrigation, which is a good method for these crops. However, about 22 per cent farmers adopt sprinkler irrigation for coconut, which is not an efficient irrigation method for widely spaced, mono cropped coconut. For cardamom, black pepper and coffee, most of the farmers irrigate using sprinkler. Adoption of drip irrigation for crops is poor, even when financial subsidy is provided by the Agriculture department for promoting this irrigation technique.

66.7 per cent of coffee farmers have irrigation adoption index between 75 to 100 per cent of the maximum possible index value, while 63.6 per cent of cardamom farmers have 66.7 per cent of the maximum index. However, this is not the case for arecanut and coconut. In these crops, only a lesser number of farmers come within the maximum range of adoption index, when compared to the lower ranges of adoption index. This shows the problem faced by arecanut and coconut farmers to practice irrigation, resulting in either some or all of the following conditions, namely, less area under irrigation, non-adoption of improved irrigation methods, difficulty in continuing irrigation and delay in starting irrigation.

Table 3.3.13. Soil and water conservation adoption component scores and adoption index of farmers

Number of conservation practices adopted	Area of adoption score as % of maximum score	Farmers (%)	Year of adoption score as % of maximum score	Farmers (%)	Soil conservation index as % of maximum index	Farmers (%)
1	< 50	27.3	< 50	50.0	< 50	100
	50-79	nil	50-80	33.3	50-79	nil
	80 and above	72.7	> 80	16.7	80 and above	nil
	Total	100	Total	100	Total	100
2	< 50	32.0	< 50	70.6	< 50	52.9
	50-79	20.0	50-80	23.5	50-79	47.1
	80 and above	48.0	>80	5.9	80 and above	nil
	Total	100	Total	100	Total	100
3	< 50	11.1	< 50	33.3	< 50	11.1
	50-79	66.7	50-80	66.7	50-79	88.9
	80 and above	22.2	> 80	nil	80 and above	nil
	Total	100	Total	100	Total	100
4	< 50	18.2	< 50	45.5	< 50	9.1
	50-79	81.8	50-80	45.4	50-79	81.8
	80 and above	nil	> 80	9.1	80 and above	9.1
	Total	100	Total	100	Total	100
5	< 50	nil	< 50	41.2	< 50	5.9
	50-79	52.9	50-80	58.8	50-79	94.1
	80 and above	47.1	> 80	nil	80 and above	nil
	Total	100	Total	100	Total	100
6	< 50	nil	< 50	nil	< 50	nil
	50-79	100	50-80	100	50-79	50.0
	80 and above	nil	> 80	nil	80 and above	50.0
	Total	100	Total	100	Total	100

Table 3.3.14. Innovativeness of farmers in adoption of soil and water conservation measures

No. of measures adopted	Farmers (%)		Farmers (%)		Farmers (%)	
	Area of adoption		Earliness in adoption		Adoption index	
	Exhibiting Innovativeness*	Non-innovative	Exhibiting Innovativeness*	Non-innovative	Exhibiting Innovativeness*	Non-innovative
1	72.7	27.3	50.0	50.0	Nil	100
2	68.0	32.0	29.4	70.6	47.1	52.9
3	88.9	11.1	66.7	33.3	88.9	11.1
4	81.8	18.2	54.5	45.5	90.9	9.1
5	100	Nil	58.8	41.2	94.1	5.9
6	100	Nil	100	Nil	100	Nil

* includes "Very innovative" and "Innovative" categories of farmers

These factors would have contributed to lower adoption index values observed in the case of coconut and arecanut farmers.

Coffee, cardamom and black pepper give higher returns to farmers than coconut or arecanut, which have been maintaining a low market value in Kerala for some years. Coffee and cardamom have a comparatively better yield response to irrigation than coconut and arecanut. The problem of water scarcity in the State is also less in areas where these crops are cultivated, since the population density there is not as high as in coconut or arecanut growing areas. Coconut and arecanut are mainly cultivated on undulating terrain, where it is not easy to practice irrigation due to the sloping nature of land and also the labour cost involved to irrigate in such areas. Further, the extension support on irrigation management available to farmers from agencies such as Coffee Board and Cardamom Board is more than what the coconut or arecanut farmers receive. All these factors would have contributed to the findings in this study that more number of coffee, cardamom and black pepper farmers have higher values of irrigation adoption index, adopt scientific irrigation scheduling and also improved irrigation methods like sprinkler.

As far as soil and water conservation is concerned, about 50 per cent of the farmers are innovative in adopting more number of conservation measures in their landholding. In the case of farmers adopting three and more measures, more than 80 per cent of them exhibit innovativeness with regard to the extent of area where the measures are adopted. The number of measures adopted and area of adoption of the measures are the two main factors, which contribute to innovativeness of farmers with respect to SWC adoption index.

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3.4. Sustainable Water Management Practices Followed by the Farmers

During the field visits to different farmers' plots, many traditional water management practices were observed to be adopted by farmers. All the agro-ecological zones, physiographic regions, revenue districts, land holding classes and crops in Kerala were covered under the study. Some of the common practices like stone pitched contour bunds, post monsoon tillage etc were seen to be followed by many farmers irrespective of the crop, cropping system, agro-ecological zone or the size of holding. However, some practices like contour strip terraces, circular basins, cover cropping etc were found to be specific to certain crops and cropping systems. Almost all the practices have been indigenously developed and traditionally adopted by the farmers. Some of the practices are innovative. A narrative account of the practices was collected from each farmer at the time of interview. These practices may be broadly grouped under soil and water conservation measures, water resources development and rainwater harvesting works, irrigation methods and drainage measures.

Fifty one selected traditional practices are described in this section. Various practices coming under the four different broad groups are described under five heads, viz., method, benefits, limitations, applicability and researchable components. There are 28 practices described under soil and water conservation measures, 11 practices under water resources development, 9 practices under irrigation and 3 practices under drainage. Each practice is illustrated through photographs. While describing each practice, its merits, scientific explanation, limitations and practical problems, applicability under different agro-climatic conditions etc. are included. Components for possible future research are also suggested for each practice. Video coverage has also been done for most of the practices, which have been brought out as a short film.

3.4.1. Soil and water conservation measures

1. Alignment of contour

Method: Farmers traditionally use a wooden 'A–frame' to fix up the contours for aligning soil and water conservation structures and also for planting of tree crops. Adjacent points in a contour are marked when the plumb line hanging from the corner of the A–frame runs through the mid point marked on its horizontal arm. The plant-to-plant spacing of the crop will be usually equal to or multiples of the distance between the two legs of the A-frame. The type of crop and its row-to-row spacing generally determines the horizontal distance between adjacent contour lines. For instance, in the case of coconut, where the spacing between plants ranges from 7.5 to 9 m, contour lines are also fixed at intervals of 7.5 to 9 m. A contour bund is constructed on the downhill side of each row of coconut trees planted along the contour. In sloping areas, the row-to-row spacing will be usually greater than plant-to-plant spacing

Benefits: Fixing up of contour line using A-frame is relatively a more practical method of contour alignment for adopting various soil and water conservation practices.

Limitations: Fixing up of contour line using A-frame under highly undulating terrains is a skillful job.

Applicability: It can be used for fixing up the planting points of crops and aligning soil and water conservation structures in any area.

2. Stone-pitched contour bunds

Method: The stone-pitched contour bund, known as *kayyala,* is constructed by initially cutting a trench of 30 to 45 cm depth along the contour and heaping the excavated soil on the uphill side. Then, stones are pitched on the outer face of this cut edge. As the height of the bund is increased by pitching of stones, all the inner gaps are packed with excavated soil. The bund is finished with a top riser to give a shallow depression all along the uphill side of the bund. The runoff water and silt from the uphill side drain into this depression. Drainage lines are also provided in between. The height of bund usually ranges from 1 to 2 m, depending upon the slope. In practice, the distance between two contour bunds is usually decided by the crop grown. After a few years, when silt fills the depression, the height of the bund is increased and soil is earthed up. The slope of the terrace portion in between two contour bunds gradually gets reduced and the sloping terrace will become a bench terrace over a period of 15 to 30 years.

Benefits: Stone-pitched contour bund is found to be a stable and permanent structure for conservation of top soil, organic matter and water, especially in high rainfall regions.

Limitations: High labour cost for initial construction work of stone-pitched contour bunds.

Applicability: It can be adopted in areas where stones are locally available for construction. It is not recommended for land slip-prone steep areas having profile characteristics that hinder deep percolation of water during extended high intensity rains in monsoon season.

Researchable components: Reduction in runoff and soil erosion due to stone-pitched bunds may be quantified for different agro climatic conditions and also different slopes.

3. Earthen contour bunds

Method: When stones are not available for construction of stone-pitched contour bunds, earthen bunds known as *kollu* are made along the contour line. It is mainly practiced in Kozhikode district. Here, the wet soil is thrown / spread onto the outer face of the bund / cut edge of the soil profile and beaten with flat wooden plank or petiole of coconut leaf for proper compaction. The height of the bund usually ranges from 0.5 to 1 m. The optimum wetness of the soil used for the construction of earthen bunds is highly important. By experience, people know the ideal soil moisture level for doing this work. This is mainly done during monsoon breaks and post monsoon periods. The earthen bund requires periodic maintenance work every 3 to 4 years.

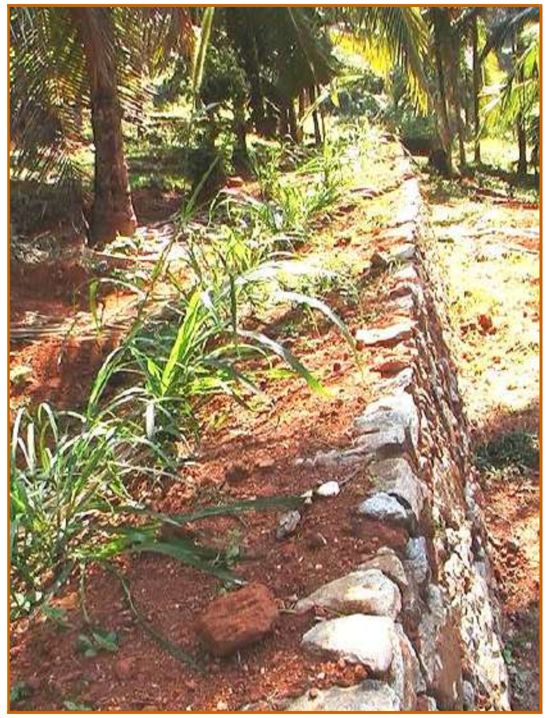
Benefits: Earthen contour bund is found to be a comparatively stable structure for soil and water conservation in places where stones are not available for making stone-pitched contour bunds. It is also cheaper than stone-pitched bunds.

Limitations: High cost of labour in the construction of earthen bund.

Applicability: It can be practiced in areas having gentle slope and where stones are not locally available for the construction stone-pitched contour bunds. But, it is not suitable for very steep areas.

Researchable components: Reduction in runoff and soil erosion due to earthen contour bunds may be quantified.

4. Vegetative stabilization of bunds



Method: In order to protect the stone-pitched or earthen contour bunds, some farmers are found to plant fodder grass, pineapple, agave etc. on the riser portion along the bund. Planting is done either in single or double rows. Replanting is done every 2 to 3 years. The roots anchor the soil and bind them together. The canopy absorbs the impact of the falling raindrops and thereby prevents splash erosion. In addition to stabilization of the soil and strengthening of the bund, it provides extra income to the farmers.

Benefits: The soil stabilization crop binds the soil together and strengthens the bund. It also gives additional income.

Limitations: During the intercultural and replanting operations of these soil-stabilizing plants, care is required not to damage the bunds.

Applicability: It can be adopted for any type of bund in suitable areas.

Researchable components:
Screening of different types of soil protecting plants of local economic importance, which can be grown for stabilization of bunds may be carried out.

5. Cross-bunds

Method: In many areas, particularly in coconut plantations, cross-bunds are constructed intermittently in between adjacent contour bunds. In the case of coconut, a cross bund is made near the basin of each tree. These bunds originate from the contour bund on the downhill side and run for about 2 -3 m towards the uphill side. The cross-bunds are either earthen or stone-pitched, known as *edavarambu* and *edakayyaala,* respectively. Cross bunds act as a barrier to the lateral flow of water in the terrace, resulting in better ponding of water. They help in protecting the soil and applied manures in the root zone of individual trees. Thus, these bunds provide a supplementary effect on soil and water conservation.

Benefits: Cross-bunds help in minimizing runoff and soil erosion.

Limitations: Cross bunds create obstruction to intercultural operations like ploughing to a certain extent.

Applicability: It is replicable in undulating areas coming under different agro climatic conditions.

Researchable components: The supplementary effect of cross-bunds on soil and water conservation may be quantified.

6. Stone-pitched boundary walls

Method: Boundary walls are constructed by packing stones on both faces of the wall, with soil packed in between. These are locally known as *iluvakayyaala*. The height of the wall usually ranges from 1 to 1.5 m. The thickness at the base of the bund is usually about 60 cm and at the top is about 30 cm. A foundation to a depth of 30 cm is given for the bund. Drainage holes are provided in between at the ground level for draining out excessive water during monsoon season. They run along the boundaries of individual land holdings / homesteads and aid in soil conservation, in addition to their primary function of partition. When they are constructed as boundary walls along the slope, they are stepped down at definite intervals based on the slope.

Benefits: Stone-pitched boundary walls are permanent structures and help in conserving soil and water in homesteads.

Limitations: The cost of construction of stone-pitched boundary wall is very high.

Applicability: It is practical in areas where stones are freely available in the land and they can be collected by just digging.

7. Contour strip terraces / platforms

Method: Contour strip terracing or platform terracing is the practice of taking continuous narrow strips of terraces having 1.0 to 1.5m width along the contour in sloping areas. The interval between strip terraces depends upon the slope of the land and the row-to-row spacing of the crop. The saplings are planted along the strip terraces at recommended spacing. The inward slope given to the strip terraces helps in collecting runoff water draining from the catchment area lying above. The large quantum of water coming as stem flow during rainfall will also get collected in the depression created by the inward slope. The flow of water along the strip terraces is checked by obstructions created by intermittent land cuttings on the uphill side of the strip terrace. This system is successfully being practiced for rubber, arecanut and black pepper cultivated in sloping areas in all the districts covered.

Benefits: Strip terracing helps in the ponding of rainwater, thus allowing sufficient intake opportunity time for water to go into the soil profile. It also acts as sediment traps to control soil erosion.

Limitations: The initial cost of formation of strip terraces is high.

Applicability: It can be adopted for other widely spaced crops grown under undulating and sloping conditions.

Researchable components: Quantification of the beneficial effects of contour strip terracing may be done for various crops.

8. Vegetative stabilization of contour strip terraces / platforms and interspaces in young rubber plantations

Method: In certain areas, farmers are seen to stabilize the contour strip terraces taken for planting rubber by growing fodder grass all along the downhill edge of the platform. The platform surface where rubber is planted is kept free of grass. The grass holds the soil together and prevents erosion of loose soil from the platform terrace. Fodder grass is grown for a period of about 3 to 4 years. The grass is cut at an interval of 1 to 2 months and fed to cattle. In young rubber plantations, the interspaces of the platforms are protected by growing cover crops or sometimes by pineapple. Pineapple planted in rows across the slope prevents soil erosion and the crop is maintained for about 3 to 4 years.

Benefits: These practices ensure effective utilization of the open space in rubber plantations during the initial 3-4 years. In this process, the soil erosion is controlled and contour strip terraces are properly stabilized.

Limitations: During summer months there is some chance of competition for water between rubber seedlings and grass or other crops. But, the growth of rubber seedlings is not found to be affected in areas where these practices are adopted.

Applicability: These practices can be adopted in all newly planted or replanted rubber plantations where the farmers are also engaged in cattle rearing.

Researchable components: The beneficial effects of these practices may be scientifically evaluated.

9. Trenches / Pits

Method: Trenches / pits are taken in between crop rows for rainwater harvesting. The general size of trench / pit is 50 to 150 cm length and 45 to 60 cm width and depth. The size of the trenches/ pits varies with plant spacing. About 100 to 200 trenches are taken in one hectare of land in a staggered manner depending upon the crops grown and space available. Runoff water gets collected in the trenches and slowly percolates through the soil profile. These trenches and pits get gradually silted up and are therefore, re-trenched periodically every three to five years.

Benefits: Trenches / pits facilitate more soil moisture storage and thus promote plant growth. This is a highly beneficial practice in old rubber plantations where soil raking operations are generally not done. Trenches / pits also protect existing bunds and terraces by breaking the velocity of runoff water as it moves down the slope.

Limitations: In homesteads, the pits and trenches cause some inconvenience to the movement of man and farm animals, especially when the area is smothered with weeds. In sloping areas, where the soil is very loose and shallow with underlying contiguous hardpan or rock, or the soil profile is not conducive for infiltration and percolation, trenches / pits can cause mud slip and hence, not advisable to go in for taking trenches and pits in such areas. Taking trenches and pits in plots that do not have contour bunds can lead to erosion of excavated soil.

Applicability: These structures are useful in both high rainfall and low rainfall areas under varying slope, soil and crop conditions where soil is conducive for percolation.

Researchable components: Standardization and design of trenches and pits for different agro climatic conditions and land use systems may be done.

10. Vegetative stabilization of trenches / pits

Method: While taking water harvesting trenches / pits as already mentioned, the excavated soil is put only on the downhill side and thus small embankments are formed. In order to protect these embankments, fodder grass or pineapple is planted for stabilizing the soil. After some years, when new pits / trenches are taken across the slope in between the earlier trenches, the embankments get connected and form a continuous bund. In certain cases, pineapple is found to be grown inside the pits to make best use of the silt deposited and also to protect the pits.

Benefits: The soil stabilization crop binds and holds the soil on the embankment. It also gives additional income.

Limitations: During the intercultural and replanting operations of these soil-stabilizing plants, care has to be taken to prevent damage to the bunds.

Applicability: It can be adopted for stabilization of pits / trenches in all soils in suitable areas.

Researchable components: Screening of more types of soil protecting plants of local economic importance, which can be grown for stabilization of embankments may be done.

11. Formation of check basins / blocks

Method: In several areas having gently sloping to plain land, it is a common practice to divide the entire cultivated area into several blocks / check basins separated by raised earthen / stone bunds called *varambu* having a height and thickness of about 30 to 60 cm. This is mostly found in coconut and arecanut plantations. Various intercultural operations within these blocks help in increased infiltration. Rainwater falling in these blocks does not escape as runoff, but gets ponded and helps in the recharge of groundwater. The size of the block is usually dependant on the slope of the land. In fairly plain lands, comparatively large blocks accommodating 10 to 15 trees in each block are formed, while in sloping areas check basins are formed even for individual trees.

Benefits: These blocks help to prevent surface runoff, soil erosion and loss of applied manures and fertilizers from the cultivated areas. It leads to increased soil moisture storage and better crop growth.

Limitations: In situations where the blocks are small, they interfere with the intercultural operations like ploughing.

Applicability: It is replicable in all plain and gently sloping lands having well drained soil.

Researchable components:
Establishment of the beneficial effects of these blocks on soil moisture and groundwater recharge can be done by scientific monitoring.

12. Planting pits – water draining and water harvesting types

Method: In plantation crops, different types of planting pits were seen in different parts of the state, suiting to the crop, soil, topography, etc. Usually the pits are cubical in shape with their size ranging from 30 to 100 cm depending upon the crop. In areas where soil drainage is a problem during monsoon season, pits are taken with suitable risers on all the four sides so that run off water does not flow into the pit. In certain water scarce areas having well drained soil, large water harvesting type of planting pits are noticed. Here, the run off from the surrounding area of each pit is actually allowed to fall into the pit. In some of the sloping areas, a practice of taking twin pits, one smaller pit just on the uphill side of a bigger pit, is seen. Planting is done in the bigger pit. The smaller pit acts as a silt pit and also protects the pit and the seedling below it from being washed off by heavy mud flow. In certain areas, very skillfully made pitcher-shaped, narrow pits are observed for planting coconut. These pits with a wide bottom and a narrow neck protect the young seedlings by providing a cool condition inside them during the summer season. Here, sprouted nuts are planted in the pits as it is difficult to plant bigger seedlings in such pits.

Benefits: Different types of pits have their specific advantages on soil and water conservation under different conditions.

Limitations: In areas having large underground boulders, it is often difficult to take the desired type of pits.

Applicability: Different types of pits are suitable for different agroclimatic conditions.

Researchable components: It is required to scientifically evaluate the relative advantages of different types of pits under different slopes and agroclimatic conditions.

13. Centripetal terraces / circular basins

Method: In the case of tree crops, taking centripetal terraces/ circular basins around individual trees for the application of manures during monsoon season is a highly beneficial practice for rainwater harvesting. The radius of the basins often equals to the radius of the active root zone of the particular crop. In the case of coconut, it is a common practice to take centripetal terraces of about 2 m radius and apply green manure during the south west monsoon season. These basins harvest a large quantity of rainwater coming as stem flow. Once the applied leaves settle down and start to decay, the basin is half covered with soil, leaving space for harvesting rainwater from the succeeding north east monsoon also. During October-November, the rest of the basin is filled.

Benefits: Water coming down as stem flow gets ponded in the basins and percolates into the soil profile. This results in increased soil moisture storage.

Limitations: Due to the high cost and non-availability of labour, there is an increasing tendency among farmers to refrain from the practice of taking centripetal terraces regularly. In plots that do not have contour bunds, taking basins around the trees every year can lead to soil erosion.

Applicability: This practice is applicable under different agroclimatic conditions to almost all crops.

Researchable components: The beneficial effects of centripetal terraces may be scientifically evaluated.

14. Multi-storied cropping and mixed cropping

Method: Multi-storied cropping is a mixed cropping practice of growing crops of different heights, canopy architecture and rooting depth in the same field in a geometric pattern. Here, the roots of different crops extract water and nutrients from different soil depths. Similarly, the canopies of different crops intercept light as well as raindrops at various levels. Multi-storied cropping with a variety of crops is being practiced in several coconut and arecanut plantations. Cocoa, tree spices, black pepper, banana, pineapple, ginger, turmeric, fodder grasses etc. are grown as multi-storied crops in coconut gardens. Cocoa, tree spices, coffee, cardamom etc. are grown in arecanut plantations. The cropping intensity can go upto 200 per cent or more in a good multi-storied cropping system.

Benefits: Multi-storied cropping makes best use of the available space, sunlight, nutrients and water in an area. The soil structure is improved by the high biomass recycling under multi-storied cropping. This cropping system increases the net returns per unit area.

Limitations: Since it requires more farm labour work, the timely availability of the required agricultural labourers is a serious problem in many parts of Kerala.

Applicability: Multi-storied cropping is well adoptable in widely spaced, tall growing crops like coconut, arecanut etc. under different agroclimatic conditions.

Researchable components: The best crop combinations for higher water use efficiency may be investigated for different agro climatic zones. The irrigation requirements for different crop combinations should also be studied.

15. Application of farm yard manure / compost

Method: In humid tropical regions, improving the organic matter content of soil is highly essential for sustainable agriculture. It is a practice in most of the homesteads to apply farm yard manure in different forms to the cultivated crops. In unirrigated farms, farm yard manure is applied during monsoon season. However, in irrigated areas, its application is practiced during summer also. Cow dung, goat manure, poultry manure, compost, sewage etc. are used. Many homesteads are found to have biogas plants from which the cow dung slurry coming out is applied through large diameter pipes or irrigation channels to crops like coconut, arecanut, cocoa, nutmeg etc. Some farmers are seen to have established vermicomposting units wherein, all the crop residues are composted and applied to crop plants. Coconut coir pith composting is also done by some farmers

Benefits: In addition to enrichment of the fertility of soil, the application of farm yard manure or compost improves organic matter content, structure and water holding capacity of soil. It also promotes the proliferation of soil fauna, which helps in soil aeration, better infiltration of water etc.

Limitations: The availability of sufficient quantity of organic manure is a limiting factor.

Applicability: The various methods of organic manure production and application can be adopted on a large scale. Some methods like vermicomposting, coir pith composting etc. need to be popularized through awareness and training programmes.

Researchable components: The diverse benefits of various types of organic manures with special reference to soil moisture and groundwater recharge may be studied for different agro-climatic regions.

16. Addition of organic clay in the root zone area

Method: In areas located near backwaters in Kuttanad and Alappuzha region, lumps of hard clay, locally known as *chettukatta* collected from deep backwaters are spread in the basin of coconut trees. These hard lumps of clay are very rich in organic matter and nutrients. They also have very high water holding capacity, which enables them to store more moisture in the plant root zone for the summer season. They are manually excavated from deep backwaters by means of special shovels, gathered in country boats and brought to the farmland.

Benefits: This practice improves the growth of plants very much because of enrichment in soil fertility and soil moisture.

Limitations: High labour cost of is involved in the collection of *chettukatta*.

Applicability: It can be adopted for all tree crops grown in areas near backwaters.

Researchable components: The effects of alternate wetting and drying of the *chettukatta* during the monsoon and summer seasons may be investigated. The extent of soil moisture stored and made available to the plants during the summer season may also be studied.

17. Vegetative fencing

Method: It has been observed that many farmers grow perennial green leaf manure plants like *Glyricidia sepium* as vegetative fence along the border of their farms. *Glyricidia,* being a legume, fixes atmospheric nitrogen to the soil. It has high biomass production capacity. Within 2 or 3 years after planting, these plants start producing large quantity of green leaves that can be pruned twice in a year. The pruning is done every time at a height of about 1.5 to 2m. The cut branches are applied as green leaf manure to crop plants like coconut, areacanut etc. Application of green leaf manure enriches the organic matter content of the soil.

Benefits: The enrichment of organic matter content of soil by the application of green leaves improves soil structure and its water retention capacity. It also encourages the growth and multiplication of soil fauna that in turn increases soil aeration and infiltration of water. Vegetative fence also acts as wind break to a certain extent.

Limitations: Vegetative fence does not form a strong permanent barrier against trespassers and thieves.

Applicability: The planting of vegetative fence can be done along the border of individual plots.

Researchable components: Introduction and evaluation of new species that gives high biomass yield may be done for planting as vegetative fence in different agro-climatic conditions.

18. Coconut husk burial

Method: The burial of coconut husk in staggered trenches/ pits in plantations is found to be a highly beneficial water conservation practice adopted in certain areas. Coconut husk, with their concave side facing upwards are spread in pits / trenches of 45 to 75 cm depth and convenient length and width. Three to five such layers of husk are spread. The top layer of husk is placed with their convex side facing upwards. Finally, soil is spread over these husks. When linear trenches are taken, it is usually taken across the slope. In the context of the general poor biomass recycling in coconut plantations, this is found to be a very healthy practice. In certain areas, husk burial is done at the bottom of the planting pits of coconut and arecanut seedlings for their better establishment and growth.

Benefits: This practice significantly increases water retention capacity of the soil, thereby increasing the soil moisture status in the area. Coconut husk is reported to hold more than eight times its weight of water. The husk, rich in potash, also enriches the nutrient content of the soil. The growth of several soil fauna and microbes is also encouraged by this practice. The beneficial effects of husk burial may last for several years.

Limitations: In small homesteads having fresh water sources for drinking, large scale husk burial can lead to certain extent of pollution to the drinking water source.

Applicability: It is replicable in all coconut and arecanut plantations, especially in sandy tracts.

Researchable components: The beneficial effects of husk burial may be established through scientific studies. The probable pollution to fresh water sources because of this practice, especially in homesteads is also an area of investigation.

19. Coconut husk-pitched bunds

Method: In coconut growing areas, some farmers are found to construct bunds by pitching coconut husk instead of stones. This is done in areas where stones are not locally available for making bunds. Bunds are made in a way similar to the construction of stone-pitched bunds, with coconut husks used in place of stones. The split coconut husks are pitched with their narrow end going in to the bund and the convex side facing upwards. Once the husks are pitched, the bund will remain intact in good condition for a period of about 4 to 5 years.

Benefits: The bunds help in soil and water conservation by controlling surface run off from the plots. Since they are made of husks, the bund harbours many soil fauna, which helps in improving soil structure.

Limitations: Since husks are biodegradable, the bunds have to be repaired every 4 to 5 years. The availability of large quantity of husks required for making bunds is also a problem.

Applicability: This practice can be adopted in coconut growing areas where sufficient quantity of coconut husks is available for making the bunds.

Researchable components: Chemical treatment of husks may be tried for improving their durability.

20. Husk burial in the interspaces of coconut trees and planting of pineapple and other intercrops

Method: Pits measuring about 1.5 m at the sides and 1 m depth are taken in a line in between coconut rows at intervals of about 3 to 4 m. These pits are buried with coconut husks with their concave side facing upwards. Soil is spread as the top layer of the pit and then pineapple is planted at a spacing of about 45 to 60 cm. The area in between these pits is planted with black pepper or vanilla at their recommended spacing and spread on suitable standards. The whole area in between adjacent pits is mulched with coconut husk. Dry fronds of coconut are spread over the husk.

Benefits: Husk burial and mulching facilitates more soil moisture storage for the summer season. It also adds nutrients to the soil and promotes the growth of soil fauna. Pineapple and other intercrops fetch additional returns from the farm.

Limitations: Husk burial very close to fresh water sources may pollute the water and hence, should be avoided.

Applicability: It can be adopted in all coconut plantations where other intercrops are not cultivated.

Researchable components: The beneficial effects of this practice may be established through scientific investigation.

21. Husk burial in a ring around coconut and planting of pineapple

Method: Circular trenches of about 60 cm depth and 75 cm width are taken around the coconut palm at a radius of 2 m during the monsoon period. These trenches are filled with coconut husk with their concave side facing upwards. The top portion of the trench is filled with soil. Pineapple suckers are planted in single or double rows in this circular trench at spacing of 30 to 45 cm between plants and 60 to 70 cm between rows. By the second year after planting, thick vegetative barrier will be formed around the trees that control soil erosion from the root zone area of coconut trees.

Benefits: This practice helps in conserving the soil and moisture in the coconut basin. Growing of pineapple gives additional income to the farmers.

Limitations: It causes some inconvenience for entry into the basin area of the trees for some of the operations. Rodent control may become necessary in the plot due to the cultivation of pineapple.

Applicability: It is replicable in coconut plantations under any conditions.

Researchable components: The soil moisture status under conditions of with and without this practice is a good area of research.

22. Cover cropping in rubber plantations

Method: Cover cropping is the practice of growing leguminous creepers in the interspaces of the main crop to provide a thick cover to the soil. It is widely practiced in rubber plantations, especially during early years of crop establishment. It takes 7 to 8 years for rubber seedlings to develop full canopy that covers the whole soil surface. Hence, if suitable soil erosion-resisting intercrops or cover crops are not grown in the interspaces, the soil will be fully exposed to the erosive rainfall resulting in the early silting up of inward slope of the platforms. The most common cover crops grown in rubber plantations are *Puereria phaseoloides* and *Mucuna bracteata*. The strip terrace or platform is usually left free of cover crops to save rubber seedlings from being smothered by the cover crop.

Benefits: The cover crop shields the soil from the impact of raindrops, controls soil erosion, suppresses weed growth and controls soil temperature. Due to the high biomass recycling and root activity of cover crops and the increased activity of various soil fauna, the soil structure gets improved, which in turn helps in increased infiltration of water. The leguminous cover crop also fixes atmospheric nitrogen to the soil by the action of the associated *Rhizobium* bacteria.

Limitations: During the wet season, the cover crop grows luxuriantly. So, constant attention is required to control the spread of cover crop for preventing them from twining on the rubber seedlings. Cover crops can also lead to high transpiration losses from plantations during dry season.

Applicability: It is a healthy practice that can be adopted for widely spaced crops grown as mono crop.

Researchable components: The pros and cons of cover cropping may be studied in detail. Results of exploratory studies conducted under the project are given in section 3.5. The evapotranspiration from cover cropped rubber plantations is a good area for investigation.

23. Cover cropping in coconut plantations

Method: Cover cropping, which is successfully practiced in rubber plantations is found to be adopted in certain mono cropped coconut plantations also. In mono cropped coconut plantations, the wide open interspace causes land degradation. Under such situations, cover cropping can be practiced with great advantage. The basin area of the coconut palms to a radius of about 2 to 2.5 m is left free of cover crop in order to facilitate various cultural practices for the trees. Walkways are also left free. The cover crops suitable for coconut plantations are *Puereria phaseoloides* and *Mucuna bracteata*.

Benefits: The cover crop protects the soil from erosion, suppresses weed growth, controls soil temperature, fixes atmospheric nitrogen in soil, favours the proliferation of soil fauna and microbes, improves soil structure etc.

Limitations: The thick ground cover formed by the cover crop creates restrictions on free movement of people through the coconut plantation. Sometimes, the falling coconuts get lost inside this thick vegetal cover. There is also a chance for competition for soil moisture between the main crop and the cover crop during the summer season.

Applicability: As an effective soil conservation measure, it is adoptable in areas having sloping topography. As a soil regeneration measure, it is effective in soils poor in organic matter content. As a soil coolant it is effective in lateritic areas.

Researchable components: The advantages and disadvantages of cover cropping in coconut plantations may be subjected to detailed scientific investigation.

24. Mulching the root zone area with crop residues

Method: Mulching of the soil surface in the root zone area of crop plants with various crop residues, trash or other organic materials is a very healthy practice observed in many areas. Coconut husk is a highly beneficial material used for mulching the basins of trees in coconut and arecanut plantations. Mulching using crop stubbles is widely practiced in cardamom plantations during summer season. In arecanut-cardamom intercropped plantations, arecanut husk is usually used for mulching cardamom and arecanut. Growing of green leaf manure crops like *Glyricidia* for the generation of organic material for mulching is also observed.

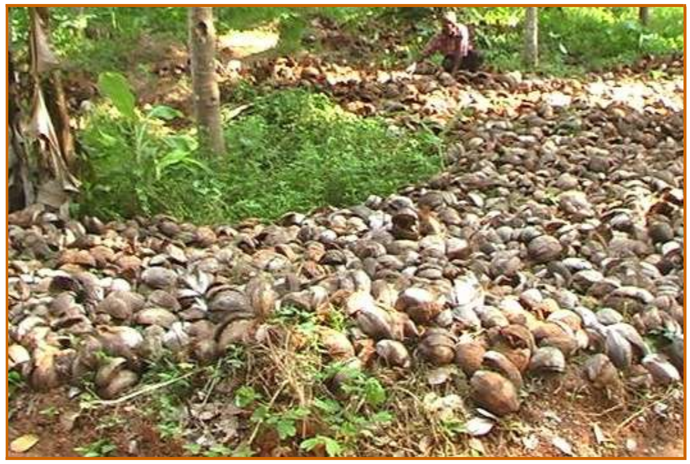
Benefits: The use of organic material/ crop residues as mulches during summer season helps in reducing evaporation losses and controlling the undue increase in soil temperature. During monsoon period, mulching helps in minimizing the impact of raindrops, controlling splash and sheet erosion, controlling weed growth, encouraging faunal and microbial growth and adding nutrients to the soil.

Limitations: The unavailability of sufficient organic materials for mulching is a problem.

Applicability: Organic mulching can be advantageously done for any crop under any conditions, except in water logged situation.

Researchable components: Soil temperature, soil moisture status and other ecological effects due to the use of different organic mulch materials can be investigated.

25. Mulching the whole farm area with coconut husk



Method: Mulching the entire soil surface in a farm by laying coconut husk is practiced by some farmers. This is done in areas where intercrops are minimal. A layer of coconut husk is closely spread over the soil surface with the concave side facing down. Walkways and irrigation channels are left in between to facilitate easy movement. After the laying of husks, coconut fronds are also spread over that. The basin area of the coconut palms to a radius of about 2 m to 2.5 m is left free to enable the application of green leaf / organic manures and fertilizers. Depending upon the availability of coconut husk, subsequent layers of husk are spread over the earlier layers every 4 to 5 years.

Benefits: Husk mulch protects the soil from runoff and degradation. Soil temperature is controlled, weed growth is suppressed, evaporation loss is minimized, microbial and faunal growth is promoted, nutrient availability is increased and soil structure is improved by the husk cover.

Limitations: The high cost of labour for laying husk is the major constraint. It also causes some restrictions on the movement of man and cattle in the farm area.

Applicability: This practice can be adopted in all monocropped coconut and arecanut plantations.

Researchable components: The beneficial effects of husk laying can be quantified by experimental monitoring.

26. Post-monsoon tillage of soil

Method: Ploughing / digging the entire farm land just after the cessation of monsoon season in November (coinciding with the Malayalam months *Thulam* and *Vrichikam*), locally known as *thulakkothu,* is a widely followed water conservation practice in all the regions covered under this project. The surface soil is dug using spade or ploughed with the help of bullocks or tractor/ tiller during the second fortnight of the month *Thulam* or the first week of *Vrichikam*. Soil is turned to a depth of about 15 to 20 cm. This is done to get the surface soil aerated and to retard the process of drying up of soil. Some farmers restrict *thulakothu* to the active basin area of tree crops to minimize the cost of labour. Nowadays, the practice of *thulakothu* in garden lands is slowly disappearing due to the high cost and scarcity of labour, low market price of commodities, declining interest of in agriculture etc.

Benefits: In the process of *thulakkothu,* the continuity of soil capillary pores with the atmosphere is broken to a great extent. The loose and dry layer of surface soil acts as soil mulch that slows down the capillary rise and evaporation of water and thus conserves sub soil moisture.

Limitations: High labour involvement and cost of labour are the major constraints. If a farmland, especially on slopy terrains, is not protected by other permanent soil conservation measures, ploughing of the entire area will lead to great soil erosion with the onset of monsoon.

Applicability: It is applicable in soils of loamy and clayey texture in different regions.

Researchable components: The capillary rise of water and evaporation losses from different land cover systems under situations of with and without this practice is an important topic for investigation.

27. Formation of soil mounds / cones *(Poliyidal & Polikoottal)*

Method: In many of the coastal regions of Ernakulam, Thrissur and Kannur districts, farmers follow a traditional practice of making soil mounds in coconut gardens during the monsoon season. This is known as *Poliyidal* or *Polikoottal.* It starts by the end of *Karkidakam* (middle of August) when the weeds in the area are cut and piled into intermittent small heaps of about 30 to 45 cm height at a spacing of 75 to 90 cm. The soil around these heaps are loosened by digging with a spade and spread over these heaps of weeds to form conical soil mounds having a diameter and height of about 45 to 75 cm. The removal of soil from around the heaps creates a depression, where rainwater will stand and percolate into the soil. The decaying of organic matter within these soil cones adds organic matter to the soil. While taking coconut basins, the weeds in the basin area are first heaped in a circular ring around the palm and then the soil is dug and put over this to form a bund with the basin inside. This is locally known as *thadapoli*. Towards the end of the rainy season in *Vrichikam* (middle of November), the mounds are broken down to spread the soil that forms soil mulch. This loose surface soil layer will help in retaining the sub soil moisture of the farmland for much longer time during summer season.

Benefits: This practice helps in higher infiltration of rainwater and also conservation of soil moisture during summer season. In areas of high acidity / excess salts, it helps in washing out the acids and salts.

Limitations: This is a highly labour oriented practice, and hence it is declining in the recent past.

Applicability: It can be adopted in low lying areas, particularly in the coastal regions.

Researchable components: Soil moisture status and groundwater table conditions under situations of with and without this practice are good topics for investigation.

28. Providing shade to crop plants

Method: Shading the crop plants during summer season, especially during the early stages of their establishment and growth is a highly beneficial practice followed by most of the farmers. Shading creates a good microclimate by obstructing wind flow and increasing the humidity in the microenvironment of the plants. Live shade is provided in many cases by planting banana and tapioca on the south-west side of the main crop seedlings to be protected. Dry coconut fronds are commonly used as a shade material. Application of slaked lime on the upper surface of leaves to provide contact shade is a common practice mainly in coconut, arecanut and black pepper plantations during their immature stages of growth. In tea and coffee plantations, trees like silver oak (*Grevillea robusta*), dadap (*Erythina lithosperma*) etc. are grown as shade trees. During the dry seasons, stems of young dadaps and silver oak are either painted with slaked lime or wrapped with long dry leaves to protect from sun scorching.

Benefits: Shading minimizes heat injury to the plants. It helps in bringing down evapotranspiration loss to a certain extent. Live shade also acts as wind breaks and protects the crop from damages caused by strong wind.

Applicability: This practice is widely applicable.

Researchable components: The efficacy of different contact shade materials on different crops may be investigated.

3.4.2. Water resources development

1. Open dug wells

Method: Open dug wells are found in most of the homesteads in Kerala. Some of these wells are used for irrigation also. Laterite stone walls are aesthetically constructed along the circumference of the inner wall of many of these wells to prevent their collapse. Laterite stones are believed to have some water purifying property also. In order to prevent the differential settlement of the walls of wells and their collapse, structures called *nellipadi* were generally used in olden days. Here, the walls on the inner periphery of wells are constructed on a wooden foundation made from the timber of gooseberry *(Phyllanthus emblica)*, locally known as *nelli*. Gooseberry wood will not disintegrate easily and possesses water-purifying property too.

Vaalkinar is a special type of open well seen in Thiruvananthapuram district that allows people to easily step down into the well for taking water for irrigation purpose. A sloping walkway is provided up to the water table on one side of the well for this purpose. These wells are generally square in cross section and occupy about 1 to 5 cents of area, depending on the irrigation demand.

Benefits: Open dug wells are very suitable sources of water for irrigation in the homesteads of Kerala. Water from wells is comparatively free from impurities for use in micro irrigation systems such as drip irrigation.

Limitations: Perennial availability of sufficient water for irrigation from open wells is a problem in many areas.

Applicability: It is replicable in areas where groundwater is available.

Researchable components: Methods of artificial recharge of wells may be evaluated.

2. Farm ponds and tanks

Method: Farm ponds and tanks seen in the homesteads in Kerala serve as good water storage structures and irrigation source for different crops. There are large community level farm ponds and also small farm ponds located in all parts of Kerala. In Palakkad area, the specialty of many of the farm ponds is that they extend up to an area of about 1 ha. Farm ponds of even up to 10 ha are also there. Farm ponds are used either for extracting groundwater or for harvesting runoff water or for both purposes.

In early days, most of the small watersheds (*elas*) in Kerala had a large farm pond (*kulam*) known as *thalakulam* or *melekulam* at the upstream point or head reach, which not only facilitated gravity flow to the lower elevations and valleys, but also helped in recharging the groundwater and maintaining the soil moisture. Many such *thalakulam*s are seen in several parts of Palakkad and Thiruvananthapuram districts. Palakkad is famous for its innumerable number of farm ponds and tanks.

Benefits: Apart from water storage, farm ponds also act as percolation tanks helping in the recharge of groundwater.

Limitations: Construction of farm ponds is costly. Siltation of the ponds is a major problem, especially in sloping areas if they are not protected by parapet walls. With the decline in the involvement of farmers in community activities due to many reasons, siltation, leading to degradation of ponds is a very serious problem in the case of large community level farm ponds.

Applicability: Digging of farm ponds in suitable locations is widely adoptable either for harvesting runoff water or for extracting groundwater or both.

Researchable components: Methods of artificial recharge of ponds and tanks may be evaluated for different agroclimatic conditions. The impact of such ponds and tanks on groundwater status in the locality also need investigation, especially under different soil / rainfall conditions.

3. Networking of farm ponds

Method: In the erstwhile Cochin State, several large tanks were interconnected for developing a cascading system of water storage. The water from the farm pond in the upper reaches flows to a series of farm ponds in the lower reaches. This helps in storing water, regulating the water level and achieving optimum use of water for irrigation in various crops. These 'connected / networked tank system' are still found in this area. They are mainly seen in the plains. In certain areas of Palakkad and Thiruvananthapuram districts also, networked ponds are found. Most of these are community ponds and are several years old. One such network consisting of seven ponds (*yeri*) could be seen in Puthussery Panchayat in Palakkad district.

Benefits: The networking of farm ponds helps in harvesting of rainwater and recharging groundwater aquifers.

Limitations: Due to the high rate of fragmentation of holdings and also slackness among the farming community, the question of sustainability of large system of networked farm ponds remains.

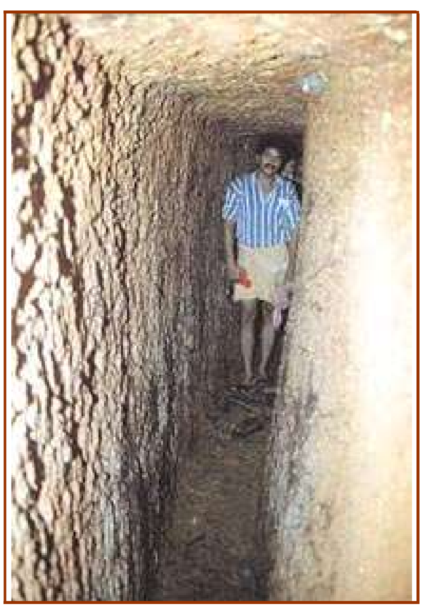
Applicability: It is highly adoptable, especially in plain areas where community participation can be ensured.

Researchable components: The irrigation management practices using these tanks may be evaluated. The groundwater recharge brought about by networking of farm ponds in an area is an interesting area for investigation.

4. Surangams

Method: *Surangams* are basically horizontal tunnels dug through the laterite hill slopes in Kasargod district, from the periphery of which, water flows out by gravity usually into an open pit/ tank/ pond called *mathakkam*. The undulating topography provides suitable condition for constructing *surangams*. A *surangam* hardly requires any maintenance. The general width and height of surangams range from 0.45 to 0.70 m and 1.8 to 2.0 m respectively. The total length varies from about 3 to 300 m. Sometimes, there are several subsidiary *surangams* excavated inside the main *surangam*. When the *surangam* is very long, many vertical airshafts are provided to get air inside the *surangam*. *Surangams* are used mainly for irrigation and domestic purposes. It is used for irrigating cash crops and also for stabilizing the second crop of rice.

Benefits: Since *surangams* are horizontal wells, water flows by gravity from *surangam* to the pond/ *mathakkam* and from *mathakkam* to the field. Surangams have a large recharge area and hence, the yield is high.



Limitations: The cost of construction of a *surangam* is high and the skilled men needed for its work are few in number. In certain areas, crabs cause damage to *surangams* by *burrowing* the walls, resulting in the caving in of *surangams*. In order to prevent crabs, wild tobacco and Chlerodendron plants are planted near to the mouth of *surangams*. Drying up of *surangams,* possibly due to land use changes, has been reported from some areas.

Applicability: It can be adopted in areas having undulating topography and hard soil such as laterite soil.

Researchable components: Artificial recharge measures may be studied for rejuvenation of dried up *surangams*

5. Springs

Method: In the highland and midland regions of Kerala, many perennial springs are present on the hill tops and side slopes. Apart from being a good drinking water source in hilly tracts, many farmers are seen to divert water from high yielding springs to their homesteads for irrigation. It is also observed that some farmers take water to their land through long hose pipes from distant springs located on the uphill side. In certain cases, water coming through the hose pipes is first collected in large storage tanks located on their farms, and from there, it is taken for irrigation. Even sprinkler irrigation is found to be practiced in some sloping areas solely by making use of the kinetic energy of the flowing water.

Benefits: Springs are locally available cheap sources of water for meeting domestic and irrigation needs. Electricity is not required for tapping water from springs located on the uphill side.

Limitations: In case of extreme drought, the springs dry up during some years. Sharing of water from springs located in common / public property may sometimes lead to social problems.

Applicability: The springs located in hilly terrains can be effectively exploited for meeting domestic and irrigation needs.

Researchable components: The impact of land use changes on the yield of springs may be studied.

6. Pallams

Method: In some parts of Kasargod and Thiruvanathapuram districts, water harvesting structures locally called *pallam* are seen. These are large natural depressions, where runoff water gets collected and stored. There are also *pallams,* where the water gets collected in extensive natural rock depressions in foothills/ valleys. Some of these *pallams* are very extensive and perennial. The *pallams* mainly serve the purpose of irrigation of both plantation crops and field crops. Since lots of sediments are carried along with the runoff water, the *pallams* are very fertile.

Benefits: It facilitates harvesting a large quantity of rainwater at nominal cost by making use of topographic features of the area.

Limitations: A considerable extent of land is covered by the reservoir of each *pallam*. So, in thickly populated areas, there is a chance of pressure arising in future to reclaim *pallams* located on private lands.

Applicability: Pallams are possible to be developed in sparsely populated areas, especially in public lands having the required topographic features.

Researchable components: The impact of *pallam* on groundwater recharge in the adjoining and down stream areas may be studied.

7. Brushwood check dam and earthen check dam

Method: Construction of temporary check dams across streams for partially obstructing stream flow and diverting water to adjacent plots for irrigation is seen in some regions of Kerala. These structures are generally put up by the farmers themselves through collective effort, utilizing locally available low-cost materials like stones, wooden stumps, bamboo, reeds, arecanut stem etc. Several such check dams are seen in Wayanad, Palakkad and Kasargod districts. Wayanad district has several brushwood check dams and also earthen check dams known as *manchira*. Construction of check dams usually starts with the cessation of north east monsoon season in November.

Benefits: Apart from providing water for irrigation, these check dams help in recharging the groundwater aquifers in their surrounding and down stream areas.

Limitations: Since they are temporary structures, recurring expenditure is involved every year for their construction.

Applicability: It can be adopted in small streams in areas where community participation can be ensured and required construction materials are available.

Researchable components: The effect of check dams on the groundwater regime in the area has to be investigated.

8. Katta

Method: *Katta* is a type of temporary check dam seen in certain parts Kasargod district. They are skillfully made of stones, sand bags and/ or soil across small rivers and streams. Sometimes, a series of *kattas* are constructed in the same stream at an interval of about 500 m. The construction of *kattas* is started by November-December with the cessation of north-east monsoon and is usually demolished in May. About 75 per cent of the construction materials are stored for re-use. The average width of *kattas* ranges from 10 to 30 m and height ranges from 1.5 to 2.5 m. The mean storage capacity ranges from 60 to120 million litres. The water from the *kattas* is taken for irrigation either by gravity flow or through pumping. The construction of *kattas* is done through community participation.

Benefits: Apart from being a source of irrigation water, *kattas* are reported to help in groundwater recharge in nearby areas.

Limitations: The major limitations reported for *kattas* are their recurring cost, lack of Government aid/ subsidy, damage by crabs etc.

Applicability: It is replicable in areas where many streams are present and community cooperation exists for collective work.

Researchable components: The impact of *katta* on groundwater recharge may be quantified.

9. Anicut

Method: *Anicut* is a type of permanent check dam mainly seen in Palakkad district, which is made across small rivers or streams using stone boulders and a material called *kaara* or *soorki*. *Kaara* is a mixture of sand and lime along with minute quantities of jaggery, extract of 'kadukka' *(Terminalia chebula)* seeds, egg and bark of cotton plant. Strong iron nails are driven in for strengthening the check dams and preventing the stone boulders from moving-off due to the force of water current. It is constructed through community participation. Ponnambilla *anicut* in L.G. Palayam, Elapully panchayat, Palakkad district is more than 100 years old. Another such traditional check dam of more than 100 years old is seen at Moonnukannu *yeri* in Chullimada of Palakkad. The water from *anicut* is usually taken by gravity flow for irrigation of both tree crops and seasonal crops.

Benefits: Apart from providing water for irrigation, *anicuts* help in recharging the groundwater aquifers in their surrounding and down stream areas.

Limitations:

Applicability: It can be adopted in suitable areas having water availability.

Researchable components: The impact of *anicuts* on groundwater recharge may be quantified.

10. Rainwater harvesting in large silpaulin pond/ tank

Method: Silpaulin has become very popular in plantation areas for the construction of rainwater harvesting ponds. In many farms, especially in the high ranges, such farm ponds are dug and lined with silpaulin. These types of farm ponds are locally known as *paduthakulam*. During monsoon season, rainwater from rooftops, surface runoff or water diverted from water sources like streams is collected in these ponds/ tanks. This water is pumped or taken by gravity flow for irrigation of plantation crops during the summer season. In certain areas, even sprinklers are being operated by gravity flow from such large ponds located at a high elevation in the farm. Large farm ponds of up to ten lakh litres capacity have been come across in the survey. Some farmers are found to practice pisciculture also in these ponds.

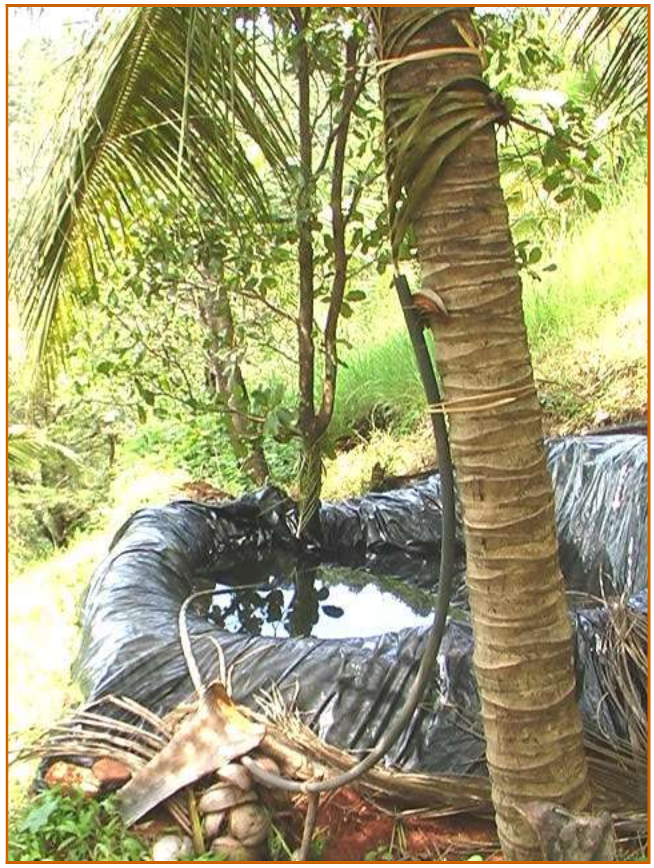
Benefits: Silpaulin ponds/ tanks helps in the harvesting and storage of rainwater for irrigation during summer season.

Limitations: The cost involved in digging of ponds and lining with silpaulin is the limitation.

Applicability: It can be adopted in areas where rainwater from rooftops, surface runoff or water diverted from water sources like streams is available for harvesting and storage.

Researchable components: The efficacy and economics of different lining materials have to be evaluated.

11. Harvesting of stem flow in silpaulin tank



Method: Medium to large pits are taken near the base of individual trees during the monsoon season and lined with silpaulin. The stem flow from the trees is directed to these pits by tying suitable devices on the trunk. The water thus stored is used for irrigation purpose. The water from the pits / tanks is taken through hose pipes by gravity flow to irrigate the trees located in the adjacent rows on the downhill side. This innovative method is seen to be tried on a small scale by a farmer in Kannur district for irrigating coconut.

Benefits: The stem flow is effectively harvested and stored for irrigation during summer season, which otherwise would have been lost as surface run off.

Limitations: The cost involved in the digging of ponds and lining with silpaulin is a limitation.

Applicability: It can be adopted in coconut plantations grown in highly sloping areas where irrigation water is otherwise not generally available. Irrigation can be done cheaply by gravity flow.

Researchable components: The size of the pits / tanks, quantity of water that is available for storage etc. may be quantified and standardized.

3.4.3. Irrigation

1. Flood irrigation

Method: In flood irrigation, water from the source is either diverted by gravity flow or pumped through channels or hose pipes to the farmland. The entire soil surface is flooded by letting out water from the farm channel or hose pipe into the cultivated area. Water spreads and gets ponded on the soil surface, depending upon the infiltration rate of the soil and the duration and rate of irrigation. In gravity flow, when water gets ponded in a block/ terrace, the opening is closed and channel is opened to the next block and so on. Water is also let out from the block at higher level to the blocks at the lower level. It often leads to over irrigation, leading to soil saturation and sometimes causes water stagnation. The soil may develop cracks when the irrigation interval is wider. It is usually practiced in coconut and arecanut plantations situated in plains. A considerable extent of shaping and leveling of land is required to practice flood irrigation.

Benefits: Flood irrigation is a conventional method of irrigation that gives good crop yield.

Limitations: There is wastage of large quantity of water under flood irrigation. It also leads to leaching of nutrients from the soil, weed growth, soil crusting etc. The labour requirement for flood irrigation is also very high.

Applicability: It can be done in any areas having proper shape / level of land and where water is available in plenty.

Researchable components: The impact of over irrigation; particularly the quantification of leaching of nutrients, is a component to be investigated.

2. Channel / furrow irrigation

Method: Channel / furrow irrigation is widely practiced for crops like coconut and arecanut grown in many of the gently sloping to plain areas. Water is either diverted from a source by gravity flow or pumped from a source into the main farm channels. Subsidiary farm channels of about 45 to 75 cm width and 30 to 45 cm depth are taken in between rows of plants and water is let into these channels. Water from the subsidiary channels laterally seeps into the root zone area of the crop. In certain cases, water flowing along the main farm channels is diverted to the basin of each tree / plant. In some areas, cow dung slurry is also applied to the plants along irrigation channels. The channels / furrows are formed / repaired every year at the beginning of the summer season. Depending upon the crop, soil type and availability of water, irrigation is done at an interval of 5 to 15 days. In large farms, the total area is divided into different blocks for practicing rotational irrigation.

Benefits: It is a conventional method of irrigation that increases crop yield.

Limitations: It leads to wastage of a huge quantity of water. It also leads to wastage of nutrients through leaching. Moreover, it is highly labour oriented.

Applicability: It is adoptable for mixed cropping system in areas of sufficient water availability.

Researchable components: The irrigation efficiency of channel/ furrow irrigation under different agroclimatic conditions have to be worked out for various crop combinations.

3. Basin irrigation

Method: In basin irrigation, water pumped through hose pipes or discharged from hydrants running from irrigation project canals is applied in shallow basins taken around the trees. The entire soil surface in the farm area is not irrigated. This is mostly practiced in coconut, arecanut, nutmeg, cocoa etc. under homestead farming system. In the case of coconut, irrigation is done in a basin of about 2 m radius. The basin is often thickly mulched with dry leaves or other organic materials to prevent evaporation loss. Since water flows through pipe system, its conveyance loss is less. Irrigation to individual trees is given in a controlled manner. The interval of irrigation is one to two weeks, depending upon the crops and availability of water. Some farmers also pump cow dung slurry from the Gobber gas plants into the basins at periodical intervals.

Benefits: Compared to flood irrigation, basin irrigation requires only less water.

Limitations: The alternate wetting and drying of soil, weed growth in the basins and crusting of soil surface are some limitations of basin irrigation. Labour requirement is also high.

Applicability: It can be adopted for comparatively widely spaced crops like coconut, arecanut, cocoa, nutmeg etc. in any agroclimatic conditions.

Researchable components: Irrigation scheduling for different plantation crops under different agro climatic conditions may be studied.

4. Splash irrigation

Method: Splash irrigation is an indigenous surface irrigation method practiced for plantation crops like arecanut in some parts of Kasaragod district. It is mainly adopted in small holdings situated in plains. Irrigation is done daily or on alternate days with the help of planks made of cashew wood or leaf sheath of arecanut. Water from the pond / channel is scooped and splashed into the basin of the tree. Irrigation is primarily done by family labour. A person can irrigate about 150 to 200 arecanut palms through splash irrigation per day.

Benefits: It is a very simple method of irrigation that can be practiced in small holdings.

Limitations: It often leads to wastage of water by over irrigation.

Applicability: It is suitable for arecanut and other closely spaced crops grown in small holdings having sufficient water for adopting this method. Since it is highly labour oriented, it is not suitable for large holdings.

Researchable components: Considering the full involvement of family labour, the socio-economic benefits of splash irrigation may be worked out.

5. Pitcher irrigation

Method:: Pitcher irrigation is an indigenous type of drip irrigation, which was practiced by people since ancient times. Unglazed earthen pots of about 5 litres capacity are placed in shallow pits at the base of seedlings of plants / trees and filled with water. The mouth of the pot is kept closed by a coconut shell or a lid. Depending upon the type of crop and its age, 1 to 3 pots are placed. The water drips continuously through a wick placed in a narrow orifice made at the bottom of the pot. This watering system very much saves the quantity of water used in irrigation. Once filled, the pitcher supplies sufficient moisture for about a week and after that it should be filled again. This method of irrigation is practiced by many farmers mainly in Palakkad, Thiruvananthapuram and Kasargod districts.

Benefits: The soil in the root zone is continuously maintained in a moist condition that brings about better growth of seedlings during summer season.

Limitations: Recurring cost of labour involved in burying and removing the pots every season.

Applicability: It can be adopted for irrigating seedlings under any agroclimatic conditions, especially in dry and water scarce areas.

Researchable components: In plain areas, automation of pitcher irrigation by connecting the pots in series using low cost pipes to a tank can be experimented.

6. Drip irrigation

Method: Water from the source (well or pond) is directly pumped to the drip system pipe line or it is first pumped to an overhead tank from where water is taken to the drip line by gravity flow. Water finally reaches the active root zone of each plant through drippers connected on the lateral pipe line of the drip system. Drip irrigation is practiced by some farmers mainly for coconut. In the case of coconut, three to four drippers are provided for each tree. Irrigation is done for one to two hours every day. Filters are provided to prevent dirt materials from entering into the system and clogging the drippers.

Benefits: There is saving in water, labour, energy etc. under drip system. The root zone soil is always maintained in a moist condition near to field capacity moisture level. It is suitable for the undulating topography, where traditional irrigation practices are highly labour intensive.

Limitations: High capital investment for drip system and clogging of emitters are the major problems. The economical viability of the system is less for very small homesteads. The installation of the system is difficult in small holdings under heterogeneous system of planting. The proper design of the system ensuring emission uniformity through emitters is a difficult task under highly undulating topographic conditions.

Applicability: It is adoptable for widely spaced crops under a variety of soil and climatic conditions. It is highly suitable for sandy tracts.

Researchable components: Water application rates, number of wetting points, effects of fertigation etc. for different crops are some of the areas where research is needed.

7. Sprinkler irrigation

Method: In sprinkler irrigation, water from the source is pumped through large diameter aluminium pipes and discharged in the farm area by means of overhead sprinkler heads. Irrigation in the farm is done sector-wise by dismantling the pipe system and assembling in a new area after the irrigation of each sector. Sprinkler irrigation is practiced in crops like coffee, tea, cardamom, coconut, areacnut etc. In coffee, overhead sprinkler irrigation is widely done during February-March to supplement summer rainfall for inducing uniform flowering. It is called blossom irrigation. Again, back up irrigation is given after pollination and fertilization. Sprinkler irrigation is very popular in tea plantations. This irrigation system is efficient for coconut only under mixed cropped situations. Under mono cropped conditions, it leads to wastage of water because of unnecessary wetting of the interspaces also. The irrigation interval and rate of application of water vary from crop to crop, ranging from 25 to 40 mm at fortnightly intervals.

Benefits: Since the system does not require any land development work for practicing irrigation, it is highly advantageous under undulating topographic conditions. Labour requirement of the system is lower than that of other surface irrigation systems.

Limitations: High capital cost is the main limitation for sprinkler system. If the interspaces of the crops are wide, it will lead to wastage of large quantity of water.

Applicability: It is applicable for all high density crops, especially when grown under undulating topographic conditions.

Researchable components: The irrigation scheduling and emission uniformity under different agro climatic and topographic conditions for various crops may be studied.

8. Micro sprinkler irrigation

Method: In this method of irrigation, water is pumped through the pipe system and discharged through small sprinkler heads called micro sprinklers. The micro sprinklers give a fine jet spray of water in a radius of about 1.5 to 2 m from a height of about 75 to 90 cm. It is practiced by many cardamom farmers in Wayanad and Idukki districts. Sprinkler lines are usually laid in between alternate rows of plants. Each micro sprinkler can irrigate about 4 to 6 plants. Irrigation is done at weekly or fortnightly intervals, depending upon the availability of water during the summer season.

Benefits: The use of micro sprinklers help in saving large quantity of water, compared to other surface irrigation methods. It also helps in creating a congenial humid micro climate in the area.

Limitations: The high capital cost is the main constraint in the adoption of micro sprinkler irrigation.

Applicability: It is suitable for comparatively closely spaced crops under any agroclimatic conditions.

Researchable components: Water spread, wetting pattern and micro climatic changes brought about by micro sprinklers under different conditions is an area to be investigated for suitable modifications in the installation of the system.

9. Mist irrigation

Method: Mist irrigation is usually followed for crops where maintenance of a humid micro climate is needed for proper growth and development. In mist irrigation, water is sprayed as a fine jet through spray jet emitters from a height of about 1.5 to 2 m depending upon the crop for which it is installed. The spray jet emitters are connected to low density polyethylene pipes that run as overhead laterals above each row of plants. A spray jet is provided for each plant. Irrigation is done daily or on alternate days for about half an hour to one hour duration during the early morning hours. About 2 to 3 litres of water is discharged for each plant. Efficient filters are provided for the system to prevent clogging of the spray jets. Many vanilla growers are found to practice mist irrigation for irrigating their vanilla crop.

Benefits: It satisfies both water demand and humidity requirement of the crop.

Limitations: The initial capital cost of the system is very high.

Applicability: It is suitable for those high value crops that require humid microclimate.

Researchable components: The micro climatic changes brought about by mist irrigation under different crop combinations is an interesting area of investigation.

3.4.4. Drainage

1. Formation of border channels

Method: In the midland and lowland belts of Kerala, border channels are made in the farm compounds to drain away storm water during the monsoon months. These channels often run along the boundaries of plots and end up in ponds and tanks. Many of the wide land strips that serve as drainage channels are under the control of the government. Several such channel depressions in many areas have been converted over the years into walk ways and roads. The reclamation of drainage networks for roads is resulting in waterlogging and flood in many areas.

Benefits: This system of channels and ponds / tanks helps in the conservation and storage of rainwater, replenishment of soil moisture and recharge of groundwater. Some of these channels are used for irrigating coconut seedlings and vegetables during summer season.

Limitations: Providing wide drainage channels will transform them into walk ways, leading to the loss of land as they get widened in due course of time.

Applicability: It can be adopted in low lying areas and plain lands.

Researchable components: Quantification of surface runoff and soil loss from the farm area through these channels may be carried out.

2. Formation of on-farm drainage channels

Method: In areas affected by water logging during the monsoon season, it is a common practice among many of the farmers to provide surface drainage channels in the farm. The soil taken to form the channel is put in the root zone area of the crop, thereby increasing the depth of the channel. Surface drainage network depends upon the type soil, crops grown and also the gravity of the problem. Drainage channels are sometimes provided for every row or in between alternate rows of plants. This is widely seen in coconut and arecanut plantations situated in low lands.

Benefits: This practice brings in proper aeration of the root zone, which facilitates better nutrient uptake and plant growth.

Limitations: The major constraint is the high labour cost involved in taking large drainage channels.

Applicability: This can be suitably adopted in lowland areas depending upon the crops cultivated.

Researchable components: Drainage system suitable for different crop combinations may be designed. The possibility of pisciculture in such areas during monsoon season may be explored.

3. Planting on raised mounds / beds

Method: In lowland areas, planting of seedlings is done on large raised mounds, sometimes made of imported red soil so as to make the active root zone free from the harmful effects of water logging. When the seedlings grow, these large mounds are connected by importing more soil from outside the farm area and filling it in between adjacent mounds to form a raised ridge. This is specially practiced for crops like coconut, arecanut, nutmeg etc. In cardamom growing areas in the high ranges, planting of cardamom in the valley portion is seen to be done on raised beds with drainage network in between.

Benefits: Taking large mounds for planting allows rainwater to get ponded in between the mounds, facilitating recharge of groundwater aquifers.

Limitations: The major constraint is the high labour cost involved for taking large mounds and subsequent filling of the area with imported soil. Such filling of soil in extensive lowland areas can cause many ecological problems also.

Researchable components: The beneficial and harmful effects of providing artificial drainage for growing tree crops in lowland areas on the ecology of the area may be scientifically quantified.

3.5. Effect of Traditional Soil and Water Management Practices on Soil Properties

3.5.1. Background

All physical, chemical and biological processes in soil are influenced by soil temperature and soil moisture. The functional activity of plant roots such as absorption of water and nutrients can be affected at both low and high soil temperature (Baver *et al,* 1972). Soil temperature exercises a major influence on the growth and development of plants through its effect on germination, seedling development and functions of roots (Ghildyal and Tripathi, 1987). According to Sonia Aggarwal *et al* (2003), even a small change of 1°C in soil temperature can influence the growth and nutritional behaviour of plants.

Among the traditional soil and water conservation practices adopted by many of the farmers, post monsoon tillage and cover cropping are two practices, which are expected to significantly influence important soil properties. Post monsoon ploughing is done in coconut and arecanut plantations by most of the farmers interviewed under the project. Similarly, cover cropping is the most common practice observed in rubber plantations. Some farmers are found to practice cover cropping in coconut plantations also. Therefore, these two traditional practices were evaluated in the farmers' fields to study their effects on soil properties.

3.5.2. Methodology

The investigations were conducted in a mono-cropped coconut plantation owned by a progressive farmer, located at Manassery in Kozhikode district. The site had laterite soil of loamy texture. The two treatments being practiced by the farmer viz. cover cropping with legume (*Mucuna bracteata*) and post monsoon ploughing were taken for experimentation, with unploughed area kept as control. The following parameters were studied from the three treatment plots.

Plate 3.5.1. Soil thermometers installed in cover cropped area

- Soil temperature at 2.5 cm, 5 cm, 10 cm, 20 cm, 30 cm and 50 cm depths during the summer season (December 2004 to May 2005).
- Soil moisture at 2.5 cm, 5 cm, 10 cm, 20 cm, 30 cm and 50 cm depths.
- Atmospheric temperature *(from the nearby weather station)*
- Rainfall *(from the nearby weather station)*
- Physico-chemical parameters

A set of soil thermometers each was installed at three representative locations in each treatment plot. Daily observations were recorded at 8.30 am and 2.30 pm (Plate 3.5.1). Soil samples were taken at weekly intervals during April and May from representative sites in each treatment plot for gravimetric estimation of soil moisture. Soil samples were also taken for physico-chemical analysis.

3.5.3. Results

3.5.3.1. Weather

Annual mean maximum and minimum temperature in the area were 31ºC and 23ºC respectively, while the mean annual rainfall was 3000 mm.

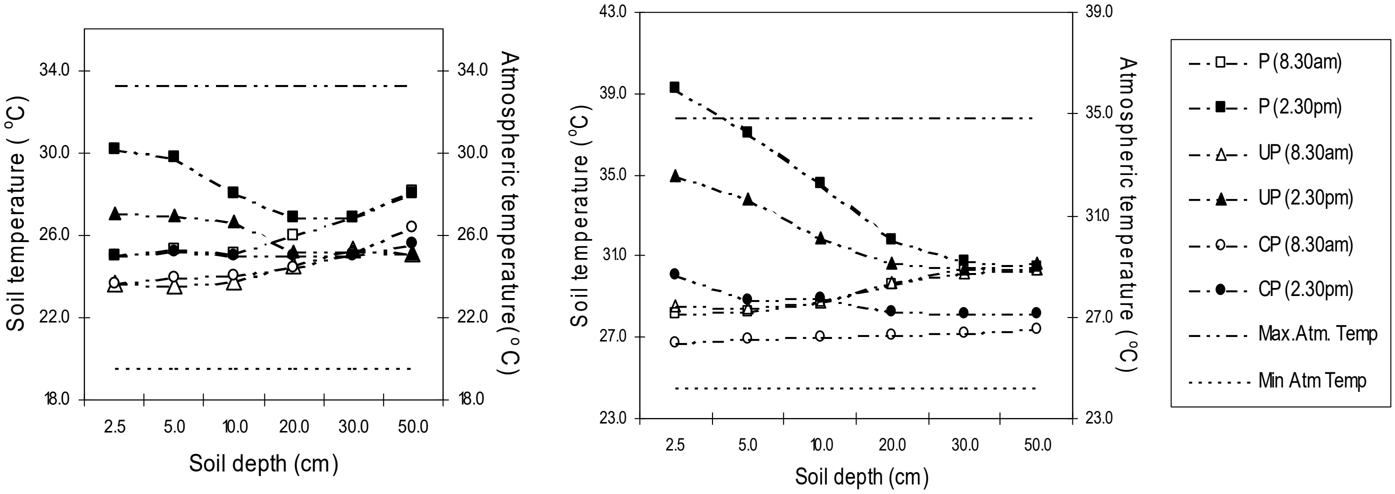
During the experimental period from December to May, in January, February, April and May there were 1, 1, 6 and 2 rainy days and 8.8, 6.8, 158.8 and 95.2 mm of rainfall respectively. The monthly mean maximum and minimum temperature during the months from December to May were 33.3, 33.2, 33.8, 34.9, 34.3, 34.8°C and 19.5, 21.5, 22.0, 24.3, 24.8, 26.3°C respectively.

3.5.3.2. Soil temperature

Soil temperature was found to be influenced by both cover-cropped and ploughed treatments. The analysis of soil temperature revealed that cover cropping had a significant effect in preventing the increase in soil temperature during summer season. During the month of December, the afternoon soil temperature at 2.5 cm depth in the cover-cropped plot was found to be 3ºC and 5.4ºC less than that of the unploughed plot and ploughed plot respectively. This effect of cover crop in lowering the soil temperature was noticed at 10 cm and 30 cm depths also. During March, the soil temperature difference at 2.5 cm depth between the two plots was 10.65ºC. During March, the soil temperature at 2.5 cm depth in ploughed plot was found to increase to 39.9°C, while the atmospheric temperature was only 34.8°C (Figure 3.5.1. a & b).

Cover crop intercepted a considerable portion of solar radiation, thereby preventing the soil from becoming as warm as bare soil. Both at the surface and deeper soil layers, the morning temperature difference between control plot and cover-cropped plot was minimal. This is due to the cooling of the warm unploughed soil at night, which takes time to get warmed up again on the next day.

The fluctuations in the sub-soil temperature between day and night were found to be minimum in all the treatments. As a result, the sub-soil was found to be warmer than the surface soil at 8.30 am, while the surface soil was much warmer than sub-soil at 2.30 pm. The specific heat of the high moisture content in the sub-soil may be one of the reasons for the minimal fluctuations in the sub-soil temperature between day and night.



a) December 2004 b) March 2005

Figure 3.5.1 (a & b). Mean soil temperature at different depths under ploughed (P), unploughed (UP) and cover-cropped (CP) coconut plantations during December 2004 and March 2005

Where the sub-soil moisture content was least (cover-cropped area), the fluctuations in sub-soil temperature was observed to be more. In the morning (8.30 am), the temperature of the surface soil layers (2.5 cm, 5 cm and 10 cm) were found to be less than that of the deeper layers. At 2.30 pm, the temperature of the deeper soil layers (20 cm, 30 cm and 50 cm) did not increase much, whereas the surface soil layers showed significant increase in temperature. The rate of increase in the temperature of surface soil layers was high in the case of ploughed and unploughed plots, whereas in the case of cover-cropped plot, the increase was only marginal. Conversely , during most of the months, the rate of increase of temperature in the deeper soil layers was found to be more in cover cropped plot than in ploughed and unploughed plots. During the period of study, the soil temperature in the ploughed plot was found to be higher than the cover-cropped and control plots (Figures 3.5.2 & 3.5.3). This may probably be because of the higher thermal conductivity of soil in the ploughed plot due to high moisture content, which was observed under this treatment.

Both sub-soil and surface soil temperature during day and night in the cover-cropped area were found to be much lower than that of the other two treatments throughout the summer season. Thus, cover cropping provided a cooling effect to the whole soil profile. The ploughed loose soil was found to be warmer than unploughed soil. The soil profile upto 50 cm depth in ploughed plot was warmer than the other two treatments both in the morning and afternoon (Table 3.5.1).

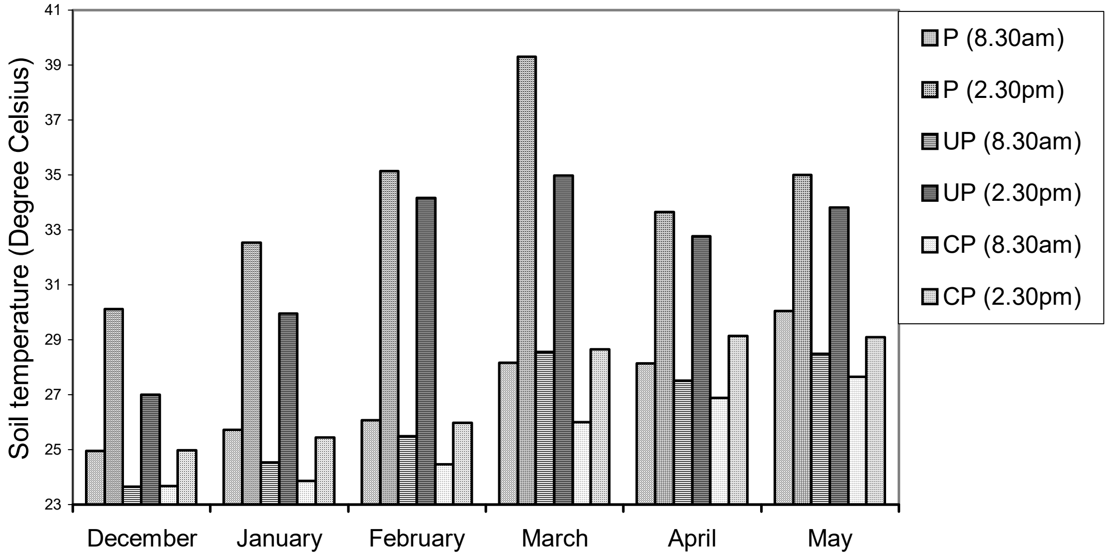


Figure 3.5.2. Soil temperature at 2.5cm depth in ploughed (P) , unploughed (UP) and cover-cropped (CP) coconut plantations

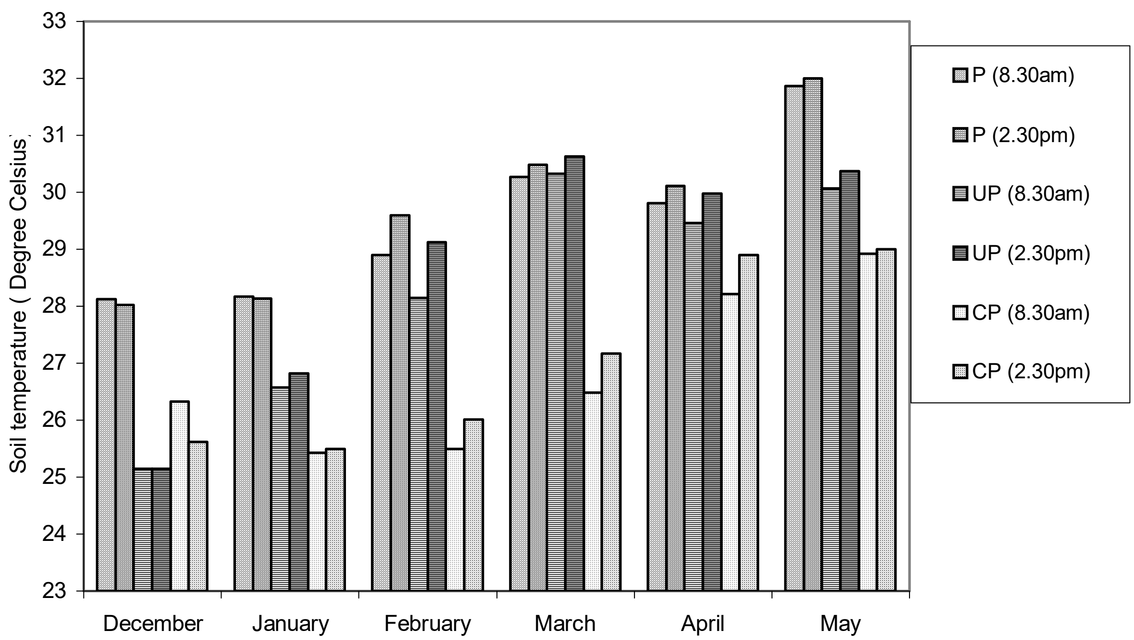


Figure 3.5.3. Soil temperature at 50 cm depth in ploughed (P) , unploughed (UP) and cover-cropped (CP) coconut plantations

Table 3.5.1. Mean soil temperature under various treatments.

Month	Time	Mean soil temperature upto 50 cm depth (°C)		
		P	UP	CP
December	8.30 am	26.1	24.1	24.6
	2.30 pm	28.1	26.2	25.1
January	8.30 am	26.9	25.7	24.8
	2.30 pm	29.5	28.0	25.5
February	8.30 am	27.6	26.8	25.0
	2.30 pm	31.1	30.8	27.6
March	8.30 am	29.4	29.5	26.3
	2.30 pm	33.8	32.0	27.7
April	8.30 am	28.9	28.3	27.6
	2.30 pm	31.3	30.8	28.8
May	8.30 am	30.6	29.3	28.3
	2.30 pm	32.7	31.8	29.1

P- Ploughed, UP – Unploughed, CP- Cover cropped

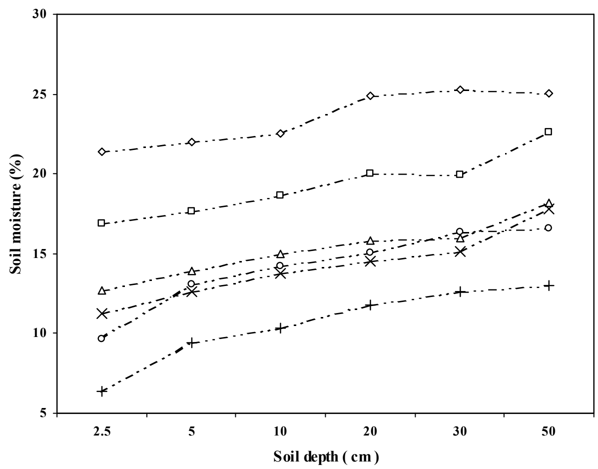
Though atmospheric temperature was high during April and May also, the soil temperature did not increase as high as in March. The reasons could be the microclimatic changes and high soil moisture contributed by the summer showers received during the first week of April.

The observed increase of soil temperature in unploughed and ploughed soils can affect the root system and physiology of the plant, especially in the case of highly drought-sensitive crops like arecanut, black pepper, cardamom etc. This may be one of the limiting factors of crop productivity in humid tropical latosols.

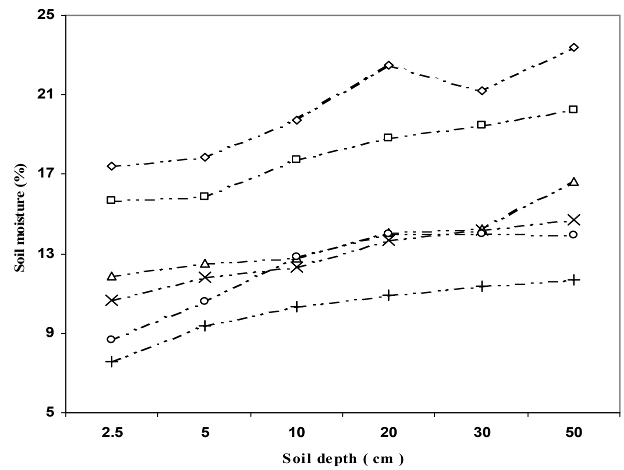
3.5.3.3. Soil moisture

Cover cropping and tillage systems have influenced the moisture content in the soil profile. The soil moisture in deeper layers of the soil profile was found to be higher than that of surface layers in all the treatments. Post-monsoon ploughing was found to have a definite advantage in conserving soil moisture. The soil moisture content at all the depths was higher in ploughed treatment compared to that of the other treatments. The mean soil moisture content at 2.5 cm and 50 cm depths under ploughed, unploughed and cover-cropped plots ranged from 13 to 19 per cent, 12 to 17 per cent and 12 to 16 per cent respectively. The high soil moisture content under ploughed treatment may be due to the breaking of capillarity with the atmosphere, thereby minimizing the capillary rise of water from the sub-soil to the atmosphere. The loose soil forms dry soil mulch over the surface.

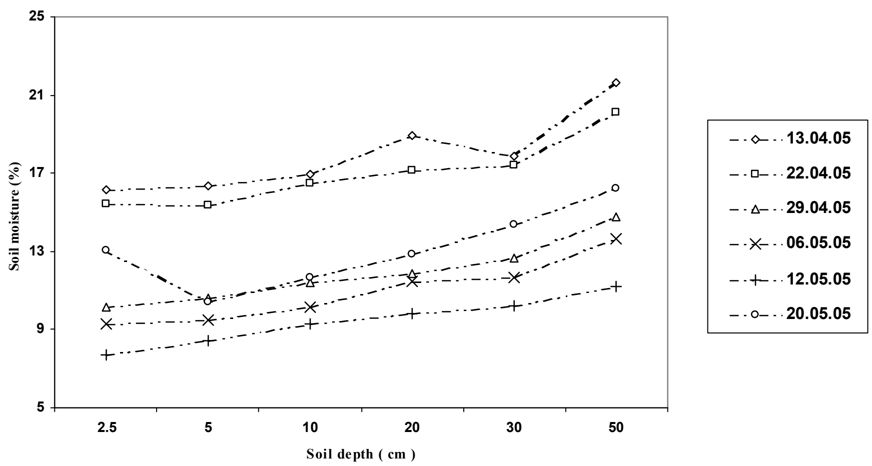
The treatment having cover crop was found to have the lowest soil moisture content at all the depths (Figure 3.5.4 a, b & c). This may be due to the high transpiration demand of the cover crop, in spite of the low soil temperature maintained under it.



a) Ploughed soil



b) Unploughed soil



c) Cover-cropped soil

Figure 3.5.4 (a, b & c). Soil moisture at different soil depths in coconut plantations under Ploughed, Unploughed and Cover-cropped treatments

It was seen that the summer showers in middle of May increased the soil moisture at all the depths in cover cropped plot more than that of ploughed and unploughed plots. This indicated more infiltration of rainwater in cover cropped plot. Cover cropping results in the addition of lot of organic matter to the soil in the form of stubbles. Due to this high organic matter content, different types of fauna are expected in the cover cropped area. The combined effect of high organic matter content, diversity of fauna and root activity would lead to a high rate of infiltration in cover-cropped area.

3.5.3.4. Physico-chemical properties of soil

Table 3.5.2 shows soil physico-chemical properties of different treatment areas.

Physical properties

The average bulk density of soils in ploughed (P), unploughed (UP) and cover-cropped plots was found to be 1.21, 1.47 and 1.13 g/cc in the surface layer (upto 25 cm depth) and 1.31, 1.5 and 1.15 g/cc in the subsurface layer (26 to 50 cm depth) respectively. Higher bulk density in unploughed plot is due to the compactness of soil and lower bulk density in cover-cropped plot is due to loose soil with high organic matter content as revealed by chemical analysis. However, much difference was not observed in the particle density of soils under different treatments as it is a characteristic of the chemical and mineralogical composition of different soils. Particle size analysis of soils indicated clay accumulation in subsurface soil layer under different treatments. More accumulation of clay was found in cover-cropped plot. This can be attributed to the improved structure with high porosity in the plot, which facilitated easy movement of clay particles down the soil profile.

Chemical properties

The experimental site had acidic soil with pH ranging from4.8 to 5.9. The average organic carbon content in ploughed, unploughed and cover-cropped plots was found to be 1.03, 0.89 and 1.11 per cent in the surface layer and 0.86, 0.76 and 1.03 per cent in the subsurface layer respectively. Surface soil obviously had more organic carbon than sub surface soil. High organic carbon in cover-cropped plot is due to the deposition of residues from cover crop on the soil surface and also due to reduced soil erosion. The mean total nitrogen in ploughed, unploughed and cover-cropped plots were 0.114, 0.097 and 0.139 per cent in the surface layer and 0.113, 0.097 and 0.126 per cent in the subsurface layer respectively. High total nitrogen in cover-cropped plot is the result of high biomass recycling.

3.5.4. Conclusion

Though post-monsoon ploughing increased the soil temperature during the summer season, it helped in conserving soil moisture. It was observed that post monsoon ploughing improved the soil moisture content by 1 to 5 per cent. Under irrigated conditions, wherein the crop basins are irrigated and the inter-spaces are ploughed, soil temperature may not excessively increase in the root zone area. However, the influence of increase in soil temperature during the summer season on crop yield has to be investigated further. In highly sloping areas, ploughing could lead to high rate of soil erosion even when good conservation measures are adopted. This soil loss has to be quantified. In plain areas, post-monsoon ploughing is definitely advantageous.

Table 3.5.2 Physico-chemical properties of soil under different treatments

Parameter		Ploughed plot (P)		Unploughed plot (UP)		Cover-cropped plot (CP)	
		Surface soil*	Sub-surface soil**	Surface soil*	Sub-surface soil**	Surface soil*	Sub-surface soil**
Bulk density (g/cc)		1.21	1.31	1.47	1.5	1.13	1.15
Particle density (g/cc)		2.77	2.75	2.72	2.81	2.74	2.63
Particle size distribution of soil (%)	Sand	78.5	69.1	77.8	71.6	76.7	61.7
	Clay	15.9	26.1	16.0	20.2	16.5	32.0
	Silt	5.6	4.8	6.2	8.2	6.8	6.3
pH		5.6	5.4	5.4	5.1	5.5	5.5
Organic carbon (%)		1.03	0.86	0.89	0.76	1.11	1.03
Total nitrogen (%)		0.114	0.113	0.097	0.097	0.139	0.126

* Surface soil – upto 25 cm depth; ** Sub-surface soil – 26 to 50 cm depth

Cover cropping with leguminous crops helped in minimizing the increase in soil temperature during summer season. The physical and chemical properties of soil are also improved by cover cropping. However, data showed that there is high loss of soil moisture from all the soil layers under cover-cropped condition than other treatments. This loss of soil moisture would account for the transpiration requirement of the cover crop. Hence, allowing the cover crop to grow during the summer season would mean a drastic decline in soil moisture and also competition between the main crop and cover crop for moisture. Therefore, it advisable to cut the entire cover crop with the cessation of rainy season and spread the stubbles over the soil to form a dry mulch. During monsoon, cover crop would act as a protective cover over the soil, thus minimizing soil erosion from plantations. The effect of cover crop in preventing soil erosion from coconut plantations, especially under mono cropped situation, needs to be evaluated.

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3.6. Recommended Practices of Scientific Water Management for Plantation Crops in Humid Tropics

3.6.1. Background

Though Kerala receives an average annual rainfall of 3000 mm and the region is mostly covered by perennial green vegetation, agricultural drought is almost a recurring phenomenon in the State due to the peculiar physiographic, climatic and soil features. This highly affects the productivity of various crops in the State, and therefore enrichment of soil moisture through harvesting and conservation of rainwater, and supplementary irrigation assumes great significance.

Kerala State has been delineated into 13 agro-ecological zones and large varieties of crops are cultivated. The average size of land holding in the State is only 0.24 ha and homestead farming system is widely adopted. Coconut, occupying 42 per cent of the agricultural area in the State, is an integral component of the homestead farming system. Rubber is the second major crop covering 22 per cent of the area. Adoption sustainable water management practices in the homesteads of Kerala is extremely important from the crop production point of view and also for maintaining the ecological balance in this fragile region. Scientific land and water management practices can alleviate the problems caused by high intensity rainfall, sloping terrain, and weather aberrations.

3.6.2. Soil and water conservation measures

3.6.2.1. Contour alignment and contour farming

Contour farming, wherein the crops are planted along the contour, minimizes surface runoff and soil erosion, and thereby controls the loss of nutrients and increases the soil moisture retention.

Contour alignment can be done in a simple and practical method by using a wooden 'A–frame'. The adjacent points in a contour are marked when the plumb line hanging from the upper corner of the A–frame runs through the midpoint of its horizontal arm. In the case of plantation crops, which are comparatively widely spaced, the plant-to-plant spacing of the crop will be usually equal to or multiples of the distance between the two legs of the A-frame. The type of crop and its row-to-row spacing generally determines the contour interval. In sloping areas, the row-to-row spacing will be generally greater than plant-to-plant spacing.

3.6.2.2. Contour bunds

Stone-pitched contour bunds: Stone-pitched contour bund, locally known as *kayyala,* is a stable and permanent structure for soil and water conservation. It is constructed by initially cutting a shallow trench along the contour and heaping the excavated soil on the uphill side. Then, stones are pitched on the outer face of this cut edge. As the height of the bund is increased, all the inner gaps between stones are packed with excavated soil. The bund is finished with a top riser so that a shallow depression is formed all along its length on the uphill side. The runoff water and silt drain into this depression. Depending upon the slope, the height of bund ranges from 1 to 2 m. Interval between two contour bunds is usually determined by the type of crop grown. The slope of the terrace portion in between two contour bunds gradually gets reduced and the sloping terrace will almost become a bench terrace in due course of time.

Earthen contour bunds: Earthen contour bunds called *kollu* can be made when stones are not available for construction of stone-pitched contour bunds. For the construction of earthen contour bunds, wet soil is spread on the outer face of the cut edge of soil profile and beaten with a flat wooden plank for proper compaction. The height of the bund usually ranges from 0.5 to 1 m. The earthen bund requires periodic maintenance work every 3 to 4 years. Fodder grass, pineapple, agave etc. can be planted along the riser in order to protect the stone-pitched or earthen bunds. Apart from strengthening the bund, it provides extra income to the farmers.

Cross-bunds: Intermittent stone-pitched or earthen cross-bunds can be constructed in between adjacent contour bunds at definite intervals depending upon the crop grown. This will act as a barrier to the lateral flow of water along the uphill side of the riser and helps in conservation of water, soil and applied manures.

Stone-pitched boundary walls: Stone-pitched boundary walls can be constructed by packing stones on both faces of the wall, with soil filled in between. Height of the wall usually ranges from 1 to 1.5 m. and they run along the boundaries of homesteads. In addition to the primary function of partition, they also aid in soil conservation.

3.6.2.3. Contour strip terraces or platform terraces

Contour strip terraces or platform terraces shall be formed along the contour in sloping areas for the planting of crops like rubber, arecanut, black pepper etc. Contour strip terraces are narrow strips of terraces of about 1.5 m width taken along the contour. The interval between strip terraces depends upon land slope and row-to-row spacing. The inward slope given to the strip terraces helps in collecting runoff water and sediments draining from the uphill side and help in groundwater recharge. Stem flow during rainfall also gets collected in the inward slope portion of the terrace. Leaving intermittent small land cuttings that project into the terrace from the uphill side can obstruct the flow of water along the strip terraces. Contour strip terraces can be stabilized by growing fodder grass all along the downhill edge of the platform. The grass holds the soil together and prevents erosion of loose soil from the platform terrace.

3.6.2.4. Rainwater harvesting trenches and pits

Rainwater harvesting trenches and pits can be widely adopted in rubber, coconut, and coffee plantations. Trenches or pits shall be taken in between crop rows. The size of the trench depends on cropping system, rainfall, slope and soil. The general size shall be about 50 to 150 cm length and 45 to 60 cm width and depth. About 100 to 200 trenches can be taken in a staggered manner in one hectare of land. Runoff water gets collected in the trenches and slowly percolates through the soil profile. Fodder grass or pineapple can be planted on the raised embankment formed by the excavated soil on the downhill side of the pit to protect and stabilize the soil.

3.6.2.5. Check basins or blocks

Check basins or blocks separated by small earthen or stone bunds that accommodate 4 to 10 plants can be formed in coconut and arecanut plantations located in plains. Various intercultural operations within these blocks help in increased infiltration. Rainwater falling in these blocks does not escape as runoff and helps in the recharge of soil moisture and groundwater.

3.6.2.6. Planting pits

Planting pits of different patterns, suiting to the crop, soil and topography can be adopted to conserve soil and water, and protect the plant. In areas where soil drainage is a problem during monsoon season, pits are taken with suitable risers on all the four sides so that runoff water does not flow into the pit. But, in water scarce areas having low rainfall and well drained soil, large water-harvesting type of planting pits can be taken wherein the saplings planted on a soil mound inside the pit. The runoff from the surrounding area is allowed to flow into the planting pit and the sapling is protected from submergence by the soil mound.

3.6.2.7. Centripetal terraces or circular basins

Centripetal terraces or circular basins shall be taken around individual trees during monsoon season in coconut and arecanut gardens that aids in rainwater harvesting. The radius of the basins shall be equal to the radius of the active root zone of the particular crop. In the case of coconut, centripetal terraces of about 2 m radius can be taken during the southwest monsoon season. Green manures / farm yard manures / fertilizers can be applied to this basin. The basins harvest the stem flow and through fall during rainfall.

3.6.2.8. Multi-storied cropping

Multi-storied cropping shall be adopted in homesteads to protect and conserve the natural resources in the area and to increase the net returns. Multi-storied cropping is a system of growing crops of different heights, canopy architecture and rooting depth in a geometric pattern in the same field. The roots of different crops extract water and nutrients from different soil depths. Similarly, the canopies of different crops intercept light as well as raindrops at various levels. Multi-storied cropping with a variety of crops is possible in coconut and arecanut plantations. Cocoa, arecanut, tree spices, black pepper, coffee, cardamom, banana, pineapple, ginger, turmeric, fodder grasses etc. can be grown as multi-storied crops in different crop combinations. In a good multi-storied cropping system, the cropping intensity can go upto 200 per cent or more. Multi-storied cropping makes best use of the available space, sunlight, nutrients and water in an area. Soil structure is improved by good biomass recycling under multi-storied cropping.

3.6.2.9. Mulching

Mulching the root zone area of crop plants with various crop residues, trash or other organic materials is a very essential agronomic practice in humid tropics to conserve soil and water. Coconut husk can be used for mulching the basins of trees, especially in coconut and arecanut plantations. If sufficient coconut husk is available, the entire farm area can be mulched by laying coconut husk. Coconut husk is closely spread over the soil surface with the concave side facing down. Walkways and irrigation channels are left in between to facilitate easy movement. Coconut fronds are spread over the husks after its laying. Mulching using crop stubbles can be practiced in cardamom plantations. Mulching helps in reducing evaporation losses and controlling soil temperature during summer season. During monsoon period, it helps in minimizing the impact of raindrops, controlling soil erosion and weed growth, encouraging faunal and microbial growth and adding nutrients to the soil.

3.6.2.10. Coconut husk burial

Coconut husk burial is a highly beneficial practice that can be adopted in homesteads. Husks are buried, with their concave side facing upwards, in trenches or pits of 45 to 75 cm depth and convenient length and width taken across the slope. Three to five such layers of husk are spread like this. The top layer of husk is placed with their convex side facing upwards. Finally, soil is spread over these husks. Pineapple can be planted above these pits. The area in between these pits can be planted with crops like black pepper, vanilla etc. Coconut husk is a highly useful material that helps in water conservation. Coconut husk can hold more than eight times its weight of water. Husk is also a rich source of potash. It promotes biological activity in soil. The beneficial effects of husk burial may last for many years.

3.6.2.11. Cover cropping

Cover cropping in the interspaces of crop plants with leguminous creepers provides a thick protective cover to the soil. It shall be adopted in rubber plantations, mono cropped coconut gardens etc. Cover crop protects the soil from the impact of raindrops, controls soil erosion, suppresses weed growth and controls soil temperature. Due to high biomass recycling and root activity of cover crops and increased activity of soil fauna, the soil structure gets improved, which in turn helps in increased infiltration of water. The leguminous cover crop also fixes atmospheric nitrogen to the soil. With the cessation of monsoon season, it advisable to cut the cover crop and spread the stubbles over the soil to form dry mulch.

3.6.2.12. Tillage

Tillage of farm land soil with the cessation of monsoon season in November is a good water conservation practice. This is locally known as *thulakkoth.* The surface soil is tilled during the second fortnight of the month *Thulam* or the first week of *Vrichikam* for soil aeration and also for slowing down the process of drying up. In the process of *thulakkothu,* the continuity of soil capillarity with the atmosphere is broken and the loose dry soil acts as a mulch to minimize evaporation losses.

3.6.2.13. Soil mounds / cones

Making of soil mounds / cones called *poliyidal* during the monsoon season is a healthy practice in coconut gardens in the coastal regions. It can be done by first cutting the weeds in the area and heaping them at intermittent intervals. The soil around these heaps are tilled and spread over these heaps of weeds to form conical soil mounds. The removal of soil from around the heaps creates a depression, where rainwater will stand and percolate into the soil. The decaying of organic matter within these soil cones adds organic matter to the soil. With the onset of summer season these mounds are broken down to spread the soil that forms soil mulch, which helps in soil moisture conservation.

3.6.2.14. Application of farm yard manure / compost

Application of farm yard manure / compost in soil for maintaining the soil organic matter content is essential in humid tropical regions for sustainable agriculture. Cow dung slurry from biogas plants is a good option in homesteads. Application of farm yard manure / compost improves organic matter content, structure and water holding capacity of the soil.

3.6.2.15. Application of green manure

Green leaf manure producing plants / shrubs / trees can be planted in between the crops or as vegetative fence along the borders. The pruned branches can applied as green leaf manure to crop plants. This enriches the organic matter content of the soil and promotes the growth and multiplication of soil fauna that in turn increases soil aeration and infiltration of water.

3.6.3. Water resources development

Open dug wells, farm ponds, tanks, springs, surangams etc. can be developed in homesteads for irrigation purpose. Large farm ponds and tanks can also be interconnected for developing a cascading system of water storage. Check dams can be constructed across streams for storage of water for irrigation. Check dams also help in recharging the groundwater aquifers in their nearby areas. Silpaulin-lined farm ponds for harvesting of rainwater can be made, especially in highland areas for irrigation purpose.

3.6.4. Irrigation

3.6.4.1. Channel / furrow irrigation and basin irrigation

Depending upon the source of water, water availability, crops and cropping system, topography, soil type, size of land holding etc. suitable irrigation method shall be adopted in the homesteads for increasing crop productivity. Channel / furrow irrigation and basin irrigation, which are improvements over conventional flood irrigation, shall be adopted in homestead farming system for water saving. Cow dung slurry from biogas plants can also be applied to the plants along these irrigation channels. The irrigated basins shall be mulched with dry leaves or other organic materials to prevent evaporation loss.

3.6.4.2. Drip irrigation

Drip irrigation system, which is a highly water saving method of irrigation, is very much suitable to plantation crops grown in undulating terrains and coastal sandy tracts. Fertigation can also be done in drip irrigation, whereby the nutrient use efficiency can be increased.

3.6.4.3. Sprinkler irrigation

Sprinkler irrigation is suitable in comparatively closely spaced and short / medium statured crops like tea, coffee and cardamom, which are mainly grown as mono crops. In coconut and arecanut plantations, sprinkler irrigation is efficient only under mixed cropped situations. Under mono cropped conditions, it leads to wastage of water because of unnecessary wetting of the interspaces.

3.6.5. Drainage

In areas affected by water logging during the monsoon season, surface drainage channels shall be provide within and along the border of the farm. The soil taken to form the channel shall put in the root zone area of the crop, thereby increasing the depth of the channel. In such areas, planting of coconut, arecanut and nutmeg seedlings shall be done on large raised mounds or beds, in order to free the roots from harmful effects.

4. SUMMARY AND CONCLUSION

The humid tropical region of Kerala is characterized by the presence of heavy rainfall and highly undulating topography having steep slopes. Tropical wet evergreen forests, semi-evergreen forests and wet deciduous forests are the main natural vegetation in the region that helps in maintaining environmental balance. But, many of the natural ecosystems have given way to various agricultural ecosystems, which are dominated by spices and plantation crops of perennial nature. In Kerala, agriculture is practiced even in areas above 100% slope. The rapidly increasing population, undulating topography, heavy and unevenly distributed rainfall, deforestation and large-scale human settlement in ecologically fragile areas, wide-spread reclamation of lowland rice fields, unscientific agricultural practices, pollution, climatic vagaries etc. are threats to the environment that leads to land degradation and water scarcity in the region. With an evergreen land cover throughout the year, Kerala's problem of drought, especially agricultural drought is rather unique.

Many of the water-related problems in Kerala are due to the lack of proper awareness and seriousness among people in adopting appropriate water management measures. Farmers in Kerala have traditionally evolved various water management practices that greatly help in conserving soil and water. However, the indigenous wisdom and traditional water management practices are disappearing due to the influx of modern technologies and changes in the social set up and life style of people. With 3000 mm of mean annual rainfall and 55 per cent of area under agriculture, of which, 75 per cent is constituted by small and marginal holdings, adoption of traditional knowledge and sustainable farming practices in the homesteads of Kerala is extremely important from the crop production point of view and also for maintaining the ecological balance in the region for the conservation of land, water and other natural resources.

Aimed at future dissemination of the knowledge for creating awareness on the significance of traditional water management practices, a project on "Documentation and scientific analysis of farmers' practices on water management for plantation crops in Kerala" was undertaken by the Centre for Water Resources Development and Management, Kozhikode with funding from Indian National Committee on Irrigation and Drainage, New Delhi. There is great scope for dissemination of this knowledge to similar agroclimatic regions in coastal Karnataka, Goa, coastal Maharashtra and other humid tropical areas.

As a part of the project, field visits were carried out to about 250 farms located in different agro-climatic zones of Kerala, which are cultivated with various spices and plantation crops. Personal interviews using a detailed questionnaire were conducted with 91 farmers.

About 51 traditional water management practices followed for various plantation crops in different agroecological zones of Kerala were documented and analyzed. The areas of water management covered under the study included soil and water conservation measures, water resources development works, irrigation methods and drainage measures. For each practice, the method, its scientific explanation, benefits, limitations, applicability under different agro-climatic conditions and possible components for future research have been identified and described. Video coverage has also been done for most of the practices, which has been brought out as a short film.

Eventhough a good proportion of coconut and arecanut farmers interviewed were found to irrigate at intervals specified in the State recommendations for the crops, majority of them are not in a position to apply water according to the recommendation. As far as irrigation methods are concerned, most of the arecanut and coconut farmers practice basin irrigation, which is a good method for these crops. Adoption of drip irrigation for crops is poor, even when financial subsidy is provided by the Agriculture department for promoting this irrigation technique.

About 67 per cent of coffee farmers have irrigation adoption index between 75 to 100 per cent of the maximum possible index value, while 63.6 per cent of cardamom farmers possess 66.7 per cent of the maximum index. However, in the case of arecanut and coconut, only a lesser number of farmers come within the maximum range of adoption index, when compared to the lower ranges of adoption index. A good proportion of coffee, cardamom and black pepper farmers have higher values of irrigation adoption index, adopt scientific irrigation scheduling and also improved irrigation methods like sprinkler.

About 50 per cent of the farmers are innovative in adopting more number of soil and water conservation measures in their landholding. In the case of farmers adopting three and more measures, more than 80 per cent of them exhibit innovativeness with regard to the extent of area where the measures are adopted. The number of measures adopted and area of adoption of the measures are the two main factors, which contribute to innovativeness of farmers with respect to the adoption index of soil and water conservation measures.

Post-monsoon tillage and cover cropping are found to be two traditional management practices, which are expected to significantly influence important soil properties. Therefore, these two practices were evaluated in the farmers' fields to study their effects on soil properties. Though post-monsoon tillage raised the soil temperature during the summer season, it helped in increasing the soil moisture content by 1 to 5 per cent.

Cover cropping with leguminous creepers was found to be significantly controlling soil temperature during summer season. It increased the organic carbon and total nitrogen contents of the soil. But, the loss of soil moisture was observed to be high under cover-cropped condition. This loss of soil moisture would account for the transpiration requirement of the cover crop. Therefore, allowing the cover crop to grow during the summer season would lead to decline in soil moisture and also competition between the main crop and cover crop for water. Hence, it advisable to cut the cover crop with the cessation of monsoon season, and spread the stubbles over the soil to form dry mulch. During the rainy season, the cover crop would act as a protective cover to the soil, thus minimizing soil erosion, especially from mono crop coconut plantations.

With high rainfall, highly undulating topography, high population density and 55 per cent of the total area under agriculture, awareness on traditional knowledge and adoption of sustainable water management practices in the homesteads of Kerala has great relevance from the crop production point of view and also for maintaining the ecological balance in this fragile region. Some of the traditional water management practices are disappearing due to the changes in the social set up and life style of the people, scarcity and high cost of labour, low market price of commodities etc. This may also be contributing to the increasing incidence of drought and water scarcity problem in many parts of Kerala. Adoption of many of these time-tested traditional water management practices will definitely pave way for the sustainability of land, water and bioresources in humid tropical regions. Hence, it is necessary to disseminate such practices among people through different extension methods and media.

Based on the available literature and the information collected from the field survey, the recommended practices of scientific water management for plantation crops under homestead farming system in humid tropics are evolved. A video film on recommended practices of scientific water management for plantation crops is also made.

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APPENDICES

Appendix-1: List of progressive farmers covered under the study

Sl.No.	Name	Address	Phone No.
KASARGODE DISTRICT			
1	Ms. Lissy Abraham	Attupuram house, Nr.Railway rest house, Nileswaram Post, Kasargode	0467- 2283148
2	Shri.Yusaf Haji	Shareefa Mansil, Kanhangad kadappuram, Kanhangad Post, Kasargode	0467- 2202546- Res & 2207995
3	Shri. A Kunhabdulla	Valappady, Kaalichanadukkam Post, Nileswaram, Kasargode	0467- 2256196
4	Shri.Kuruvila	Anchukandam, Konnakkad Post, Parappa via, Kanhangad, Kasargode- 671 533	0467- 2249058
5	Shri.K.J Mathachan	Kaduthodil house, Maalakkallu Post, Rajapuramvia,Kanhangad Kasargode	0467 2226736, 944608936
6	Shri.Sebastian P. Augastine	Palamattam house Bheemanady Post, Kasarkkode- 671314	0467 2241343, 2241725, 9447347041
7	Shri. Johny T.J	Thengupallyl house Rajapuram Post, Kanhangad, Kasargode	0467 2224045, 9446775015
8	Shri.G.S Gulmuhammed	Gulsthan, Near Padanna Panchayath Office, Cheruvathoor, Kasargode	0467 2276465, 9447176465

KANNUR DISTRICT			
9	Shri.V.P Koran	Puthoor, Kozhummal Post, Karivallur via, Payyannur, Kannur	04985- 260256
10	Shri.Sunny George	Elamthurithiyil, Prappoyil Post, Cherupuzha, Cheruppadavu, Kannur- 670 511	04985- 232188
11	Shri.P Muhammed	Kayakkad estate, Thillanery Post, Irutty, Kannur	0490- 2405212, 9447470218
12	Shri.K. V Gopy	Anjanam, Pathyrayadu Post, Thalassery, Kannur- 670 741	0490 2385286, 9447644358
WAYANAD DISTRICT			
13	Shri.Abdul Latheef	Bee Yem estate, Nr.MRF show room, Chundel Post, Wayanad- 673 123	04936- 203430
14	Shri.T.R Peethambaran	Thandassery veedu, Valavayal Post, Munnanamkuzhy, Azheekkodan Nagar, Kenichira via, Meenangady	04936- 214694
15	Shri.K Krishnan	Kavumkunnu veedu, Kottarakkunnu Post, Vellamunda, Wayanad- 670 731	04935- 231911 (PP)
16	Shri.K Rarappan	Kunjothummal, Achooranam Post, Pozhuthana via, Wayanad	04936- 250138 (PP- Mr.Thomas)
17	Shri.Johny Patany	Patany Plantation, Nr.Kalpatta KSRTC garage, Wayanad	04936- 203532

18	Shri.Ajith Prasad	Maniyamkode Estate, Maniyamkode Post, Kalpatta North, Wayanad	04936-202480
19	Shri.M.P Chandhranadh	Rajagriha, Puliyarmala, Kalapatta North Post, Wayanad	9895172844 and 04936- 203532
20	Ms. Shanthy Swaroop	Shanthy Nikhethan, Kalapatta North Post, Wayanad	04936- 202742
21	Shri.Rathnakaran	Ratnakar house, Kalpatta North Post, Wayanad	04936-202427
22	Shri.Thomas	Ulakamthara, Achooranam Post, Pozhuthana via, Wayanad	04936- 250138
23	Shri.K.G. Anathanan Nair	Sunil Mandir, Kottanad Post, Meppadi, Wayanad	04936-282365
KOZHIKODE DISTRICT			
24	Shri.P.K Balakrishnan Nair	Parakkandy veedu, Vattoly basar Post, Balussery, Kozhikkode	0495- 264 2199- Res and 2642 458- (O)
25	Shri.Abraham Mathew	Kadukkammackal veedu, Kallanode Post, Kakkayam via, Kozhikkode	0496- 2660310
26	Shri.P.K.Bhaskara Raja	“Sree Raj”, Kannadipoyil, Balussery, Kozhikkode	0496- 2644438
27	Shri.P.T Joseph	Puthottu house, Mattanode Post, Kayanna, Koorachundu, Kozhikkode	0495- 2659527
28	Shri.K.J Joseph	Kanjirathinkal veedu, Kunduthode Post, Kavilumpara, Kozhikkode- 673 513	0496- 2566815

29	Shri.T.V Joseph	Thakarappullil, Vayalada Post, Unnikulam via, Kozhikkode	0496- 2643832
30	Shri.E.G. William	Ambattu house, Kodanchery Post Kozhikkode- 673 580	0495- 2236355, 9447275732
31	Shri.M.A Francis	Mangalappilli house, Shandhi Nagar Post, Pachakkad, Kozhikkode- 673 573	0495- 225 4185
MALAPPAURAM DISTRICT			
32	Shri.P.K.Kunnjhu Muhammed Haji	Kottancharil house, Olakkara Post, Thirurangadi via Malappuram- 676 306	0494 - 2490339
33	Shri.C.P.Aboobacker	Pattathil, Chettiyanparambu house Thalakkadathur (North), Ovungal, Tirur, Malappuram-676 103	0494-22587127
34	Shri. P.Ramachandran	Kallingalthody, B.K.Road, Nilambur Post, Malappuram	04931- 222159
35	Shri. Veeran Haji	Thiruthiyattu House, Kolathur, Neetani – Kondotty, Malappuram	0483 - 2713338
36	Shri. M.P.Abraham	Mundukottackal House, Chulliode Post, Nilambur, Malappuram	04931-260445
37	Shri. T.P Velayudhan	Thuppayi Parambil, Ozhoor Post, Tanur, Malappuram- 676 313	0494 - 2444005
38	Shri. T.V Thomas	Vettath house, Vethilappara Post, Areekkode, Malappuram	0483- 2759118

39	Shri. K.M.Divakaran Nair	Kallolikkal House, Marutha Post, Manimooli via, Nilambur, Malappuram	04931-287302
40	Ms. Mary Mathew	Maruthanamkuzhi, Pookottumana Post, Nilambur, Malappuram	04931-240363
41	Shri. P.M. Ilias Aroor	Aroor, Olavatoor Post, Kondotty Via , Malappuram – 673 638	0483 – 28301018, 9895254273
42	Shri. Mathew	Panamkayam Estate, Uppada, Chungathara, Nilambur, Malappuram	04931- 240297, 534535, 9447180535 (Manger's mobile)
43	Shri. Jose thomas	Maramattathil, Nilambur Post, Malappuram	04931-223356
44	Shri. N.Balakrishnan	Nerthethil House Thrikannapuram Thavanoor Via, Malappuram	0494 - 2687065
45	Dr. Velayudhan K.P	Karumathazhathu parambil, SukapuramPost, Edappal Via, Malappuram 679 576	0494 2681388
PALAKKAD DISTRICT			
46	Shri. K.J Xavier	Kallolil, Cheenikkapara, Palakkayam Post, Mannarkkad, Palakkad	04924- 256341- Res 256214-(S)
47	Shri. K.K Sooryanarayanan	Kakkottil, Thenoor Post, Paraly, Palakkad	0491- 2856117

48	Shri. K Koran	Janasree estate, Puthukkad, Karimba Post Mannarkkad, Palakkad	04924- 240091
49	Shri. Mani Varghees	Azhakedath, Dhoni Post, Olavakkode, Palakkad- 678 009	0491- 2555601
50	Ms. C.P Goury	Cholamana, Kuttanassery, Muriankanny Post, Sreekrishnapuram, Palakkad	0466- 2285556
51	Shri. K.P Sivaramakrishna Iyar	Kottingalmadam, Kalloor Post, Keralassery via. Palakkad- 678 641	0491- 2840657
52	Shri. M.T Joseph	Mukalel, Machamthode, Thachampara, Mannarkad, Palakkad	04924- 240369
53	Shri. Varghees K Thomas	Koodethinalil house, Canaan Estate, Kolakkode, Paruvassery Post, Kannambra via, Palakkad	0492- 2255293
54	Shri. Denny Manual	Thengumpillil, Elavampadam Post, Velambuzha, Vadakkenchery, Palakkad	0492- 2268240
55	Shri. Kesavan Namboodiri	Mundurkaramana, Kundalasserry Post, Pathiryppala, Palakkad	0491- 2845396
56	Shri. K.C Kuriakkose	Kureechirayil, Kottappara Post, Cheerakuzhy, Mannarkkad,Palakkad 679 518	0466 2266064, 2208185
57	Shri. K. Mohanan	Polanikkalam, Thathamangalam Post, Palakkad 678 102	04923 227270, 9447533969

THRISSUR DISTRICT			
58	Shri. T.M Pavithran	Kerakesary, Thachampully house, Engandiyur Post, Thrissur- 680 615	0487- 2290314
59	Shri. P.K Sashindran	Parayil veedu, Engakad Post, Agamala, Wadakaanchery, Thrissur	04884- 234632
60	Shri. James Poulose	Anikootathil veedu, Amalur, Elanad Post, Chelakkara via, Thrissur	04884- 287016
61	Shri. T.K Aravindhakshan	Thachampully house, Thrithalloor Post, Chavakkad, Thrissur	0487- 2290990
62	George Zacharia	Srakath, Ponnukunnu estate, Erumappetty, Nelluvayal, Thrissur	04885- 263573 & 944723783
63	Shri. V.K Pathmanabhan	Vadakkekkara house, Kadangode Post, Erumappetty, Thrissur	04885- 263017
64	Shri. T.V Sebastian	Thannikkakuzhiyil, Kattylappoovam Post, Thrissur- 680 028	0487- 2694474
65	Ms. Soumini Kunjunny	Melepurath veedu, Chiramangad Post Marathangode, Thrissur	0488- 5280577
66	Shri. V.S Gangatharan	Vattapparambil, Pathazhakkad Post, Kodungalloor, Thrissur- 680 665	0480- 2850375
TRIVANDRUM DISTRICT			
67	Shri. Roman. V	Kuzhiyamvila Veedu, Kaakkamoola, Kalliyur Post, Trivandrum 695 042	0471 2403873

68	Shri. Salim	Santhosh Bavan, Kanchampazhinji Post, Poovar via, Trivandrum 695 525	0471 2213580
69	Shri. Gopinathan Nair	Manimandiram, Opp. Block office, Povathoor Post, Nedumangad, Trivandrum 695 561	0472 -2812142
ALAPPUZHA DISTRICT			
70	Shri.T.P.Jacob	Tharamekkalam House, Kavalam PO. PIN 688506	0477-2747510
ERNAKULAM DISTRICT			
71	Shri. Jose V Arancheril	Arancheril, Thirumarady PO, Koothattukulam 686662 , Ernakulam	0485-2875412
72	Shri. Sajimon C Kurien	Chettiyamkudiyil, Pothanikkad PO, Moovattupuzha Ernakulam 686671	0485-2562678
73	Shri. Varkey Ouseph	Mattathil Veedu, Nellau PO, Ernakulam dist. Pin-686721	0484-2767191
IDUKKI DISTRICT			
74	Shri. Sabu Vargheese	Vanderkunnel, Valiya Thovaala, Pin - 685510	04868-276229
75	Shri. Vakkachan Palluruthil M	Palluruthil Mukkulam East PO, Koottichal (via) Pin – 686514	0482 8286191

76	Shri. Vijayan E K	Ennaseril, Swaraj Thoppipala P.O, Pin - 685511	04868-271248
KOTTAYAM DISTRICT			
77	Shri. P J James	Peringattuplavil, Vaikkaprayar P O, Kottayam	04829-222629
78	Shri. T B Rajagopal	Thevalaikkattu Veedu, Chirakkadavu P.O	04828-228821
79	Shri. Thomas Joseph	Naduvidedathu Panthamakkal, Kootrappalli PO Karukachaal, Changanasseri	0481-2488008
KOLLAM DISTRICT			
80	Shri. D Kochunnunni	Karimpinam Poyyayilveedu, Thekketteri, Pattazhi, Kollam-691522	0475-2399735
81	Shri. Gopinathan Pillai	Shiji Mandiram, Thazham Thekku, Chathannoor	0474-2059188
82	Shri.P A George	Akamuttathu Punnanmoottil, Govt. Hospital Road, Pathanapuram P O.	0475-2351919
83	Shri. Veenadharan Vaidyar	Kochuveedu, Melkulangara, Wayaikkal PO., Kottarakkara, Kollam.	0474-2470483
84	Shri.G Prabhakaran Pilla	Kalpalathinkal veedu, Elambal P O, Punaloor 691322	0475-2322887
85	Shri.M Rajkumar	Padma vilasam, Edathara, Kadaikkal PO	0474-2422788
86	Shri.Parameswaran Unnithan	Wariya Veedu, Chathannoor PO.	0474-2591195

87	Shri. George Vellapally	Varoorpoika, Thekkemuri, Kizhakkekallada-691502	0474-2587185
88	Shri.N Nirmalanandan	Rohini, Temple Road, Kadaikkal PO	0474-2422481
89	Shri.V Vasudevan Namboodiri	Avaneeswarathumadam, Panthaplavu PO, Pattazhi, 691522	0475-2354412
PATHANAMTHITTA			
90	Shri. K.Thankappan	Ponmedethu Thekkethil Veedu, Thumpaman, KeerukkuzhiPO, Pathanamthitta	0473-267026
91	Shri. D.Nalinakshan	Ushas, Angadikkal South (PO), Kodumon, Pathanamthitta Pin 691555	04734285544

Appendix 2: Questionnaire

Centre for Water Resources Development and Management

Kunnamangalam, Kozhikode

INCID-funded project on 'Documentation and analysis of farmers' practices on water management of plantation crops'

Questionnaire

1) Name of the Farmer :

2) Address with pin code :

3) Phone No. with area code:

4) Survey No. & Village :

5) Panchayath & C.D.Block :

6) Taluk & District :

7) Family details:

Name	Sex	Age	Education	Occupation		Income	
				Primary	Secondary	Monthly	Annual

8) Amenities (Tick mark):

a) Type of house: *Kacha*/ Tile roof/ Concrete roof/ Two-storied/ Posh

b) Household articles possessed: TV/ Fridge/ Washing machine/ L-phone/ Mob. phone

c) Type of vehicles: Scooter/ Motor cycle/ Car (make)/ Lorry/ Tractor/ Others

d) Newspapers & magazines subscribed:

9) Land resources:

Total area owned (ha)	Cultivated area (ha)	Garden land (ha)	Wet land (ha)

a) Topography & slope category:

b) Type of soil & fertility status:

10) Cropping pattern / systems (with details)

a) Mono cropping:

b) Mixed cropping (give details):

c) Any other (give details):

11) Crops cultivated:

Crops	Area (ha) / No. of plants	Variety	No. of plants		Av. yield (kg/ha or no./palm)
			Bearing	Non-bearing	

12) Water Management practices:

13)

a) Source of water (tick mark): Wells, Canals, Ponds, Others

b) Whether perennial or seasonal:

c) Depth to water table (in summer):

d) Irrigation Methods:

Crops	Age of the crop	Area irrig-ated (ha)	Irrigat-ion meth-od	Reason for adoption of this method	Year of start of irrgn.	Whether irrgn. continued uninterruptedly. If no, why?	Irrigat-ion Interval (days)	Qty. of water used per plant

d) Cost of installation of irrigation system (method-wise):

e) Operation and maintenance cost of the system per year:

f) Financial assistance received and the source:

g) Increase in yield (crop-wise):
(in quantitative & monetary terms)

h) Problems faced, if any:

13) Soil and water conservation measures followed (tick mark and give details):

SWC measure	Crop	Area (ha)/ No. of plants	% of total area	Year of adoption	Frequency of maintenance	Reasons for adoption
Contour bunds (stone pitched/ earthen)						
Contour farming						
Strip/ platform terracing						
Trenches/ Pits						
Strip cropping						
Circular basins						

Husk burial						
Cover cropping						
Use of compost, FYM, etc						
Mulching						
Vegetative hedges/ barriers						
Summer ploughing						
Green manure cropping						
Others						

a) Financial assistance received for SWC measures and the source:

14) Extension advisory services being received:

15) Recognitions received:

16) Cost of cultivation of crops per ha (Rs.):

Item of expenditure	Coconut	Arecanut	Rubber	Coffee		
a) No. of plants						
I) Initial land preparation						
a) Clearing the land						
b) Land development (SWC)						
c) Planting pits						
d) Planting material						

II) Recurring cost a) Manuring						
Items						
Qty/plt/yr						
Total Cost(Rs)						
Application cost						
b) Fertilizer Items						
Qty/plt/yr						
Total Cost(Rs)						
Application cost						
c) Inter-cultural operations						
i) Ploughing						
ii) Weeding						
iii) Basin opening						
iv) Rain pits						
d) Plant Protection						
e) Irrigation a) Fuel b) Labour						
f) Harvesting						
g) Processing						
h) Marketing						
i) Miscellaneous (Specify)						
Total						

17) Income from crops:

Crops	Area (ha) / No. of plants	Qty. of produ-ce	Value (Rs)	Qty. of bye product	Value (Rs)	Gross Income (Rs)	Expend-iture/ha (Rs)	Net returns/ha (Rs)

18) Credit & indebtedness / benefits (details) :

19) Agrl. (including water management) problems faced and suggested solutions:

20) Other subsidiary activities:

Activity	Extent / No. of animals or birds	Gross returns (Rs)	Expenditure (Rs)	Net returns (Rs)
Dairying				
Fish Farming				
Poultry Farming				
Pig rearing				
Others (specify)				

21) Whether other farmers have visited the plot for advice (details):

22) Whether other farmers have adopted practices based on their visit to the plot (details):

23) Brief description on the activities being followed by the farmer (attach, if needed):

24) List of items for video documentation / needing further study (attach, if needed):

25) Traditional knowledge/ practices on related aspects (attach, if needed):

26) Personal Assessment (health of plants, yield status, truthfulness of statements)

27) Shortest route to the plot

Date: Data collected by: Signature: