A Bird's Eyeview through Theses on Soils of Kerala (1958 - 2015)

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FOREWORD

The 68th UN General Assembly declared 2015 as International Year of Soils (IYS). The UN drives home the relevance of soil health for achieving global food and nutritional security and in eco-system functioning. The main agenda of IYS is to create awareness on the fundamental roles of soils for human welfare, to sensitize decision makers towards formulation of effective policies for sustainable management, protection of soil resources and enhance capacities and systems for collection of soil information and monitoring.

The KAU is committed to the development and promotion of sustainable soil and land management practices so as to ensure a productive food system and thereby improve livelihoods while ensuring a green, healthy environment. Soil is not only the basis of our biological wealth and agriculture, but is also essential for the production of many goods that we use daily for food, shelter and clothing like processed food materials, wood, paper, cotton, cement, paints, iron and steel, bricks etc. No other pursuit of natural resources has contributed to the welfare and sustenance of the whole mankind to the extent as soil does. The University has been in the forefront to generate bench mark data and knowledge on the Soils of Kerala'. The knowledge pool created by our soil scientists is helping our farmers, scientists, planners and the Government in adopting strategies for protecting soil health and improving productivity. I understand that the compilers of this publication have taken necessary efforts to showcase the research efforts of the university from 1958-2015 in soils and had classified the findings under different soil groups of Kerala for ready reference.

I congratulate the Director of Research, Associate Directors of Research, and the team of soil scientists for this useful compilation and presentation of the research findings. I am confident that this will be a valuable reference material for the research scholars and scientists interested in Soil sciences.

Prof. (Dr.) P. Rajendran
Vice Chancellor
Kerala Agricultural University
Vellanikkara.

PREFACE

The diverse type of soils in State of Kerala present a unique scenario that is seldom observed within a short geographic limit. Another appreciable feature is the high number of research projects and contributions made on soils due to the tireless efforts of scientist in the field both past and present. Some of the pioneering works like those on acid sulphate and laterite soils have also come from this tiny State. The large volumes of work needs to be properly documented so that the volume of aknowledge generated both published and unpublished are available on a common platform.

It is in this line that the earnest efforts taken by Dr. P. K. Sushama, Professor & Head, Dept. of Soil Science & Agricultural Chemistry, College of Horticulture; Dr. Sumam Susan Varghese, Professor & Head, Dept. of Soil Science & Agricultural Chemistry, College of Agriculture, vellayani & Dr. A. K. Sreelatha, Assistant Professor, Rice Research Station, Vyttila are to be complemented. Firstly, the research contributions are made open to all, secondly, it is available at a glance or a click and most importantly it will prevent duplication and thereby save precious time, energy and money.

I plan on record my deep admiration for the sincere work undertaken and also hope that this efforts opens the eyes of scientist in other disciplines and faculty.

Dr. Sajan Kurian
Director of Research
Kerala Agricultural University
Vellanikkara,
Thrissur

A Bird's Eye View through Theses on Soils of Kerala- A Prelude

This is our humble effort in the "International Year of Soils-2015". We tried our best to document and catalogue all the theses of Soil science & Agricultural Chemistry available in our departments at all the Agricultural Colleges of Kerala Agricultural University, different college libraries and central library. Some of our efforts failed owing to the non availability of certain theses and so we could not include all the abstracts according to their relevance and importance. Again, the soils of Kerala are being categorized under different headings according to the maps included. We cautiously followed this manner just for convenience and also most of our theses are earlier works which made use of the earlier soil classification. However we have included the recent soil classification which is based on the Agro ecology of Kerala.

We are deeply indebted to Dr. P. Rajendran , Honorable Vice Chancellor, KAU, who blessed us by writing a commendable foreword for this publication. Grateful acknowledgement is also made to Dr.Sajan Kurien, Director of Research, KAU for the valuable help rendered by him. Our heartfelt gratitude to Dr. I. Johnkutty former Director of Research, and Dr. Jim Thomas, Associate Director of Research who gave the green signal for publishing this document from the Directorate of Research, KAU. The Heads of all the institution of KAU deserves special thanks for the needful help rendered.

We sincerely acknowledge the compilations such as 'A glimpse to problems soils of Kerala' 'Thesis abstracts in Soil Science and Agricultural Chemistry' and 'Three decades of Soil Research. These forerunning publications really helped us and we profusely thank the authors of these forerunners. We are also grateful to all the staff members and Post Graduate students of the Dept. of SS & AC in the three colleges for the many courtesies extended.

In this occasion we sincerely remember the contributions made by the former Heads of Department of SS& AC at each college for their dynamic leadership in the execution of different research projects. We extend our heartfelt appreciation to all soil scientists who paved the way to strengthen the soil science research in Kerala.

Let us place our deep sense of gratitude to Dr.S.Sindhu, Teaching Assistant of the Dept. of Soil Science & Agricultural Chemistry, College of Horticulture for the valuable help extended by her for bringing the publication in this particular layout and design. We appreciate comments concerning shortcomings and errors that we could attempt to rectify in the next edition.

Compilers

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1. Soils of Kerala - A brief outline

Kerala state, occupying the south western corner of Indian peninsula, is located between 8°18' to12°48' north latitude and 74°52' to 77°22' east longitude with an area of 38,864 km^2. The state has a long coastal line of 560 km and width ranging from 11 km to 124 km.

Physiography

The state is divided into three distinct parallel regions, i) the highland (above 75 fom MSl, ii) the midland (7.5 to 75 m above MSl and iii) the lowland (below 7.5 m from msl). Out of the total geographical area of the state, 10.2 percent constitutes lowland, 41.8 percent midland and 48 percent highland region.

Geology

The region is occupied by four major rock formations namely, crystalline rocks of Precambrian age, sedimentary rocks of Tertiary age, laterites capping the crystalline and sedimentary rocks and recent and sub recent sediments forming low lying areas and river valleys.

Climate

The state has a humid tropical climate with two predominant rainy season caused by south-west monsoon and northeast monsoon. The mean annual rainfall is 3000 mm. The annual average ambient temperature is 27.5 °C and the relative humidity varies from 70 to 95 per cent.

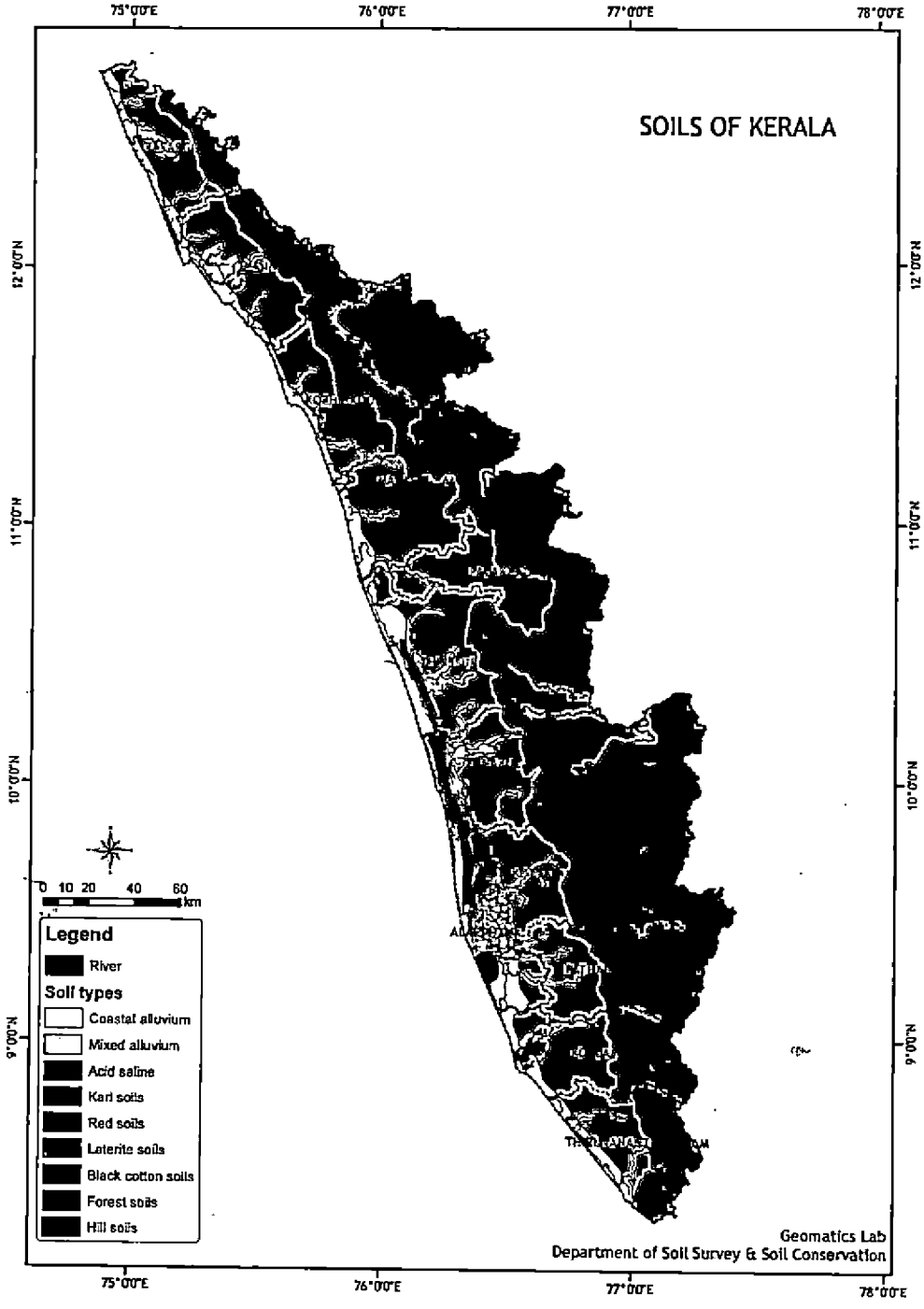
Genesis of soils of Kerala

Climate and topography appear to be the most dominant soil forming factors in Kerala. The soils of Kerala are developed under humid tropical climate with high rainfall and under varying degree of moisture regimes and dry period. On the basis of the morphological features and physicochemical properties, the soils of the State have been classified by the Department of soil survey and soil conservation into coastal and mixed alluvium, acid saline and Kari soils, red soils, laterite soils, black cotton soils, forest and hill soils. Majority of the area under these soils is extremely acidic to moderately acidic (3.5 to 6.0) with low in organic matter content, Cation Exchange Capacity (CEC) and water holding capacity. The exceptions are neutral to

slightly alkaline soils of dry hill areas of Idukki, Attappadi and the black cotton soils of Chittur taluk in Palakkad.

Laterization is the predominant soil forming process. The process is characterized by the leaching (eluviation) of bases (Na, K, Ca, and Mg), silica and organic matter due to high rain fall (3000 mm) with susequent accumulation of sesquioxides of Al, Fe and to some extent Mn. The net effect is formation of soils with dominance of low activity kaolinitic clay with the lowest possible CEC, low organic matter content and high acidity.

The soils in general are low to medium in organic carbon, and hence in nitrogen, high in P due to continuous application of P fertilizers which are being fixed and accumulated and low in K. Severe deficiency of Ca (45 per cent) and Mg (80 per cent) are observed. Sulphur deficiency is seen in about less than 5 percent soils. The content of Fe and Mn are abundant in plant available form which is to the tune of toxic levels in wet lands submerged with water. Zinc deficiency is to the extent of 15 per cent. Deficiency of copper is usually less and its level is sufficient in soils where Cu based fungicides are used especially under plantations like rubber, cardamom, pepper etc. Boron deficiency is severe and wide spread (65 per cent) and symptoms are common in banana, coconut, areca nut, nutmeg, cabbage and cauliflower as well as in rice.

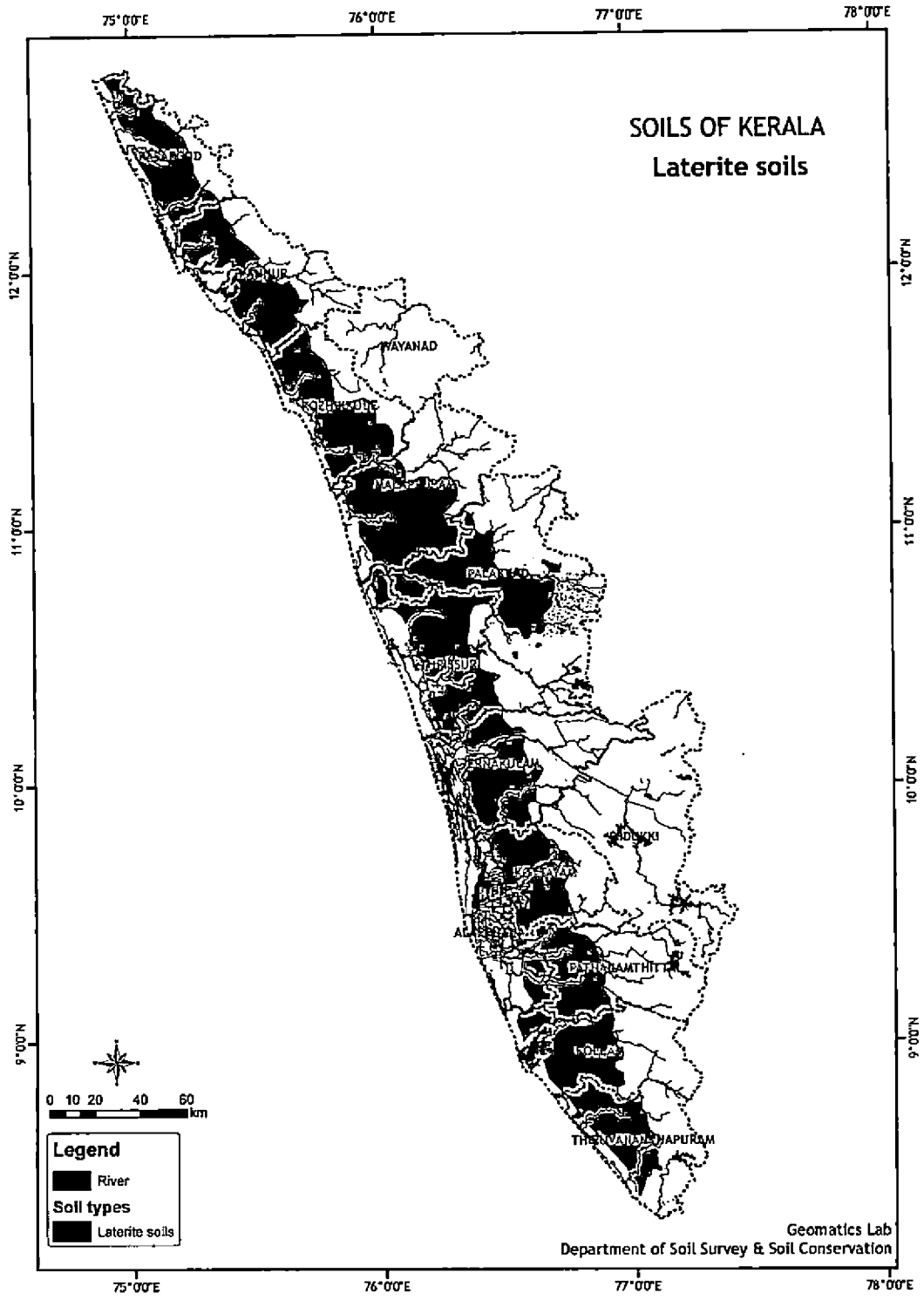

SOILS OF KERALA
75°00'E
76°00'E
77°00'E
78°00'E
12°00'N
11°00'N
10°00'N
9°00'N
0 10 20 40 60
km
Legend
River
Soil types
Coastal alluvium
Mixed alluvium
Acid saline
Kari soils
Red soils
Laterite soils
Black cotton soils
Forest soils
Hill soils
Geomatics Lab
Department of Soil Survey & Soil Conservation

2. Laterite soils

Laterite and lateritic soil are the weathering products of rock in which several courses of weathering and mineral transformations take place. This involves removal of bases and substantial loss of combined silica of primary minerals. In laterite and lateritic soils, acidity of rocks, induration and zonation are more pronounced. This induration is greater if the iron content is higher. These soils mainly occur in the midlands and part of lowlands at an elevation of 10 to 100 m above MSL as a strip between the coastal belt and hilly mid upland. The area comprises of mounds and low hills with gentle to steep slopes. Laterite soils are generally suitable for most of the dryland crops. It is mainly cultivated with coconut, arecanut, banana, tapioca, vegetables, yams, pepper, pineapple and fruit trees. The percentage of gravel content in the soil and reduced soil depth limits the choice of crops. In laterite outcropped area with shallow soils, only cashew and vegetables can be grown.

Area and distribution

The important soil types in the Madakkathara panchayat were lateritic soil, variable shallow soils, colluvial soils, riverine aluvium and forest loam soils. The spatial extent of their distribution revealed that lateritic soil dominated the panchayat in spread. The contours of the panchayat ranged from 20 m above mean sea level to 320 m above mean sea level. The digital terrain model (DTM) of the panchayat was created using the Geographic Information System (GIS) and was used to delineate the Kachithode Kothara watershed. The watershed consisted of a perennial dam and streams contributing water to the dam. Water drained through several first order and second order streams in the watershed. The main stream of the watershed was non perennial and drains the overflow water of the dam during monsoon to Kallayi thodu. The soil of the watershed is a member of the fine, mixed, iso hyperthermic family of typic Kandiustalfs. The soil of the watershed was acidic in reaction with the pH ranging from 5.0 to 5.2 in different horizons of the profile. The water availability of the water shed was low in the upper areas of the watershed due to the fact that the settlements were higher than the dam. The upper reaches of water shed being hilly, faces the threat of soil erosion due to the mixed cropping of erosion permiting crops. So, it was concluded that micro level data integration is needed for arriving at various decisions for integrated resource utilisation in the Panchayat and the study reported has resulted in a functional GIS that can be


SOILS OF KERALA
Laterite soils
75°00'E
76°00'E
77°00'E
78°00'E
12°00'N
11°00'N
10°00'N
9°00'N
WAYANAD
0 10 20 40 60
km
Legend
River
Soil types
Laterite soils
Geomatics Lab
Department of Soil Survey & Soil Conservation

effectively used by all those interested in agricultural and overall development of Madakkathara Panchayat and Kachithode Kothara watershed. (Anup Balakrishnan, 2005).

Genesis, morphology and general characteristics

According to Koshy, M.M. (1962) the laterite formation, both sedimentary and residual can be the secondary parent material for the formation of other soil groups.

Fertility investigations of laterite soils revealed that the upland soils contain a higher percentage of the coarser fractions, lower percentages of total and available P and available K than the corresponding low land soils. Their base status is also lower. The lime requirement values of the low land soils are higher than that of the upland soils. However, water logging the low land lateritic alluvium for 10 days to stimulate field conditions results in an increase in available N, available P and available K to the extent of 10- 15 percent and a decrease in the lime requirement values. Results revealed that CEC, exchangeable cations and organic matter, total and available nutrients were low in laterite soils (Hassan. M. A, 1976).

Laterite possess the characteristics plinthite horizons of varying depth and consistency which were absent in red soil profile. Laterite soils had better aggregation, water retention capacity and other physical properties than red soils. The laterite soils were more weathered than red soils. Laterite and red soil profiles of Pilicode are aluminous but soils of Varkala and Pachallur are ferruginous and siliceous respectively. The laterite soils were slightly more acidic, had lower organic carbon content, C/N ratio, total N,P,K, Ca and Mg, C.E.C and exchangeable cations than the red soils.Total Fe_2O_3 and Al_2O_3 were more in the laterite than in the red soil (Subramonia Iyer, M., 1978).

Pedological investigations on lateritic catenary sequences in Kerala revealed that a striking gradation in colour ranging from red to brown and finally different shades of grey was noted on descending the toposequence fom crest to valley and a decrease in coarse fragments downslope. Kaolinite was found to be the dominant clay mineral in the clay fraction of these soils (Venugopal, V. K., 1980).

In another study, twelve specific geoclimatic locations representing the coastal, midland and highland regions with varying elevations, moisture regimes and different vegetation were selected. The locations were

a. Coastal : Vellayani, Varkala, Thrippunithura, Calicut
b. Midland : Neyyattinkara, Valakom, Perumbavoor, Angadipuram
c. Highland : Vazhichal, Aryankavu, Deviculam, Vythiri

These geoclimatic locations had unique features with regard to their pedogenic environment, the effects of which were reflected in the characteristics of the pedons. Studies on the genesis, morphology and physico chemical properties of laterite soils of Kerala revealed that all the coastal and midland locations come under the order Oxisols and those of highland locations belong to Ultisol.The colour vaied from reddish brown to dark brown and the structure varied from honey comb to vermicular (Thomas Varghese,1981).

The vesicular nature of plinthite clay was observed at Varkala upland, are typical of Kerala laterite. The vesicles were mainly constituted of crystallized iron compounds with the content inside the vesicles, mainly aluminiferous. The study explained the pedological process during the accumulation of aluminiferous materials at a point of separation of plinthitic layer to the lower non-plinthitic layer (Sankarankutty Nair, 1984).

An investigation on the root activity pattern of black pepper vine (variety Panniyur I) and allied aspects was conducted to determine, 1) the soil zone of maximum nutrient absorption by the vines trailed on erythrina and teak poles, 2) to assess the root density of erythrina in the rizhosphere of black pepper, 3) to evaluate the root competition between the vine and the live standard for applied P and 4) to compare the nutrient removal by the vine and erythrina and also to examine whether the climbing roots of the vine are capable of nutrient absorption. The results indicated that fertilizer application in black pepper gardens must be restricted to a semicircle of radius 30 cm facing the vine irrespective of the type of standard for the maximum utilization of the added inputs. Growing the vine in association with erythrina as support was found to reduce the uptake of ^{32}P by at least 20 percent as compared to that grown on teak pole (Jayasree Sankar.S, 1985).

A study was conducted using seven selected profiles of Oxisols and Ultisols representing the important pedological units with a wide geographical distribution in Kerala so as to understand the electro-chemical behaviour of these soils. A laboratory study with thirty six samples from seven profiles representing six Ultisols and one Oxisol had been carried out. Path coefficient analysis of important contributing factors against two parameters, for measurement of charge and the inter-relationship of 15 soil characters showed that organic matter, clay per cent, R_2O_3 per cent, Aluminum oxide and Iron oxide were found to be the major factors that controlled the surface charge behaviour of the soils. The studied factors explained only 55 percent and 48 percent of the variability of cation exchange and anion exchange respectively. The titration curves at different ionic strengths crossed at the common point of intersection, the zero-point of charge (ZPC). The zpc for the surface horizons was found to be lower than the sub-surface horizons in all the

soils studied. Soil to soil variation in ZPC between surface and sub-surface horizons were more or less the same for all samples. Thus ZPC could not be recommended as a taxonomic tool in soil classification to distinguish Oxisols from Ultisols. From known values of surface area and ZPC of these soils, the values for net electric charge was calculated by the applica tion of the Gouy-Chapman model of double layer and was found to obey the theory only at acritical electrolyte concentration. Direct measurement of adsorption ofions from solutions of KCL, NaCl and $CaCl_2$ showed that the nature and valence of index cations also influenced the magnitude of the negative charges on the soil particles. On the basis of the influence of pH, electrolyte concentration and the valence of counter-ions on the electric charges of the soils most of the conventional methods of ion-exchange determinations using buffered electrolytes at high concentrations appears to be inappropriate for tropical soils. The traditional ammonium acetate method was found to give over estimations of CEC and thus very high values. Calcium chloride (0.002) M was found to be equally effective owing to the simplicity of the procedure, the former appeared better. The compulsive exchange method was free from the inherent defects of neutral normal ammonium acetate and hence would seem well suited for the Oxisols and Ultisols of Kerala. This was confirmed by different methods and was found in good agreement with the estimated theoretical results. However under field conditions the expression of this constituent was minimum and the variable charge components such as Iron and Aluminium oxides certainly controlled the electro-chemical characteristics. In a separate experiment to find out the contribution of organic matter and sesquioxides towards exchanges properties of soils, it was observed that about 64 percent of the negative sites and 8 percent of the positive was contributed from organic matter. Sesquioxides explained only 11 percent of the variablility in CEC and 22 percent of the variability in AEC. Mineralogical investigation revealed the presence of kaolinite as the dominant clay mineral. Appreciable amounts of smectities, quartz and gibbsite was also identified.The presence of smectities was not reflected in the CEC of any of the samples. (Rajendran, P., 1992).

An integrated, micromorphological, physical, chemical, mineralogical and micromorphological characterization and interpretation of soil gravels of the representative profiles of the major soil series of Trivandrum district namely Palode, Nedumangad, Varkala, Thonnackal and Trivandrum series were studied. All series except Thonnackal were gravel in nature. Palode, Varkala and Trivandrum series showed increased gravel content with depth but there was no specific profile pattern observed at Nedumangad and Thonnackal series whereas Palode series was unique with all the different gravel fractions (2 mm to 2.5 cm, 2.5 to 7.5 cm and 7.5 to 25 cm) with the presence of gneissic cobbles. The comparative gravel contribution to

available nitrogen content of the soil were in the increasing order Palode < Nedumangad < Thonnackal < Varkala < Trivandrum. The potential of gravels to supply nitrogen was 1/4th of the soil while in the case of potassium it was about 1 ½ to 2 times. For available phosphorus, it was in the order Nedumangad < Trivandrum < Varkala < Palode < Thonnackal. For exchangeable potassium it was in the order Nedumangad < Varkala < Trivandrum < Palode < Thonnackal. Higher total phosphorus and potassium content of gravels indicated that gravels are the potential source of phosphorus and potassium for crop production. Then, for exchangeable calcium, it was in the order Trivandrum < Varkala < Nedumangad < Palode < Thonnackal. The contribution of total calcium by gravels was about half the contribution by the respective soil while the mean contribution of total magnesium by both the soil and gravels were uniform throughout. Acid insoluble content of gravels were in the increasing order Varkala< Trivandrum < Nedumangad < Palode < Thonnackal. Acid solubility increased in fine fraction, in the order, Thonnackal< Varkala< Nedumangad < Palode < Trivandrum, while in the coarse fractions, the maximum content was reported in Varkala and the least by the Trivandrum series. Sequioxide and total iron content were in the increasing order Thonnackal < Palode< Nedumangad < Trivandrum < Varkala. Quartz content of the finger gravels were in the increasing order at Varkala < Nedumangad < Palode < Trivandrum <Thonnackal while those for coarse gravels were in the increasing order at Thonnackal < Varkala < Trivandrum < Nedumangad < Palode. The plinthite granules of the finer gravels were in the increasing order at Trivandrum < Thonnackal < Varkala < Palode < Nedumangad. Goethite content of gravels fraction was maximum at Nedumangad and least in the Thonnackal series. Investigations on the soil fine sand mineralogy revealed that the quartz content is increasing in the soils of Varkala < Trivandrum < Palode Nedumangad < Thonnackal. Plinthite gravels were observed only in the soil o fthese condhorizon of Varkala. Illmenite content increased in the order Palode < Varkala < Nedumangad < Thonnackal < Trivandrum (Suraj John, 1996).

Kerala Agricultural University is situated in Madakkathara panchayat in Thrissur district. It is having an area of about 380 ha in its main campus in Vellanikkara. A 1: 2000 scale map with a grid size of 80 m x 80 m was used to locate the sites of the western part of the campus. The particle size analysis of the soil samples revealed that most of the samples were sandy clay loam in nature where, in most of the soils, the texture was same for surface and subsurface samples. Most of the soil samples were acidic in nature. In the exchangeable complex, the order of concentrations of the ions were Ca > Mn > Na > K > Al > Fe. The potassium content was rated as low in 56 percent of the surface samples and 66 percent of subsurface samples. The cation exchange capacity of the soil was low since a good amount of cations were

leached off during the rainy season. The percentage base saturation was high. Percentage sodium saturation was higher than 15 per cent. Using the potential of GIS, the soil fertility map of the study area for the major parameters such as soil texture,. organic carbon, available P and K were prepared. The soil maps with FCC units super imposed would help in the delineating areas with similar limitations and management requirement. (Sajnanath, K, 2000).

From the detailed investigations on the physico-chemical characteristics related to hardening and softening of laterites, it was observed that hardening and softening of laterites have been affected by the land uses and great variation could be recorded for parameters like bulk density, clay content and movement, organic matter, water dispersible clay and iron content. The detailed studies on the pedological and management aspects of hardening and softening of laterites under different land use systems unveiled many intricate phenomena of these processes which are of great theoretical and practical importance. Contrary to the conventional concept that application of sodium chloride softened hard laterites, the study revealed the importance of amendments such as calcium silicate and application of cowdung and green manuring with leguminous crops such as sesbania in softening already hardened laterites. However, it was necessary to confirm the results of these in-vitro studies by adequate field studies in specific laterite tracts of Kerala state using these amendments. (Byju, G., 2000).

Another study was conducted in the main campus of Kerala Agricultural University, Vellanikkara with the objective of preparation of a detailed soil resource inventory covering the eastern part of the campus comprising an area of 214 ha which was divided into 25 blocks. An increase in organic carbon content with depth was observed in a few samples. Almost 91 percent of the surface and 90 percent of the sub surface samples analysed were medium in fertility, 7 percent each of the surface and sub surface samples were coming under high fertility class and the remaining 2 and 3 percent were low in organic carbon status. Available micronutrients namely manganese, zinc, copper, and iron were extracted using O.1M HCl and contents was in the order as Mn > Fe > Cu > Zn both in the case of surface and subsurface soil layers. Cation Exchange Capacity (CEC) of the soil ranged widely both in the case of surface and subsurface soils from about 1.5 to 8.0 cmol (P^{+}) kg^{-1}. Sodium saturation was observed as very high in the case of both surface and subsurface soils; in many cases exceeding 15 percent and not showing any sodicity due to low CEC and pH. The Eastern part of the campus has several limitations for crop production in terms of high graveliness, low CEC, high aluminium saturation, acidity, high P-fixing capacity, low K reserves, potential influences of Na in the exchange complex, ustic moisture regime and sloppy terrain (Seena. E., 2000).

A research work has been done to characterize the soils of Koiiyoor watershed of Thiruvananthapuram district using Geographic Information System (GIS) tools. In order to generate various thematic layers, cadastral maps (1:5000), toposheets (1:50000), DEM (ASTER-30 m) and satellite imageries of Google earth were used. The watershed was transected and soil samples were collected. The attribute data base, formulated using the results of chemical analysis of 174 soil samples was integrated into the GIS and various thematic maps were produced. The major outputs generated on the Koliyoor micro watershed were the rated fertility maps of organic carbon, available P, K, Ca, Mg, S, Fe, Cu, Mn, Zn and B. Maps showing the spatial variation of soil reaction, electrical conductivity, bulk density, water holding capacity, slope aspect and slope classes were also generated. Data of organic carbon content was used for rating of available N. Using the thematic layers of N, Available P and K, map showing NPK status also was generated. The data on soil resources of Koliyoor micro watershed were integrated in a GIS environment and thematic maps on all the parameters were generated. Spatial distribution of different classes of nutrients was used for fertility characterisation of the watershed (Appu M.G., 2012).

Nutrient dynamics

The coconut palms of two field experiments receiving different levels of K_2O and Na_2O, laid out at the Regional Agricultural Research Station, Pilicode, were made use of this study. The soil of the experiment site was laterite (Oxisols). The treatments were the substitution of K_2O (applied as KCl) and Na_2O (applied as NaCl) to the extent of 100, 75, 50, 25 and 0 per cent. In the first experiment, the fertilizer treatments were superimposed on 24-year-old palms, which were receiving N, P and K as per the recommended dose. The second experiment was in the newly planted seedlings and therefore the treatments were given to the newly planted seedlings from the very start of the experiment. The crop was rainfed. The soil and leaf samples were collected and analysed to find out the effect of sodium chloride on the uptake of nutrients and soil characteristics. The analysis of copra and quality evaluation of the oil were done only in the case of first experiment since the palm of the second experiment had not yet reached the steady bearing stage. From the observations, it was concluded that substitution of K_2O applied to the coconut palm as KCl, by Na_2O applied as NaCl to the extent of 50 percent was possible without a reduction in the yield, quality of oil and adverse effects of the soil characteristics, under the climatic and soil conditions of Pilicode (Prema, D., 1987).

A study was conducted during the first and second seasons to find out the seasonal variations in nutrient transformations in the existing two permanent manurial trials of rice (one with tall *indica* varieties and other with dwarf *indica*

varieties), which were started in 1961 and 1973 respectively at RARS, Pattambi. The experiments were laid out in RBD with four replications and eight treatments. The treatments consisted of application of entire quantity of N [90 Kg ha^{-1}, as organic alone (cattle manure alone, green manure alone and cattle manure + green manure)], inorganic alone (ammonium sulphate alone and NPK fertilizers) and combination of organics with inorganic (cattle manure + NPK fertilizers , green manure + NPK fertilizers and cattle manure + green manure + NPK fertilizers). For tall *indica* the dose of NPK applied is 40:20:20 Kg ha^{-1} whereas in the dwarf *indica* varieties the dose applied is 90:45:45 Kg ha^{-1}. Results of analysis of soil samples showed that significantly higher values of organic carbon, available N, P, K and Ca were recorded in the initial stages of crop growth namely transplanting, tillering and 50 percent flowering in the first crop season but the trend reversed in both the experiments in the second crop. In the grain, significantly higher content of N, P, K and Mg were recorded in the second season. There was not much difference in the P content between the seasons. A similar trend was noticed in the nutrient content of the both tall and dwarf *indica* varieties except for Ca (Dineshkumar, K.K., 1996).

Palmarosa, *Cymbopogon martinii* (Stampf) var. motia is an important essential oil crop grown commercially in various states of peninsular India. Comparison of the methods of hydrolysis revealed that in terms of geraniol content of the product, geraniol yield from the process and time required for the reaction, the aqueous sodium hydroxide method was found to be the best. The efficiency of the method for quality upqradation was tested on essential oils of different Cymbopogon types viz., ODP-1, ODP-3, C-3, OD-455 and Jamrosa. All the oils were characterised by low level of geraniol and high level of geranyl acetate and none of them conformed with ISI specifications for palmarosa oil. In case of all the oils, the treatment resulted in complete conversion of geranyl acetate to geraniol with commensurate increase in the level of geraniol, bringing about a vast increase in their quality. By the process, oils of ODP-3 and Jamrosa were upgraded to meet the specifications for palmarosa oil. Verification of the sodium hydroxide hydrolysis method on pilot plant scale showed that it can be employed on large scale for the quality improvement of palmarosa oils which contain appreciable amount of geranyl acetate (Mullakoya C P. 1997).

The efficiency of phosphobacterin (PB) culture, in increasing the availability of phosphorus from MRP and the resultant effect on the growth and yield ofbanana, cv. Nendran was evaluated by conducting laboratory incubation and field studies at FSRS, Kottarakkara during 1993-96. It was concluded that for increasing the efficiency of utilization of applied P to banana in the acidic laterite soils, a combined application of MRP and PB along with FYM and mulch was found to be essential.

This package was found to be very effective in increasing the available- P status of soil by promoting plant growth and increasing the yield of banana with a lower level of P than recommended. For achieving a higher net return from banana cultivation along with other inputs like FYM and mulch, the use of 3/4 level of P and PB inoculation must be considered as a viable alternative to general recommendation in the package of practices of KAU (Shehana R. S, 1997).

A study was conducted at College of Horticulture, Vellanikkara, during the period 1993-95 so as to assess the suitability of Tunisia rockphosphate (TRP) for direct application in acid rice soils of Kerala as a source of P compared with single superphosphate (SSP) diammonium phosphate (DAP) and Mussoorie rockphosphate (MRP). Comparing the two extractants, Mathew's triacid extracted more available P than that of Bray solution in both soil types. In general, Kuttanad alluvium recorded higher content of available nutrient as compared to laterite. The extent of fixation of P was higher in Kuttanad soil with Fe-P as dominant fraction while in laterite soil it was Al-P which was dominated. Of the different soils Kuttanad alluvium registered a higher yield compared to laterite soil. It was found that TRP registered a comparable uptake of phosphorus and gave a comparable yield of grain and straw with other sources in laterite and Kuttanad alluvium. The residual effectiveness of rockphosphate was found to be higher than that of water soluble sources and TRP gave the highest. Of the two different types of soils Kuttanad soil showed a higher residual effectivenes and resulted in higher yield for 2nd crop while laterite soil registered a lower yield (Santhoshkumar. V.C, 1997).

Rock phosphate sources collected from different locations were analysed for both phosphorus content and heavy metals namely cadmium and lead. Those sources which analysed relatively higher content of heavy metals were included for conducting a pot culture experiment using chilli (*Capsicum annuum* L.) as test crop. To derive meaningful comparison in the study, partially acidulated rock phosphates as well as direct water soluble source of cadmium and lead were also applied to assess their bioavailability to plants. The influence of organic matter when applied alone or in conjunction with heavy doses of heavy metals was also assessed in the study. The pot culture experiment was conducted in the Vegetable Research Farm, Department of Olericulture, Vellanikkara during the kharif season of 1996, with chilli as the test crop. The entire fertilizer management was based on package of practice (N, P and K at 70, 40 and 25 kg ha^{-1}) recommendation. Five different sources of P selected for the pot culture experiment were (1) Maton rock phosphate, (2) Mussorie rock phosphate, (3) Gafsa rock phosphate, (4) Rajasthan rock phosphate and (5) Single superphosphate. The maximum content of cadmium (55 mg kg^{-1}) was recorded in Gafsa rock followed by 25 mg Cd kg^{-1} for the Maton rock and

single superphosphate analysed the least concentration of cadmium (15 mg kg^{-1} Highest lead content of 230.5 mg Pb kg^{-1} was analysed in Maton rock while the lowest (38 mg kg^{-1}) in Musoorie rock. All the other sources maintained their heavy metal concentration in between these extremes. In general, the shoot portion of test crop chilli recorded highest cadmium uptake while root portion noted the maximum lead uptake. The least uptake of heavy metals was noted in the chilli fruit, which is the edible part of the plant. This indicates that the heavy metal load in the fruit portion is much less when compared to other plant parts, irrespective of the sources used. The same trend was evident when either partially acidulated P sources or direct source of heavy metals (through water soluble salts) were applied. However, the uptake of cadmium and lead from those sources remained higher in plant parts. Direct application of higher levels of heavy metals permitted higher cadmium and lead extraction in the post-harvest soil samples. Application of partially acidulated rock sources to soils, though could cause enhanced uptake of heavy metals, could not show higher residual effects of heavy metals in post-harvest soil samples (Jidesh, C. V.,1998).

An investigation was taken up to study the fate of applied and native potassium in a laterite soil as influenced by other major nutrients and organic matter and uptake by an annual crop, banana. The experiment was laid out at Banana Research Station, Kannara, during the period 1996- 1997. The result of the study revealed the necessity of fertilization of the field/soil for better yield. The maximum content and uptake of nutrients N, P and K occurred during the early and late vegetative stages of banana. Hence fertilizers should be applied for the crop from 2 months after planting onwards and continued up to six months after planting. Correlation studies revealed the significant relationship of total K in the soil with yield at different stages. Also poistive correlation between the exchangeable K content in the soil and yield was established. Path coefficient analysis revealed that the direct effect of total K content in the soil on yield was highest at P_4 (6 MAP). The indirect effect was maximum at P_4 (6 MAP) through P_3 (4 MAP). The exchangeable K also was found to have positive direct effect on yield. The indirect effects were not significant. Water soluble K at different stages showed a direct effect of comparable magnitude on yield (Nicy Thomas 1998).

An investigation was carried out in the College of Horticulture, Vellanikkara, during 1995-1997. The study was aimed to find out the effect of organic manuring and chemical fertilisers on the levels of IAA (Indole Acetic Acid) and its influence on growth and yield of brinjal by monitoring the activity of Indole Acetic Acid oxidase in plant leaves at different stages of plant growth. IAA oxidase activity was found to increase with the age of the plant upto the flowering stage and thereafter it was

found to decrease. Application of treatment was found to influence the IAA oxidase activity only at the fruiting stage of the plant. Application of FYM, fertiliser and their combination with and without supplementary addition of IAA permitted significant difference in the uptake of N, P and K compared to that in control. Maximum uptake of N and P was recorded by the treatment which received IAA application along with the double dose of fertiliser and FYM (Rosamma Abraham, 1998).

An investigation was taken to study the regulation of major plant nutrients and organic matter for improving the nutritional qualities of banana. The expriment was laid out at Banana Research Station, Kannara, Kerala Agricultural University during the period 1996-97. The result of this study revealed that application of fertilizer and organic matter is essential for getting better yield and quality of banana. All the food nutrients studied were increased by the application of fertilizer and hence the quality is much improved. Regarding bunch yield, the fertilizer dose of 12.5 kg FYM, 200: 125:300 g N, P_2O_5 and K_2O per plant obtained maximum yield. The treatments receiving medium level of FYM and nitrogen recorded higher content of carbohydrate. Acidity is increased by the application of farmyard manure and nitrogen. Nitrate accumulation in banana was high in plots receiving highest dose of nitrogen. Nitrogenous fertilizers increased the carotene content of banana. Fertilizer application enhances the total mineral content of banana due to increased uptake and availability of nutrients. The nitrogen content of edible portions of banana was high in plots receiving the higher doses of nitrogen. The treatments which received the highest dose of phosphorus (200 g/plant) recorded the highest content of phosphorus. Vitamin C content was enhanced by the application of nitrogenous fertilizer and farmyard manure. Correlation studies revealed that the content of major nutrients in soil at 2, 4 and 6 months after planting has got much influence on the quality parameters studied. Hence fertilizers should be applied in split doses commencing from 2 months after planting. Path coefficient analysis revealed that the direct effect of the three major nutrients on quality parameters was maximum at 6 months after planting. This indicated that the requirement of these nutrients was essential througnout the growth of the plant (Binu Thomas, 1999).

Substitution of K was tried at four levels viz., 25, 50, 75 and 100 percent of the recommended dose in Nendran banana. The important growth characters of the crop viz., height and girth of pseudostem, total number of leaves, total leaf area and leaf area index showed an increasing trend upto 50 percent substitution of K by Na. The total drymatter production was significantly higher upto 50 percent substitution. The maximum value for bunch yield was recorded by the treatment T_3 (50 percent KCI + 50 percent NaCl). The lowest yield was registered by the treatment

T_6 which received no potassium and sodium. Total and reducing sugars were highest for the treatment T_5 (100 percent substitution). Non reducing sugars was highest for POP recommendation. Shelf life did not show significant variation among the treatments. Uptake of nitrogen was highest for the treatment T_2. But the P uptake was maximum in the treatment T_3. Maximum value for available nitrogen was recorded by the treatment T. Available P was highest in T_3. T registered maximum value for available K while T_5 maximum for available Na. Significant positive correlations were obtained between the uptake of nutrients and bunch weight. Quality characters also showed significant correlations between the uptake of nutrients. The highest benefit: cost ratio was recorded by the treatment T_3. From this study it is to be concluded that there is a possibility of substitution of potassium by sodium to a level of 50 percent in banana var. Nendran without much deleterious effects especially on the yield and quality of the fruits (Lekshmi, R.,2000)

An investigation entitled "Dynamics of potassium, magnesium and sulphur in plant and soil with special reference to the application of langbeinite" was undertaken to examine the dynamics of K, Mg and S in soil as influenced by langbeinite (Sul-Po-Mag), a K-cum-Mg fertilizer in the acid laterite soil of Kerala using tapioca and bhendi as test crops. It was seen that Sul-Po-Mag application produced drymatter and yield on par with the muriate of potash treatments and hence Sul-Po-Mag could substituted for muriate of potash to tapioca in the acid-laterite soils of Kerala. Application of Mg increased the available Mg of soil but gypsum application caused a reduction in available Mg. Application of either Sul-Po-Mag or muriate of potash resulted in a significant increase in the available K of both soils. The available K decreased with incremental additions of $MgSO_4$ especially during the initial stages. Muriate of potash application gave lower available K during the later stages but Sul-Po-Mag maintained availability throughout the incubation period (Rani. B, 2000).

An experiment was conducted to study the "Effect of major nutrients on the yield and quality of nuts in graft raised cashew" at Cashew Research Station Madakkathara Kerala. The treatments consisted of three levels each of N, P and K on eight year old cashew trees. The yield of cashew nuts and apples were significantly increased due to the highest level of nitrogen applications. Application of potassium at the highest level also significantly increased the apple yield per tree. Weight and volume of cashew apples was significantly increased by the application of increasing levels of potassium but nitrogen application was found significantly decreasing the weight of fruits. Potassium applications were found to significantly increase the nut length and weight while nitrogen applications were found to reduce the nut weight. Shelling percentage of cashew nuts was enhanced by the application of nitrogen

and potassium at increasing levels. In general, among the major nutrients applied at different levels only nitrogen had shown exceedingly high effects in sustaining the growth, yield and quality parameters. The yield and quality parameters were also seen to be affected to a certain extent by potassium applications but the response of the crop to phosphorus was seen to be exceedingly limited (Rajiv Nair. R. K, 2002).

To investigate the basic physico-chemical properties of Oushadhi waste material and to standardize formulations of enriched compost, waste material was collected from the manufacturing unit of Oushadhi pharmaceuticals, Kuttanelloor, Thrissur. A preliminary study was conducted to confirm the basic physico-chemical properties of the waste material for a period of 6 months by taking composite samples from the factory at an interval of 10 days. Temperature, pH, microbial count, colour, odour and consistency as well as the major nutrient contents of the waste material were analysed during the time period. Then the waste material were categorised into three substrates namely unsieved (01), 4 mm sieved (02) and 2 mm sieved (03) fractions. Then each substrate was enriched with organic and inorganic enrichers at different levels. The organic enrichers used were cowdung, poultry manure and neemcake each at 5, 10 and 15 percent of substrate and also their mixtures. The study involved aerobic composting of enriched treatment combinations in pots of size 30 x 32 cm^2. Temperature was measured daily and other parameters like pH, dehydrogenase activity and C: N ratio were monitored at 10 days interval throughout the composting process. The selected enriched compost was tried at three levels - 5, 2.5 and 1 t ha^{-1}. A combination of the selected enriched compost at these three levels along with full doze and half doze of recommended NPK was also tried. For comparing the efficiency of the compost over FYM, FYM @ 5 t ha^{-1} and FYM 5 t ha^{-1} along with full dose of recommended NPK and absolute control was also tried. However the selected compost at the highest level i.e. 5 t ha^{-1} with full dose of recommended NPK emerged as the best treatment for economic yield return. This treatment also witnessed the increased build of available nutrient status of soil. This treatment could bring down expenditure for raising the crop without affecting the yield. The SEC application also resulted in increased nutrient availability by increasing the CEC and water holding capacity of soil (Lekshmisree, C. S., 2003).

A pot culture experiment was carried out at Radiotracer laboratory of College of Horticulture, Vellanikkara, using laterite soil (Ultisol), from the main campus of Kerala Agricultural University with the objectives to trace the fate of fertilizer P and to study the dynamics of P by the addition of amendments. Application of Phosphorus at different levels significantly contributed to available P status. Different P fractions i.e. non occluded Al-P and Fe-P, P sorbed by carbonate, occluded P and

Ca-P showed in a linear fashion at different stages of crop growth i.e. just before sowing, flowering and harvesting. The amendments also contributed to the above pools. Among the amendments Pongamia leaves was found to have better influence in contributing to the above pools except for Ca-P, where lime was found to have a better influence. This was supported by the data on plant P content, where the increasing levels of P and amendments improved the plant P content at 15 DAS, flowering and at harvest. Further Ca-P fraction was dominantly contributing to the available P suggesting that applied P might get transformed to non occluded Al-P and Fe-P, occluded P as well as P sorbed by carbonate, which might be slowly transformed to Ca-P fraction probably Ca $(H_2PO_4)_2$, the soluble form which is contributing to available P. It was observed that, non occluded Al-P and Fe-P was contributing to plant P as time proceeded due to solubilisation of this fraction.Application of P at increasing level and amendment significantly increased the dry weight of pods and haulm. Radioactive ^{32}P labelled with the applied phosphorus could be traced out in the available pools and fractions of P only at just before sowing and flowering. Percentage of P derived from applied P was the highest for higher level of P and amendment sodium silicate (Smitha M. S, 2005).

A field experiment was carried out in the main campus of College of Horticulture, Vellanikkara to study the availability indices of potassium in an Ultisol under coleus cultivation. Tuber number and tuber yield were significantly influenced by the potassium application up to 60 kg K_2O ha^{-1}. The size of the tuber was not significantly affected with potassium application. Availability of exchangeable Al and Mn in soil got reduced with the increased levels of K. Calcium and aluminium absorption was found to reduce with increase in available K. At all stages of analysis the quantity of K extracted with all reagents increased with the levels of potassium application in the soil. The water soluble, exchangeable and non-exchangeable potassium were reduced from initial stages towards harvest indicating the crop utilization and the presence of dynamic equilibrium between the various forms of potassium. Correlation studies conducted between yield attributes and quantity of K extracted revealed positive correlations between tuber yields, tuber number, water soluble and exchangeable K. The quantity-intensity parameters estimated at temperatures viz. 25°C and 40°C showed that the desorption of potassium was more at higher temperature indicating the higher availability of K in summer season. The potassium adsorption of soil under study followed the Freundlich adsorption isotherm both at 25°C and 40°C (Santhosh, C, 2007).

Five benchmark soils of lateritic origin were collected and used for the present study of Q-I relations, dynamics and transformations of P. Samples of these soils were collected from Kunnamangalam (Calicut), Angadippuram (Malappuram),

Vellanikkara (Thrissur), Pattambi and Thirumittakkodu(Palakkad) . Among the five soils, Vellanikkara soil series recorded the lowest available P and soluble P fraction, the highest P fixing capacity and highest adsorption maximum as per Langmuir equation. Based on the above characteristics this soil was selected for pot culture experiments to grow cowpea as a test crop using three different amendments (Pongamia, Cleistanthus, and lime), three levels of labeled phosphatic fertilizer and two methods of applications were followed. Available P and fractions of phosphorus in the soil was estimated at three stages. P content as well as ^{32}P counts in the plants were also estimated. Both A and L values were computed at 15 and 30 days after sowing. It was concluded from the present study that application of different amendments dictated the transformation of P in soil. The available P and soluble P could be improved significantly. A different trend in radioactive phosphorus activity in available P as well as in A and L values indicated that the applied P though contributing to the available pool in amended soils, this might be routed through the inorganic fraction Ca-P and not directly coming to the soluble/labile pool (Geetha. P, 2008).

An investigation was carried out at the Instructional farm, College of Agriculture, Vellayani to evaluate the effect of two enriched composts viz. BM compost and EM compost at different rates alone as well as in combination with two growth promoters viz, Panchagavya and vermiwash on physico-chemical and biological properties of soil and also their impact on crop performance using chilli variety, Vellayani Athulya, as test crop. The results from the field experiment revealed that the plant growth characters viz. height of the plant at 30, 60 and 90 DAT and primary branches per plant at 90 DAT showed significant variation due to the application of 75 percent N as BM compost along with Panchagavya. Significant differences were observed among yield attributing characters viz. number of fruits per plant, fruit length (cm), fruit girth (cm), fruit weight (g), green fruit yield per (g plant-1), total fruit yield (t ha^{-1}) and total dry matter yield (t ha^{-1}). The treatment T8 (75 percent N as BM compost + Panchagavya) recorded the highest values for all these characters but it was found to be on par with T7 (75 percent N as EM compost + Panchagavya). This shows that BM compost can be substituted with EM compost when used along with Panchagavya. With respect to quality characters, the treatment T8 (75percent N as BM compost + Panchagavya) registered the highest values for capsaicin, ascorbic acid and shelf life of fruits. Disease incidence percentage (*Colletotrichum* fruit rot) was found to be reduced by the treatments with organic sources. The treatment T8 (75percent N as BM compost + Panchagavya) reduced the incidence of pests and diseases to a considerable extent. Highest BC ratio also was recorded by the same treatment T8 (75percent N as BM compost + Panchagavya). Post harvest analysis of the soil indicated that organic carbon, available macro and micro nutrients

pH, EC and microbial load and dehydrogenase activity were increased by the combined application of enriched manures viz. 75 percent N as BM compost and Panchagavya or 75 percent N as EM compost and Panchagavya. Bulk density was found to be reduced favourably. From the results it was clearly indicated that 75 percent N as BM compost and Panchagavya or 75 percent N as EM compost and Panchagavya was superior to all other organic sources in promoting soil health and yield and quality of chilli (Lekshmi, V 2011).

The experiment entitled "Silicon and boron nutrition of rice (*Oryza sativa* L.) in wet land soils of northern Kerala" was carried out to standardize the dose and method of application of silicon and boron to rice crop in paddy soils, to evaluate its effect on available nutrient status and yield and to study the effect of silicon in alleviating the toxicity of Fe, Mn and Al in laterite derived paddy soils. The treatments were a combination of boron source as borax (soil and foliar application) and silicon sources as calcium silicate (soil application) and potassium silicate (foliar application). Two experiments, a pot culture and a field experiment were conducted with rice variety, Aishwarya, as the test crop. In a nutshell, both the pot and field experiments clearly indicated that application of Si and B significantly improves the available nutrient status of soil, nutrient uptake, grain and straw yield of rice. Foliar application of potassium silicate and borax (0.5 percent each) 3 rounds at 15 days interval significantly improved the available nutrient status of soil, yield and yield attributes of rice. It was also effective on alleviating toxicity of Fe, Mn and Al in laterite derived paddy soils (Sainath Nagula, 2014).

The recent soil fertility assessment of the entire state as revealed that more than 60 percent of the soil in the state is having high P status due to continuous application of P fertilizers like factomphos and bone meal. It was also established that 15 percent of the soils are deficient in Zn and about 60 percent of the soil are deficient in Boron. Antagonisitic interaction of P with Z n has already been well established. However studies on interaction of P with B are limited. This study was taken in the above backround at the Department of Soil Science and Agricultural Chemistry, College of Horticulture, KAU, Vellanikkara, during 2013 – 2015 to understand the chemistry, dynamics and bio availability of Zn and Boron with respect to the status of the soil which in turn modified the fertilizer prescription in terms of quantity and method of application of these nutrients. Application of Zn increased the Zn content in plant. However the application of P with and without B reduced the Zn content in plants. Application of P and Zn reduced the Boron content in plant and application of Boron with and without P recorded the highest Boron content. The highest grain yield was recorded in soil with medium P while the high P status in soil either due to native P or due to applied P reduced the yield resulting from induced lower uptake of Zn and Boron (Semsheer, M 2015).

Field experiments on aerobic and flooded systems of rice were conducted in second crop season with the objectives to study the nutrient dynamics and transformations in these systems in second crop season with rice (variety Jyothi), in farmer's field, at Nellikkattiri, Thirumittakode panchayat, Palakkad district. The treatments with two doses of fertilizers (as per Package of Practices Recommendations, KAU and based on soil test) and three doses of lime (as per POP, as per "pH and as per SMP buffer method) were imposed in plots of $20m^2$ area in Randomized Block Design with four replications. Under flooded condition, two field experiments were conducted to standardize the method of sampling and analysis for soil test based application of lime and fertilizers. One was based on sampling and soil testing on wet basis keeping the anaerobic environment unchanged, while the other was based on routine sampling and analysis after air drying. Better correlations with respect to available nutrients and plant nutrient content were obtained for wet analysis based recommendation and hence the data from this experiment were considered for comparison of the nutrient dynamics with that of the experiment on aerobic rice. Ultimately, aerobic rice recorded significantly higher grain and straw yield (6.23 t ha^{-1} and 6.35 t ha^{-1} respectively) than that under flooded system (5.12 t ha^{-1} and 5.52 t ha^{-1} respectively). The treatment with fertilizer application based on soil test and with lime as per SMP buffer method under aerobic situation recorded significantly higher grain yield of 6.8 t ha^{-1} because of balanced nutrition in this treatment combination. Higher root CEC, root mass, shoot mass root volume and root length were recorded under aerobic system. The decline in productive tillers during active growth phase was observed under flooded environment. Well-developed aerenchymatic tissue in the roots was observed only under flooded environment. The water requirement was reduced by 57 percent in aerobic rice, than that in flooded rice (Geetha. P., 2015).

Physical and chemical attributes

An investigation was conducted on the physical and chemical properties on the sewage of farm soil, Valiyathura in Trivandrum district.Application of sewage decreased bulk density and hydraulic conductivity while it improved the percent aggregate stability, stability index, capillary and total porosity irrespective of periods of irrigation. There was a decrease in the soil reaction because of the accumulation of organic matter. It was found that NH_4 – N was more than NO_3 – N and higher CEC with increased total and available NPK contents significant accumulation of heavy metals such as Pb, Hg, Cd and Ni was recorded (Karunakaran Nair, G, 1987).

An investigation was carried out during 1994-95 to standardise soil sampling technique for coconut and to work out fertilizer recommendation system considering physical/textural nature of soil as well as nutrient levels. Two standing populations

of WCT palms grown under good and average management practices located at Mulamkunnathukavu (Thrissur district) was utilised for the study. From each plot twenty healthy palms were selected for the study. The coconut gardens were separated by a distance of about 1 km and the soil of the site was laterite (Oxisol). Composite soil samples were collected from three depths from the surface and from three radial positions from the bole of the palm. Samples were collected in May, October and January. Leaf samples were collected from the 10th frond and observations on yield and yield attributes were also recorded along with soil samples. Physico-chemical properties of soil, root activity pattern, leaf nutrient content and yield and yield attributes of both situations were compared. Based on the above observations the most suitable sampling technique for coconut is composite sampling containing both inside and outside basin soils from a depth of 0-30 cm from the surface. It has also been noticed that organic carbon content was linked with nut production. Varying interaction of organic carbon with different fractions of soil on one side simultaneously with its direct bearing on productivity would point out to the necessity of evolving texture linked indices to get reliable information about nutrient availability status of soil. Therefore, some correction factor should be added to soil test values to account the anomalies caused by the coarser soil fraction which is not having a direct role in production and productivity (Nimba Frango, E. F. 1998).

An investigation was carried out at College Of Horticulture, Vellanikkara about the subsoil acidity amelioration in laterite soil of black pepper garden using three calcium sources- $CaCO_3$, $Ca(OH)_2$ and Phosphogypsum. On the basis of this an incubation experiment using three calcium sources, lime, slaked lime and Phosphogypsum the results revealed that lime is more effective in increasing the pH while Phosphogypsum was found to be effective for reducing the exchangeable Al in soils. This result was confirmed by the results of a leaching experiment in PVC columns using 45Ca labelled ameliorants. Radio assay and autoradiography was done on this experiment which proved that, in Phosphogypsum, Ca was highly mobile compared to $CaCO_3$ and $Ca(OH)_2$. In order to understand the response and tolerance level of Al on pepper plants specifically on its roots a solution culture experiment was also done by growing rooted plants in Hoagland solution containing different levels of Al. Solution culture experiment proved that the pepper root tolerated an Al concentration of 5 and 10 ppm and beyond this level plant died off and roots decayed. How ever at 5 ppm level of Al profuse root growth was noticed. The anatomical observations of the roots were also done and some modification in the tissue orientation is noticed. On the basis of this investigation it can be concluded that a sub surface zone with high concentration of exchangeable Al existed in laterite soil of the pepper garden and Phosphogysum offerd a potential option for

ameliorating the subsoil layers and to promote root growth of black pepper to deeper soil layers. Some promoting effect on black pepper root growth was noticed at 5 ppm Al, in solution culture.On the basis of these observations it was suggested that further investigations were needed on other soil types and also to validate by field trials (Deepa K Kuriakose, 2008).

A study was taken up on Physico-chemical properties of rain water harvested under different situations in lateritic soil in the main campus of Kerala Agricultural University, Vellanikkara during September, 2012 to August 2013. The objective of the study was to compare the physico-chemical properties of rain water from different water sources in lateritic soil. In general, it was found that the rainfall and rain water harvested in the waterharvesting pond were superior to well water. Salinity was low for water from all the sources. Surface run off in an area with moderate slope (5-10 per cent) resulted in loss of nutrients like K, P, Mg and Ca (Abdul Ibrahim Hassen, 2014).

Response to fertilizers

With a view to investigate the factors responsible for the lack of response to phosphatic fertilizers applied to rice in the laterite soils of Kerala, a pot culture trial was undertaken. A typical laterite soil collected from the Rice Research station, pattambi and river sand collected from Thiruvallam were used for this purpose. Phosphorus was applied in the form of super phosphate and ultraphos at the rate of 30 and 60 kg P_2O_5 / ha. Rice variety IR 8-288.3 was used for the trial. In order to have a better assessment of the complex soil factors governing the availability of phosphorus in soils, the treatments were simultaneously repeated in sand culture also. The availability of phosphorus increased with increasing amounts of added phosphatic fertilizers. Farm yard manure applied along with fertilizer P increased the availability of native P in rice soils. Further addition of P did not increase the status of available P in soil due to P fixation (Akbar. A, 1970).

A pot culture experiement was conducted using the laterite soils of Pattambi and Trivandrum to study the nutrioperiodism of K in rice when applied in conjunction with urea. Two varieties of rice, Jaya (medium duration, 120-125 days) and Triveni (short duration, 95-105 days) were tried at full and half the recommended doses of K for the respective varieties. Medium duration variety Jaya required the full recommended dose of 45 kg K_2O/ha for the full expression of the yield potential. Short duration variety Thriveni required only half the dose of K (17.5kg ha^{-1}). Basal dressing of 1/8 K, top dessing of ¼ K at maximum tillering and 1/8 K at panicle initiation were found to be beneficial for Thriveni. Medium duration variety Jaya

required full dose of K (45 kg ha^{-1}) for its yield. For such varieties, recommended dose should be applied half at maximum tillering stage and other at panicle initiation stage (Shehana. R. S, 1981).

A study carried out at College of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur during the period from 1993-95 to investigate the lime requirement in terms of exchangeable aluminium, to correlate pH and lime requirement (LR) values with exchangeable aluminium content in soil and to study the effect of liming on crop performance with special reference of exchangeable aluminium content in soil. The lime requirement of soil which was calculated based on various methods revealed that the LR based on the exchangeable aluminium content of soil required very less quantity of $CaCO_3$. The exchangeable aluminium contributed 69 to 86 percent towards exchangeable acidity. The high contribution of exchangeable aluminium should be taken into account in liming and nutrient management of the laterite soils and adopting this method for lime requirement determination would be more efficient and economical. Thus the results pointed out the advantages in adopting the exchangeable aluminium as an index of the lime requirement of the laterite soils of Kerala (Muhamed Sakeer, N. M, 1997).

The study was aimed to bring to light the suitability of Sul-Po-Mag as potassium cum magnesium fertilizer for banana in Kerala. The treatments included Sul-Po-Mag substitutes to the extend of -25, 50 and 100 percent in the recommended dose of NPK as urea, diammonium phosphate and muriate of potash at the rate of 190 g N, 115 g P_20_5 and 300 g K_20 $plant^{-1}year^{-1}$. Treatments of muriate of potash supplemented with magnesium and sulphur was done separately and with magnesium and sulphur together was also included and they were compared with the recommended practice. The experiment was laid out in randomised block design with three replication. The maximum yield was given by the treatment where potassium was supplied by Sul-Po-Mag and muriate of potash in half doses. Though the treatments differed significantly in yield from the control, where no fertilizer was applied, the treatments of muriate of potash and Sul-Po-Mag were on par indicating that Sul-Po-Mag was as good as MOP for its capacity to meet potassium requirement of the crop. The treatments did not differ significantly in quality parameters such as reducing sugars, total sugars, sugar acid ratio, weight of pulp and peel and pulp peel ratio. But significant difference was observed with total soluble solids, ascorbic acid content, non reducing sugars and acidity. High values of these characters were recorded with Sul-Po-Mag except for the reducing sugars and total sugars. Treatments with magnesium and sulphur were found to decrease the sugar content of fruits. High pulp peel ratio of Sul-Po-Mag treatments showed increased storage quality (Anila Mathew, 1997).

An investigation was carried out at College of Agriculture. Vellayani, to study the feasibility of using phosphogypsum as an ameliorant for correcting soil acidity in laterite soil with cowpea as the test crop. The experiment comprises of an incubation study and a micro plot field experiment. The incubation study was carried out to understand the kinetics of dissolution of phosphogypsum and the nutrient release pattern in laterite soils after its application with the following seven treatments T_1 (absolute control) T_2 (Lime @ full LR), T_3 (PG @ full LR) T_4 (Lime @ half LR), T_5, (PG @ half LR) T_6 (Lime and PG each @ half LR) T_7 (Lime as per POP). The study was conducted for a period of 60 days and the chemical parameters were analysed at an interval of 12 days as per standard procedures. The results revealed the enhanced solubility of phosphogypsum which was evident from the higher EC values in the treatments with phosphogypsum through out the study period. Most of the plant available nutrients were solubilised by the 24 th day of incubation. A reduction in exchangeable acidity was noticed by the application of phosphogypsum after a period of 24 days, which is mainly due to reduction in exchangeable aluminium. But this was not efficient as lime in decreasing the exchangeable H^+ and hence the pH, remained unaltered. The micro plot field experiment was laid in RBD with a main crop and a residue crop of cowpea var. Kanakamoni. The treatments include T_1 (POP), T_2 (Lime @ full LR), T_3 (PG @ full LR), T_4 (Lime @ half LR), T_5 (PG @ half LR), T_6 (Lime and PG each @ half LR), T_7 (Lime and PG each @ 14 LR) and T_8 (absolute control). Fertilizers and amendments were applied on the basis of soil test data except in T_1 where, they were applied on the basis of POP of Kerala Agricultural University. In the residue crop, the amendments were not added and were taken immediately after the main crop. The available nutrients in soil like, P, Ca and S were increased by the application of phosphogypsum. However, considerable leaching was noticed in the case of Mg and K. The growth characteristics of cowpea were improved by the application of phosphogypsum. The highest grain yield was recorded with phosphogypsum applied at full LR and was on par with the combination treatment which received the amendments at one fourth LR. But considering the cost factor treatment with phosphogypsum at full LR is the best. Its B: C ratio was also the highest among other treatments. The yield attributes were also improved by the treatment with phosphogypsum at full LR. The concentration and uptake of N, P, K, Ca, and S in bhusa were favourably influenced by the application of phosphogypsum either at full LR or at halfL R. The residual effect of phosphogypsum was visualized in the crop, taken after the main crop. The application of phosphogypsum increased the organic carbon content, P, and S. The leaching of calcium, Mg and K beyond the root zone was much pronounced in the residue crop. The yield attributes of cowpea were also positively related with phosphogypsum treatment. But by the time of residue crop, the bhusa yield was

more for lime treated plots. The concentration of N, Ca and Mg were more in lime treated plots, but the uptake of nutrients was more for treatment with phosphogypsum. This also emphasizes the mobility and downward leaching property of phosphogypsum. The micronutrient content and uptake were also influenced by the application of phosphogypsum. Phosphogypsum is hence highly beneficial in increasing the yield and yield attributes of cowpea, by mitigating the adverse effects of soil acidity, such as aluminium toxicity, which in effect is the major reason for acidity in laterite soils. Further, utilization of an industrial by product, which otherwise remain unutilized is also facilitated (Jeena Mathew, 2003).

Soil Test crop response studies on coleus in laterite soil of Kerala" consisting of two experiments namely fertility gradient experiment and STCR experiment was conducted during 2002 in the farm attached to the College of Horticulture, Vellanikkara. The fertility gradient experiment was conducted to create desired gradient in soil fertility in one and the same field by applying graded doses ofN, P, and K fertilizers and raising fodder maize var.Co.l. After development of fertility gradient, the STCR experiment was conducted in the same field with the test crop, coleus variety Nidhi.The treatment structure consisted of four levels of N (0,20,40, and 80 kg ha'), three levels of P_2O_5 (0,45 and 90 kg ha^{-1}) and five levels of K (0, 25, 50, 100, 200 kg ha-^{1}) along with three levels of FYM (0, 7.5 and 15 t ha^{-1}) The nutrient requirement of coleus, variety Nidhi were estimated to be 9.15, 1.38 and16.38 kg ha-$^{-1}$ N, P_2O_5 nd K_2O respectively to produce one tonne of tuber. The soil efficiencies worked out as 21, 46.85 and 40.85 percent for N, P_2O_5 nd K_2O respectively for coleus in laterite soil. The contribution of nutrients from the fertilizers for coleus was calculated as 61.6, 9.57 and 56.60 percent for N, P_2O_5 nd K_2O respectively. From the above basic data, fertilizer prescription equation for specific yield targets of coleus variety Nidhi in the laterite soil were derived as follows, Without FYM, FN =14.85T - 0.34SN, F P_2O_5 =14.42T - l.21SP F K_2O =28.98T - 0.87SK FN, F P_2O_5 FK_2O - Fertilizer N, P_2O_5 nd K_2O respectively T - Target yield of tuber in t ha^{-1} SN, SP, SK - Soil available N, P and K in' kg ha-1 respectively . With FYM FN =14.85 T - 0.34 SN - 0.34 ON, F P_2O_5 =14.42 T - 11.21 SP - 3.25 OP, F K_2O = 28.93 T - 0.87 SK - 1.22 OK Where, ON, OP and OK are quantities ofN, P and K supplied through organic manure in kg ha^{-1} Multiple regression models calibrated with yield as dependent variable and STVs for available N, P and K and applied nutrients as independent variables had 67.4 percent predictability. Among the three fertilizer nutrients, FN only showed the normal type (+, -, -) of response. The fertilizer adjustment equation fur varying levels of soil available N for maximum tuber yield (t ha^{-1}) of coleus in laterite soil was derived as FN= 168 SN, where FN is fertilizer N (kg ha^{-1}): SN is available N (kg ha^{-1}) in soil. The behavior of applied P and K was found to produce responses other than normal and hence optimization could not

be done for fertilizer P and K at varying soil test values. Simple correlations coefficient was worked out for nutrient uptake, soil available nutrients, applied nutrients with yield of coleus. Available nutrients showed higher positive correlation than that of applied nutrients. The uptake of nutrients (N, P and K) also significantly correlated with yield of coleus. This study is useful to adjust fertilizer doses based on the specific objective and available resources of coleus farmers of the state (Nagarajan, M.,2003).

The study on the "Biotic Enrichment of Organic Wastes from Ayurvedic Preparations using ayurvedic wastes" from Oushadhi (the Pharmaceutical Corporation, Indian Medicines) under Government of Kerala was conducted at College of Horticulyure, Vellanikkara. As the introduced biotic agents, two types of earthworms (*Eudrilus eugeniae* and *Eisenia foetida*) and two fungal inoculi (*Schizophyllus communae* and *Pleurotus platypus*) were tried. Dehydrogenase activity was maximum (3119.3 ug TPF s" soil h^{-1}) at thermophilic stage, followed by maturity and mesophilic stages. After the thermophilic stage, the earthworms were introduced and the counts with respect to *Eudrilus eugeniae* were more than that of *Eisenia foetida* at the two stages of sampling. Based on the C:N ratio (11.4) and the least time taken (48 days) for maturity the best treatment was selected, 'and it registered manurial contents of N (3.62 percent), P (0.85 percent) and K (0.89 percent). In the same material, the biochemical constituents of crude fibre (13.9 per cent), crude lipid (0.7 per cent), crude protein (12.68 per cent), lignin (28.2 per cent) and cellulose (18.8 per cent) were determined. The best means of composting involves the use of the unsieved substrate which must be enriched with 5 percent mixture of cowdung and quail manure (1: 1 ratio) and later vermicomposted with *Eisenia foetida*. To evaluate the effect of the selected enriched compost, the much responsive crop, amaranthus was field tested for a period of two months. The selected enriched compost was tested at two rates (5 t ha^{-1} and 2.5 t ha^{-1}), with and without full and half levels of recommended package of NPK fertilizers, along with FYM and absolute control. The results indicated that with higher doses (5 t ha^{-1}) of the selected enriched compost along with 50:50:50 NPK gave the maximum yield followed by the treatment in which 2.5 t ha^{-1} of selected enriched compost along with 50:50:50 NPK was applied (Preetha, D., 2003).

The project entitled Critical analysis of the soil plant atmosphere continuum for increasing the productivity of rice in lateritic soils was conducted at two locations of Palakkad district (Koyalmannam and Ottappalam) for two seasons during 1999-2001. At Koyalmannam and Ottappalam P, K and lime significantly influenced the yield and yield contributing characters. Application of phosphorus, potassium and lime at 35 kg ha^{-1}, 70 kg ha^{-1} and 600 kg ha^{-1} respectively, increased the grain yield. However for the second crop at Ottappalam, significant yield reduction was not

observed even with the 17.5 kg ha^{-1} of P. Pooled analysis of yield data showed significant influence of higher level of P at 35 kg ha^{-1}. Potassium at higher level of 70 kg ha^{-1} increased the yield significantly. But higher level of lime application at 600 kg ha^{-1} significantly increased only the straw yield. However higher level of P, K and lime at 35, 70 and 600 kg ha^{-1} respectively increased the major nutrient content of the plant and decreased the Fe and Mn contents.There was significant increase in the uptake of N, P and K while the Fe uptake was reduced by the higher level of K application. Potassium and phosphorus applied together in general decreased the Fe uptake while it enhanced the uptake of P and K. Soil available major nutrients also showed significant positive response to higher level of K and lime application. There was an increase in the N, P and K contents of the soil at higher level of P application at 35 kg ha^{-1}. The available Fe and Mn contents of the soil showed significant decrease at higher dose of K and lime. Correlation studies showed significant positive correlation of N/Fe, P/Fe, K/Fe and K/Ca+Mg ratios of soil and plant with yield which indicated that an increase in P and K followed a decrease in the Fe content of soil which subsequently increased the yield (Sailaja Kumari. M. S, 2005).

An investigation on amelioration of subsoil acidity and aluminium toxicity in lateritic soils under black pepper was carried out as three experiments. In the present investigation, Phospogypsom (PG) and FlyAsh (FA) were first characterised for their properties and blended at different ratios and evaluated. The blends PG: FA of 10:1, 20:1 and 30:1 ratios had desirable properties and was further utilized for the study. In the first stage an incubation experiment was done by combining PG with FA at three ratios *viz.*, 10:1, 20:1 and 30:1 and applied to soil samples at rates equivalent to lime application dose with respect to Ca content. The samples were incubated at 50 percent field capacity moisture level and samples were drawn at 15 days intervals upto 90 days and examined for various properties like pH, exchangeable Ca, Fe and Mn. After 90 days, exchangeable Al was also analysed. The results indicated that in treatments with FA, pH values were significantly higher up to the 90 days period. The exchangeable Ca contents were significantly lower for the PG-FA blends than PG, but after 30 days all the treatments were at par, and significantly superior to control. These treatments were equally effective in decreasing exchangeable Fe, Mn and Al contents during the period of study. The results indicated the over all superiority of the PG-FA blends among which PG-FA at 20:1 ratio stood superior with respect to reduction of Mn and maintenance of high pH. Fly ash blending, though it reduced the Ca content initially, made good after thirty days, and its favourable pH makes its ideal for over all effect.Based on the suitability of PG-FA blends, a pot culture experiment was conducted in the second stage with ten

treatments. The treatments consisted of four ameliorants, i.e. PG and three PG-FA blends, mixtures of these four with equal quantities of Vermicompost (VC), VC alone and an absolute control. From the results it could be concluded that the PG-FA blends were found to be better ameliorants than their separate application with respect to pH increase and reduction of Fe, Mn and Al concentrations. Mixing the blends with vermicompost further enhances their superiority (Thamarai Thuvasan, 2010).

An investigation on "Magnesium and boron nutrition of black pepper (*Piper nigrum* L.) in laterite soils" was carried out at the College of Agriculture, Padannakkad and Pepper Research Station, Panniyur during 2013-14. The results of the experiments involving soil and foliar application of Mg and B clearly indicated that in the case of soil application, application of 40g $MgSO_4$ + 4g borax in pot experiment and 200g $MgSO_4$ + 20g borax in field experiment significantly influenced the available nutrient status of soil, yield and yield attributes of black pepper. In the case of pot experiment involving foliar application, the use of 1 percent $MgSO_4$ + 0.5 percent borax was superior with respect to available nutrient status, yield and yield attributes of black pepper. In the case of field experiment, the treatment receiving 0.5 percent $MgSO_4$ + 1 percent borax was superior to all other treatments (Venkata Ramana, P., 2014).

Soil fertility evaluation

A mixture of 0.06N H_2SO_4 and 0.06 N HCl in 0.05 N oxalic acid was found to be the best extractant for determining the Ra-value of P in soil. This reagent with an equilibration period of 30 minutes and a soil solution ratio of 1:10 has been recommended for the estimation of Ra-value of P. A laboratory study including a pot culture experiement was carried out using 18 laterite soil to evolve a suitable laboratory chemical method as an index for the estimation of available phosphate reserve (Ra- value) of the soil. The total plant removable phosphorus of the soils was determined by growing the rice (variety IR-8) continuously in the soils taken in pots, till the content of phosphorus in plants become below the critical level. To evolve a suitable extractants for the estimation of "Ra- value", H_2SO_4 and HCl at different concentrations were tried (Mathew Jacob. K, 1979).

A field experiment was carried out at the Instructional farm, to study the effect of graded doses of nitrogen, phosphorus and potassium on growth, yield and quality of ginger and also to develop suitable foliar diagnosis techniques in relation to these nutrient elements. The treatments comprised of three levels of nitrogen (40, 80 and 120 kg N ha^{-1}), phosphorus (30, 60 and 90 kg P_2O_5 ha^{-1}) and potassium (40, 80 and 120 kg K_2O ha^{-1}). The experiement was laid out in a 3^3 factorial experiement

in RBD confounding the effect of interaction NP^2K^2 totally. The group of 5 th to 12 th leaves appeared to be the best suited for foliar diagnosis of N, P and K status of the crop (Johnson. P. T, 1981).

A study was undertaken to standardize the foliar diagnosis techniques in coconut palm in relation to N, P and K, making use of the experimental palms of permanent NPK trial maintained at Coconut Research Station, Balaramapuram, Thiruvananthapuram districts. The palms received applications of N, P and K viz., 0, 340 and 680 g N, 0, 225 and 450g P_2O_5 and 0, 450 and 900 g K_2O palm -1 year-1 respectively. For standardization of tissue for foliar diagnosis, samples of leaf lamina and mid-rib were drawn separately from all the leaves of the experiemental palms (Gopi, C.S, 1981).

A field experiement was carried out at the Instructional farm, to study the effect of graded doses of nitrogen, phosphorus and potassium on growth, yield, uptake of nutrients and quality of turmeric and also to develop suitable foliar diagnosis techniques in relation to these nutirent elements. The treatments comprised of three levels of nitrogen (0, 20 and 40 kg N ha^{-1}), phosphorus (0, 20 and 40 0kg P_2O_5 ha^{-1}) and potassium (0, 40 and 80 kg K_2O ha^{-1}). The experiement was laid out in a 3^3 factorial experiement in RBD confounding the effect of interaction NP^2K^2 totally. The period between 90th to 120th days after planting was recommended as optimum period for the detection of the nutrient status of the crop (Saifudeen, 1981).

Pepper vines of the variety, Panniyoor-I of the NPK fertilizers trial maintained at the Pepper Research Station, Panniyoor and Kannur District were selected for the collection of tissue sanmples. The experiment was laid out in a 3^3 factorial experiement in RBD confounding the effect of interaction NP^2K^2 totally. In order to standardize the best leaf position for foliar diagnosis, the mature leaves of the fruit bearing laterals were numbered from the youngest to the oldest, taking the youngest fully matured leaf as the first. The first mature leaf is recommended as an index for the foliar diagnosis in pepper in relation to N,P and K status of the vine.The period just prior to flusing is the most suitable season for the collection of the leaf samples indented for foliar diagnosis (Sushama. P. K, 1982).

A study was undertaken to standardize the foliar diagnostic technique in coconut palm and to work out regression models for predicting the yield based on foliar nutrient contents. Palms were selected from three different zones of Kerala state, namely the Coconut Research Station, Balaramapuram and Agricultural Research Station, Mannuthy and the Regional Agricultural Research Station, Pilicode. Leaf samples were drawn from the leaf positions 2, 10 and 14 separatively from

each palm were analysed for nitrogen, phosphorus, potassium, calcium, magnesium and sodium. The leaf lamina of position 10 can be recommended as the best tissue for foliar diagnosis of N, P and K in coconut (Krishnakumar. N, 1983)

The surface soil studies of pazhamchira Ela, at Melkadakkavur of Chirayinkil Taluk, Trivandrum revealed that soils were highly acidic with the pH ranging from 3.4 to 4.8 and CEC was low to medium ranging from 3.8 to 9.9 me/100 g with an average base saturation of 49.7 with more than 50 percent of the exchange sites occupied by exchangeable Al and Fe (Girija, V 1986).

A study was conducted for the standardisation of index leaf/leaves to assess the nutritional status of clove (*Eugenia caryophyllus*) in relation to soil fertility. The canopy of each tree was equally divided into three regions as top, middle and bottom giving due consideration to the height of the canopy. The first emergence leaf is whorl – I, leaves just below the first whorl is classified as whorl II and leaves just below the second whorl is classified as whorl III . For the different nutrients the following leaves were identified as index leaves. (Gnanadas, D 1989)

A study undertaken with cashew plants of variety BLA-39-4 of the NPK trial at cashew in relation to nitrogen, phosphorus and potassium content of the leaf and to predict the yield based on the leaf nutrient levels. The treatments consisted of three levels of each nitrogen (250, 500 and 1000 g N plant $^{-1}$ year^{-1}), phosphorus (125, 250 and 500 P_2O_5 g plant $^{-1}$ year^{-1}) and potassium (250, 500 and 100 g K_2O plant $^{-1}$ year^{-1}). For standardization of leaf position and period of sampling purpose, the leaves were serially numbered selecting the last fully matured leaf, which was not having an inflorescence in the leaf axil as leaf No.1. Multiple regression models fitted with yield and percentage of nutrients in the leaves gave a maximum prediction of 55 percent when the nutrient content of the first group of leaves collected during the first and fourth stages of sampling were considered (Rosily Mathew, 1990).

A field trial to study the relationship of sugarcane yield and nutrient status through foliar diagnosis was carried out at Sugar cane Research Station, Thriruvalla with the hybrid variety COT1 88322 (Madurai) the treatments consisted of three leverls of nitrogen (0, 165 and 330 Kg N ha-1), phosphorus 0, 82.5 and 165 kg P_2O_5 ha^{-1}) and Potassium (0, 82.5 and 165.0 kg K_2 O ha -1). In order to standardise the leaf position, the leaf that just began to unroll (spindle like) was taken as the first leaf and other leaves were counted from the first leaf below. Step wise regression model fitted with yield and percentage of nutrients in different leaf positions at various stages of sampling gave a maximum prediction of 73 percent when nutrient content of the third, fourth and fifth leaves collected at the second stage of sampling was considered (Ramesh. V, 1994).

Table 1: The standarised leaf position of clove for the analysis of N,P,K, Ca, Mg & micronutrients

Nitrogen	Leaves of whorl I of top region
Phosphorus	Leaves of whorl I of bottom region
Potassium	Leaves of whorl I of top region
Calcium	Leaves of whorl III of bottom region
Magnesium	Leaves of whorl III of top region
Cu, Mn and Zn	Leaves of whorl III of bottom region

Fertilizer prescription equations for specific yield targets of ginger var. Maran in the laterite soil were derived as given below.

Without FYM

FN = 7.8T - 0.37 SN

FP = 2. 8T - 0.64 SP

FK = 10.6T - 0.833 K

With FYM

FN = 7.8T - 0.37SN - 1.11 ON

FP = 2.8T - 0.64 SP - 0.7 OP

FK = 10.6T - 0.835 SK - 1.13 OK. Where,

FN, FP, FK - Fertilizer N, $P_2$0S, and $K_2$0 respectively in Kglha.

T - Target of fresh rhizome yield in t/ha.

SN, SP, SK - Soil available N, P and K in kg/ha respectively.

ON, OP,OK - quantities of N, P and K supplied through organic manure in kg/ha.

Based on the fertilizer prescription equations ready reckoners were developed for different yield targets. (Jayalakshmi, M., 2001).

To study the ionic interactions and to unravel the role of Net Ionic Equilibrium based on Ratio Law on soil plant system, a sample of fifty phenotypically identical palms varying in yield from 14.4 to 84.4 nuts/ palm grown under an Ultisol were selected. Exchangeable K directly controlled the plant K content and plant K was positively and significantly correlated with the NIE ratios in plant and these ratios were positively and significantly correlated with yield. The negative significant correlation of exchangeable K with plant Mn and Zn revealed the antagonistic effect

of exchangeable K in restricting the absorption of Mn and Zn by plants. Among the ionic concentrations in soil solution, Fe was positively and significantly correlated with yield in both the seasons. Soil solution concentrations of Ca and Mg were antagonistically and significantly related with plant Mn content. Potassium content and the NIE ratio in index leaves were found to have a significant direct relation with yield in the pre-monsoon season. Potassium, Ca and Mg were the dominant cations in plant deciding the total cation concentration in index leaves. The NIE ratios between the exchangeable ions, the ions in soil solution and the ions in index leaf samples were mutually positively and significantly correlated among themselves.This lead to the conclusion that there exists a consistency in the relative proportion of nutrient ions in the entire soil-plant system which followed Ratio Law. The study lead to the conclusion that the soil test values of the individual ions alone or the plant content of individual ions alone can't give a clear picture of optimum nutrient requirements for the plant. The relative concentration of K in soil through the concentration in soil solution was found to govern the relative concentration in plant which in turn influenced the yield (Priya. P, 2003).

The investigation entitled STCR studies on groundnut (*Arachis hypogaea* L.) in laterite soils of Kerala was conducted during 2003-2004 in the farm attached to College of Horticulture, Vellanikkara. The nutrient requirements of groundnut variety TAG-24 were estimated as 49.46, 4.25 and 19.52 kg ha^{-1} N, P and K respectively to produce one tonne of pod. The soil efficiencies were worked out as 28.11, 7.70 and 6.88 percent for N, P and K respectively for groundnut in laterite soil. The contribution of nutrients from fertilizers were estimated as 45.61, 11.18 and 27.33 percent for N, P and K respectively and the contribution from organic manure were 49.46, 4.25 and 19.52 percent N, P and K respectively to produce one tonne of pod. Fertilizer prescription equations for specific yield targets of groundnut variety TAG-24 were derived by using the above basic data and the equations were as follows:

Without FYM

FN = 108.44 T - 0.616 SN

FP = 38.01 T - 1.577 SP

FK = 71.43 T - 0.305 SK

With FYM

FN = 108.44 T - 0.616 SN - 1.59 OM

FP = 38.01 T - 1.577 SP - 1.87 OP

FK = 71.43 T - 0.305 SK - 1.85 OK

Multiple regression models were calibrated with yield as dependent variable and soil available and applied nutrients as independent variables. Among the three nutrients, P and K showed normal type (+, -, -) of response in both models with 15 and 17 variables. So equations were calibrated for these two nutrients. The equations were as follows:

With 15 variables

FP = 32.47 - 0.709 SP

FK = 321.36 - 0.429 SK

With 17 variables

FP = 76.27 - 2.645 SP

FK = 312.37 - 0.413 SK

Simple correlation coefficient was worked out for nutrient uptake with yield, nutrient uptake and yield with available and applied nutrients and major plant nutrient content with yield.The study is useful to adjust fertilizer doses based on the specific objective and available resources of groundnut farmers of the state (Sidha, P. S., 2004).

An investigation on the nutrient interaction in soil test crop response studies on cucumber (Cucumis sativus L) in the laterite soils of Kerala was undertaken. In this, the field works were conducted as per the pattern of soil test crop response correlation studies. The crop, cucumber (Var.: AAUC-2), popularly known as salad cucumber, was raised and managed as per package of practices of KAU. The targeted yield equations for cucumber could produce the yield of 30 and 35 t ha^{-1} from the verification experiments, conducted at the different locations. The B:C ratio also was higher in the STCR methods over the farmers' practices, blanket recommendations and STL recommendations. The information generated in the project will help in making the soil testing programme scientifically sound in terms of achieving predicted yields, maintaining soil fertility and helping the extension agencies in ensuring balanced fertilizer use according to the soil fertility status and crop requirement (Sajnanath. K, 2011).

Behaviour of various chemicals in soil

An investigation on the fate of carbofuran applied to the soil basin of black pepper *(Piper nigrum L.)* was conducted. Laterite soils collected from the predominant pepper growing tracts of Kannur and Wayanad of Kerala state were used for the study. A field study was also conducted at the KADP farm attached to the College of Horticulture, Vellanikkara. The sorption of insecticide in soil was

found to be explained by Freundlich adsorption equation. The rates of sorption of carbofuran were not influenced by the organic matter contents. An initial lag period was observed prior to carbofuran degradation in soil under laboratory conditions. Only one metabolite (3-hydroxycarbofuran) was detected as the product of degradation. The total content of 14C derived radioactivity was high in plants grown in soils with lowest organic matter content and vice versa. Hence, bioavailability of the insecticide is less in soils with high organic matter contents. The residues of 14C-carbofuran absorbed plants left after HCl extraction, retained significant amounts of radioactivity which could be recovered following combustion. This indicated that determination of extraction efficiency by spiking or fortification of the samples with known quantities of insecticides would lead to over estimation of the recovery. The main metabolite of the carbofuran in the leaves was 3-hydroxy-carbofuran. Autoradiography of the bush pepper plants which was allowed to absorb 14C-carbofuran for 6 h showed that carbofuran was absorbed and translocated to the leaves and berry. Both carbofuran and hydroxycarbofuran were leached to the lower layers of soil (0-60 cm) during SW and NE monsoons. The content of hydroxycarbofuran was less than carbofuran in soils.In the foliage and berries carbofuran and the metabolite, 3-hydroxy- carbofuran accumulated. The content of hydroxycarbofuran was greater than that of carbofuran. The early harvesting and use of immature berries may lead to more concentration of pesticide in the produce. This will lead to chances of more residue build-up in the human system (Betty Bastin, 1996).

An investigation was carried out during 1996-1998 to study the fate of carbofuran in banana. An analytical method using HPLC was standardised for the estimation of carbofuran and its metabolite residues in banana. A series of studies were conducted to investigate the absorption, translocation and metabolism of carbofuran applied to banana at different doses, at different periods of time and through different routes of administration, with special emphasis on the residues in fruit. The treatments comprised of two levels and three modes of carbofuran application viz. soil application of 750 and 1500 mg ai /plant", leaf axil filling with 375 and 750 mg ai /plant and pseudo stem implantation with 375 and 750 mg ai/ plant. Absorption of carbofuran from soil application of 1125 mg/ plant (average of two levels) and leaf axil application of 562.5 mg/ plant (average of two levels) was similar. Absorption of the insecticide increased up to 10 days, declined thereafter and ceased by about 21 days. When the granules were implanted at a rate of 562.5 mg /plant (average of two levels) by boring the pseudostem, the absorption was much higher which continued up to 33 days. When applied by foliar spray of a 100 ppm solution, one-third of carbofuran was absorbed by third day and further absorption was limited. Carbofuran applied in soil enters the plant root dissolved

in water and hence soil moisture is a decisive factor in its availability. Since leaf axil is not a natural absorption site, carbofuran applied at the axil has to penetrate the cuticular barrier to enter the plant system. These absorption limiting factors do not exist in case of pseudo stem implantation and hence the high rate of absorption from pseudo stem. This new method of administration besides being more economic will help to reduce the pesticide load of soils cropped to banana. Persistence of carbofuran in leaf was determined by the method of application. In case of soil application, it persisted up to 33 days. In case of leaf axil application, it was detected in leaf up to 63 days. Similarly, when applied by pseudostem implantation, it was detected up to 63 days in leaf but the level was much higher. Degradation rate of carbofuran in banana in the three modes of application were 9.5d, 15.8d and 13.5 d respectively. Residue dynamics in leaf was characterised by a fast depletion of carbofuran with a concomitant build-up of 3-0H-carbofuran. At the end of the 63-day period post application, the residues consisted of 1.5 percent carbofuran and 98.5 percent 3-0H-carbofuran in addition to small amounts of 3-0H-carbofuran conjugate. Though small amounts of 3- ketocarbofuran were detected at the initial stages, its presence was transitory. The metabolism of carbofuran applied as a foliar spray was much slow with the result that the residues at 18 days comprised of 84.7 percent carbofuran and 15.3 percent 3-0H- carbofuran. A pathway of metabolism of carbofuran in leaf comprising of carbofuran, 3- OH-carbofuran, 3-ketocarbofuran and 3-0H-carbofuran conjugate is proposed. Evidence was gathered for the direction of movement of carbofuran in banana plant. Carbofuran applied to leaf was found to move only upwards and reverse movement was not observed. The terminal residues of carbofuran in banana grown in three soil types were studied. Carbofuran was applied at 750 and 1500 mg/ plant at the 7th month. Carbofuran residues were not detected in fruit. In a field experiment, carbofuran was applied at 8 times the recommended dose to banana after bunching (8th month). The residue distribution at harvest showed that about 96.2 percent of the total residues of carbofuran were concentrated in the leaf. Pseudo stem core, leaf sheath, peduncle, corm and fruit contained meagre amounts of the residue. Of the residues in the fruit, 91 percent was located in the fruit peel and the rest 8 percent in the fruit pulp. Banana in Trichur and Kunnamkulam town markets were periodically sampled during 1996-97 and anlysed for carbofuran residues. All the samples tested negative for carbofuran residues. Carbofuran is readily absorbed from granules applied in the soil, placed in the leaf axil or implanted in the pseudo stem. The residues are concentrated in the leaf where it is metabolised fast to 3-0H-carbofuran that persists up to the senescence of the leaf. Mobilisation of the residues to the fruit seldom occurs even at double the recommended dose and late application up to the 8th month (Vijayan A P 2000).

Residue studies related to field experiments were conducted, College of Horticulture, Vel1anikkara. Actinomycetal population in the soil was inhibited by the application of herbicide and the maximum percent inhibition (77.00 to 85.00per cent) was at 15 DAS. Effect of butachlor on supression of soil actinomycetes was found to be intermediary to bacteria and fungi. In the plot where FYM was applied, population of bacteria, fungi and actinomycetes were higher than that of other plots, which gave an indication that FYM could reduce the adverse effect of herbicides on soil rnicroflora. The data on weed count and dry matter production of different weed species showed that *Echinochloa* spp. contributed very much to total weed population and total dry weight. Build up in the population of *Echinochloa* spp. was observed with continuous use of pre emergence herbicides. The plot where pretilachlor fb 2,4-D was applied with 100 percent NPK as inorganic fertilizer recorded higher counts of *Echinochloa* spp. Application of 2,4-D was effective in controlling broad leaved weeds. None of the broad leaved weeds showed build up in the population. The plot which received butachlor fb 2,4-D with 100 percent NPK as inorganic fertilizer recorded highest grain and straw yield. From the study it could be concluded that at the present recommended rate of application, residues of herbicides butachlor, pretilachlor and 2,4-D do not persist in paddy soil to detectable level beyond 30 days. Residues were not detected in the grain and straw. Application of FYM enhanced microbial degradation of herbicides and reduced the adverse effect of herbicides on soil microflora. 2,4-D was highly efficient in controlling broad leaved weeds in the rice-rice system. Both pretilachlor and butachlor controlled grasses except *Echinochloa* spp. Butachlor had shown its superiority over pretilachlor in the weed management of rice-rice cropping system (Muthu Kannan, M. 2003).

Experiments were carried out to study the influence of organic matter and soil moisture on the adsorption of chloroacetanilide herbicides, *viz.*, butachlor and pretilachlor, in laterite soil. The pot culture study showed that adsorption as well as dissipation of herbicides was more in vermicompost treatment. The results also indicated that initial adsorption of herbicides was lessened by dissolved organic carbon released from the farmyard manure. However, the half life of herbicides was more in FYM treatment when compared to vermicompost and control (soil alone). The half life of butachlor was 17.00 days and that of pretilachlor was 19.00 days in FYM treatment. The results indicated the superiority of FYM in retaining the herbicides for the desired period of weed control in rice. Phytotoxicity due to herbicide application was more with vermicompost treatment than that of FYM and soil alone treatments. Biometric observations on plant height, productive tillers, yield of grain and straw showed that FYM is superior to vermicompost in improving the growth and yield of rice. From the above study, it could be concluded that

butachlor and pretilachlor are strongly adsorbed on soil organic matter and their adsorption in soils is affected by the presence of soluble organic matter. Presence of high levels of dissolved organic carbon in the FYM treatment at the time of application of herbicides resulted in a reduction in the magnitude of adsorption. On comparing two organic matter sources, it was noticed that total as well as dissolved organic carbon were higher in the FYM applied soil. The dissolved organic carbon would have facilitated movement of chemicals while the particulate organic carbon improved their retention. Therefore, it is essential to consider both these factors when pre -emergence herbicides are applied to rice (Hasna K, 2011).

The thesis entitled Impact of glyphosate and chlorpyriphos on chemical and biological properties of lateritic soil was done in the year 2012-2013 in the Dept. of Soil Science and Agricultural Chemistry, College of Horticulture, Vellanikara. This study showed that all the chemicals were avoided by earthworms and the maximum avoidance was obtained with the application of Roundup (12 mL L^{-1}) followed by Glycel (12 mL L^{-1}) and Dursban (8 mL L^{-1}). Glyphosate caused short term inhibitory effect on soil fungus up to 30 days after spraying, where as application of chlorpyriphos caused short term inhibitory effect on soil bacteria (up to 30 DAS). Population of soil micro flora did not vary between treatments at 60 days after spraying glyphosate and chlorpyriphos formulations. Dehydrogenase activity and available nutrients in the soil were unaffected by the application of glyphosate and chlorpyriphos formulations used in the study (Shitha C. R, 2014).

Composting techniques

The study on the Standardization of Techniques for Production and Enrichment of Vermiwash was conducted at College of Horticulture, Vellanikkara, during the year 2003-2005. The earthworm population was found to be controlled by a substrate controlled criterion. Even the substrate combination containing good portion of coconut leaves becomes conducive for worm multiplication by the proper blending with succulent substrates like banana pseudostem. As the substrate combination, banana pseudostem: glyricidia leaves: coconut leaves: cowdung in the ratio 2:2:2:1 registered the least C: N ratio of 12.25 which attained maturity within 47 days, it was identified as the best substrate controlled environment for vermicompost production. The selected treatment which comprised of Banana pseudostem: Greenleaf: Coconut leaf: Cowdung in the ratio 2:2:2:1 registered a pH of 7.68 and nutrient contents of 1.19, 0.36 and 0.87 percent respectively. It had a relatively good load of microflora as the banana pseudostem favours the flourishment of the microbial and worm population.The selected substrate combination was taken for the further enrichment techniques. An Organic Enriching Media (OEM) was prepared using neemcake, poultry manure and bonemeal.

Vermiwash was collected after the compost maturity. The plain vermiwash was enriched by mixing OEM @ 10 percent of substrate. The resultant and best enriched vermiwash registered nutrient contents of N (1.425 per cent), P (0.096 per cent), K (0.410 per cent) and Zn (169.0 ppm) with a pH value of 8.01. The soil application of vermiwash at 50 percent field capacity also proved better than foliar application of vermiwash. The crude protein content was also higher in foliar application of urea as well as in soil application of vermiwash at 50 percent field capacity. For fertigation, the vermiwash was found to be very effective on the test crop of amaranthus (Thankamony. K, 2005).

The study on Calcium dynamics in substrate-wormcast-mushroom-plant continuum was conducted at College of Horticulture, Vellanikkara during October 2006 to May, 2010. Cow dung was the best substrate for the production of calcium rich wormcast. The wormcast, coirpith compost and termite mud dune are not suitable as substrate for milky mushroom but are suitable as casing materials. Wormcast at a level of 20 percent of substrate is the best casing material for milky mushroom as compared to coirpith compost, termite mud dune and soil. Spent mushroom at a level of 50 percent of recommended dose of vermicompost is sufficient for a mean yield of 0.770 kg pot $^{-1}$ in tomato. There is much addition of calcium from the different sources both to the exchangeable and non-exchangeable pool of soil calcium (Bindhu. C.J, 2010).

The study on Utilization of elephant dung for vermicompost production was undertaken at College of Horticulture Vellanikkara during the period 2009-11. In order to study the effect of macro and micro fauna on the in situ decomposition of elephant dung, a field monitoring was undertaken by identifying six stages of degradation of dung viz. more than one year old (E1), one year old (E2), eight months old (E3), four months old (E4), and fresh sample constituting of body washings (E5) and faecal bolus (E6). The results revealed that the temperature of degrading dung was always higher than atmospheric temperature indicating that natural decomposition was a continuos process. Higher microbial activity was observed in fresh dung which resulted in lowering the C: N ratio of old dung. Among the native microbes isolated from the dung, bacteria were found to have a predominant role in lignocellulose degradation. The manurial value of elephant dung was estimated as 48.18 percent C, 0.86 percent N, 0.34 percent P, 0.37 percent K, 0.19 percent Ca, 0.05 percent Mg and 0.25 percent Na with a pH value of 6.9. Dung was rich in crude fibre (21.4 per cent) and low in crude fat (2.8 per cent). Cellulose, hemi cellulose and lignin fractions were accounted as 35.8, 30.1 and 17.5 percent respectively. The third experiment was vermicomposting which was done to identify the suitable microbial decomposers for pre-composting and the best

substrate controlled environment for the same. *Eudrillus euginae* was used as the compost worms. The different factors involved are the microbes and substrates at different levels. The factor without microbes was compared with *Pleurotus platypus*, combination of *Aspergillus flavus* and *Bacillus subtilis* and native microbes. Different substrate levels used for vermicomposting included FYM and banana pseudostem in 1:1 and 1:8 proportion, FYM and elephant dung in 1:1 and 1:8 ,elephant dung and FYM in 1:1 and 1:8. Based on the daily observation of the compost pile of elephant dung, four stages of composting namely thermophilic (10-15 days), mesophilic (25-30 days), cooling (5-8 days) and maturity (5-10 days) were identified. After thermophilic stage worms were introduced and found that substrate combination of FYM: ED (1:8) recorded seven to eight fold multiplication in earth worm population and a maturity period of 56 days which was on par with the substrate composition of FYM: ED (1:1), recording 54 days (on an average). The biotically enriched dung also recorded the manurial value of 10.78 percent C, 1.34 percent N, 0.66 percent P, and 0.61 percent K. 0.67 percent Ca. 0.04 percent Mg and 0.12 percent Na with a pH value of 7.3. Among the microbes used, consortium of *Aspergillus flavus* and *Bacillus subtilis*, was found to be efficient in lignocellulose degradation which was on par with *Pleurotus platypus*. The FYM and elephant dung in the ratio 1: 8 must be pre composted with *Aspergillus flavus* and *Bacillus subtilis* in order to reduce the maturity period of compost. Moreover the same treatment recorded high rate of microbial activity, maximum earth worm multiplication rate and high nitrogen, phosphorous and calcium status with minimum maturity days for composting. Regarding the practical utility of work, it was found that a benefit cost ratio of 1.2 was estimated for vermicomposting of elephant dung using a tank ($1m^3$) of 300 kg capacity and with the introduction of 1500 earthworms for a period of 50- 60 days with the help of effective lignocellulose degraders, *Aspergillus flavus* and *Bacillus subtilis* (Rekha.V.R Nair,2011)

A study on Suitability of azolla (Azolla pinnata) for biogas slurry enrichment was conducted during 2010-11 at College of Horticulture, Vellanikkara to evaluate the optimum ratio of cow dung and azolla for biogas slurry enrichment, to identify the best material to prepare quality organic manure from the enriched slurry and also to adjudge the crop response to enriched organic manure. The results indicated that mixing of cow dung and azolla in a proportion of 1: 0.5 produced the highest volume of gas (0.29 m3 kg-1 TS) in 20 days of Hydraulic Retention Time (HRT). But the proportion of 1: 1 favored in terms of N (3.44 per cent) content in slurry followed by 3.23 percent in 1: 0.75 ratio. These treatments were designated as enriched slurry I (3.44 percent N, 0.74 percent P and 2.93 percent K) and enriched slurry II (3.23 percent N, 0.77 percent P and 2.91 percent K). Addition of azolla increased pH from 7.1 to 7.8 but decreased the total solids of slurry from 5.40 percent in cow

dung alone to 2.68 percent in the ratio of 1: 1. Based on the nutrient content, powdered coconut leaves were identified as the best material and the requirement was 612 g per litre in enriched slurry I and 607 g per litre for enriched slurry II.Crop response to the enriched manure I and II was assessed in pot culture with rice (variety- Jyothy) as the test crop. The treatments were control (T1), NPK+FYM (T2), FYM alone (T3), enriched manure I (T4), enriched manure II (T5), enriched manure I+NPK (T6) and enriched manure II+ NPK (T7). The grain (44.97 g pot-1) and straw (72.73 g pot-1) yield was maximum when the crop was nourished with enriched manure II in association with the recommended dose of chemical fertilizers. Crop uptake of N (4260 mg pot-1) and K (4263 mg pot-1) was also the highest in this treatment. Soil physico-chemical properties were also favorably influenced by the manure application. A shift in pH from 4.7 to 5.4 was obtained consequent to applying enriched manure I. Soil status of available N (1536 mg kg-1) and available K2O (471 mg kg-1) was the highest when enriched manure II was applied along with the recommended dose of chemical fertilizers. The content of available P2O5 in soil was the maximum (52.7 mg kg-1) when chemical fertilizers were excluded from this treatment. (Bishnu Prasad Paudel,2012).

The study on the Production and evaluation of proteinaceous earthworm meal was conducted at College of Horticulture, Vellanikkara during the period of 2011-2012. The results revealed that the best substrate for the multiplication of exotic worm was azolla. Considering the manurial value of native worm cast, the treatment with azolla as the main substrate was found to be better than other treatments (0.78 percent N, 0.39 percent P, 0.59 percent K, 0.17 percent Ca and 0.47 percent Mg). Irrespective of the substrates and types of worms, the worm cast maintained a pH range of 6.5 to 7.8. A simple and cost effective method was proposed for the preparation of worm meal with the clearing of earthworm gut using cellulose material. The crude protein (46.37 per cent), crude fibre (1.00 per cent) and crude fat (10.33 per cent) were found to be comparatively rich in exotic worm meal. The total protein content was also higher in exotic (43.45 per cent) than native worm meal (41.61 per cent), but the total carbohydrate was low in both cases with the values 15.03 and 19.06 percent (as compared to FAO specifications for fish feed) respectively. All the essential and non essential amino acids except proline, tryptophan, cystine and cystine hydrochloromonohydrate were qualitatively detected in all the feeds including worm meals. There is no appreciable change in pH and EC of aquarium water with the continuous use of worm meal as a feed for the ornamental fish, Red Oscar (Fasila, E. K. 2012).

In order to find out an efficient substrate from the available substrates in Kerala for biogas production and to determine manurial value of different types of slurry, the present study was undertaken at College of Horticulture, Vellanikkara during

2012 – 2014. After harvest, of cowpea, the highest organic carbon content was noted in soil which was irrigated with biogas slurry produced from elephant dung and cow dung combination. The highest available nitrogen and available phosphorous content was recorded for soil irrigated with slurry produced from cow dung alone and cow dung and pulse residue combination. Available potassium content in soil was highest for the soil which was irrigated with slurry produced from poultry manure and cowdung combination which was on par with slurry produced from elephant dung and cow dung combination. The plants irrigated with the slurry produced from cow dung pulse residue combination and cow dung elephant dung combination had recorded high uptake of total nitrogen. Plants raised from the seeds obtained from these treatments showed greater shoot length, seedling length and vigour index. However elaborate studies are necessary to monitor the hormone present in different types of slurry generated from different substrates (Anooja C. Lonappan, 2015).

The experiment to evaluate the effect of biogas slurry on germination of mango seed stones was done in CRD consisting of seven treatments and three replications. Two varieties (Moovandan and Bangalora) were made use of. The germination percent and vigour index was found to be maximum for pre soaking with fruit waste slurry which was closely followed by presoaking with cow dung slurry for both the varieties. After germination the reducing sugar content of mango stones of both the varieties were found to be increased compared to the initial content. The nutrient uptake for almost all the nutrients was higher with presoaking treatments with the slurry. There was significant decrease in available soil nutrient contents after the experiment as compared to the initial contents in potting mixture used for the study due to crop uptake (Aswathy Gopinathan, 2015).

Soil quality

In order to meet the objectives of the study "Assessment of Selective Retention Sites of Cadmium and lead in Tomato (Lycopersicon esculentun Mill)", a pot culture experiment was conducted in theVegetable Research Farm attached to the Department of Olericulture, College of Horticulture, Vellanikkara during the rabi season of 2003. Preliminary indications appeared on leaves with such leaves picking up yellowing and inter-veinal chlorosis depending upon the metal load. At high concentrations of the metal, invariable splitting up of the stem at the collar region leading to complete death of such plants has been noted. As concentration of the cadmium load increased beyond 1.5 mg kg^{-1} soil, the tomato plants failed to fruit and at the highest concentration of the metal envisaged in the study (2.0 mg Cd kg" soil), the very establishment of the transplanted tomato crop was questioned. However, the successful survival and fruiting of the transplanted tomato plants was

noted only at lower levels of cadmium addition (0.5 and 1.0 mg Cd kg" soil). Lower doses of addition of cadmium had exhibited negative influence on growth and development in tomato with the manifestation of significant reduction in number of branches, leaf length, leaf number, plant height, the production of trusses and subsequent reduction in yield. Roots of tomato are seen to preferentially harbour more of cadmium than its other plant parts particularly at higher levels of addition. Increasing levels of lead invariably decreased the root nitrogen content significantly while shoots content of nitrogen increased generally with lower doses of metal addition. Variation in, lead levels permitted a significant increase in the phosphorus content in roots, shoot and fruits. No specific trend was noted in the retention of potassium by roots while shoot portions indicated significant influence of the same by offering differential content of potassium in them. The total absence of any phyto-toxicity testifies that the tomato plants are able to tolerate high concentrations of lead inside them. Lead application in soil, irrespective of its levels, permitted maximum accumulation of the metal in fruits followed by shoots and roots. All accumulations noted in the plant were observed to be significant, projecting serious concern for the silent inclusion of lead in the economically important part of the plant. Variable amounts of cadmium and lead have been detected in the post-harvest soils indicating that the entire quantity of the applied cadmium and lead could not be completely absorbed by the plant (Vanisree, K. 2004).

An investigation has been carried out to study the Long term effect of field management on soil quality in Ultisol in the main campus of KeralaAgricultural University, Vellanikkara, during December, 2012 to June 2013. Five different fields were selected namely, natural forest, rubber plantation, cocoa garden, and STCR experimental field and tapioca fields. The physical characteristics like water holding capacity, soil aggregate stability and soil temperature showed a decreasing trend with depth in the different fields. Forest ecosystem showed the most conducive physical characteristics followed by cocoa and rubber. The contents of available nutrients, secondary nutrients and micronutrients were found to be the highest in surface samples. The forest ecosystem showed relatively high values for organic carbon, and available nutrients like nitrogen, sulphur, boron, iron, manganese, zinc and copper. Microbial activity was found to be the highest in surface soils in almost all fields. The highest counts of bacteria and actinomycetes were reported in forest ecosystem and lowest in tapioca field. Fungal activity was found to be the highest in the cocoa field followed by forest ecosystem. Enzyme activitywas also found to be the highest in surface soils in the different fields.Soil quality was evaluated using available soil quality indicators. Based on scoring with the soil quality parameters, the highest scoring was observed for natural forest followed by cocoa field. Correlations between various soil quality parameters of different fields were also worked out (Nithya. A. M, 2013).

The research work entitled "heavy metal contamination of laterites by accumulation of solid wastes" was undertaken during the period 2010-2014. The project aims to investigate the extent of distribution of heavy metals (As, Cd, Cr, Pb, Hg and Co) in waste dumping sites of laterite as influenced by soil and climatic conditions using geostatistical technique, to correlate the activity of major soil enzymes with the contents of heavy metals, to explore the potential of phytoremediation as well as aerobic and anaerobic methods of composting for the removal of heavy metals in solid waste and to evaluate the performance of amaranthus under different decontaminated methods adopted. In order to attain the objectives, four experiments were conducted. The effect of soil and climatic factors on heavy metal accumulation was examined with the collection of soil samples at quarterly intervals for a period of one year from two different waste disposal sites located at Laloor and Kalamassery. For the study on phytoremediation, the crops, vetiver, marigold and sunflower were experimented. Both the aerobic and anaerobic methods of composting were tried for the removal of heavy metals in another set of experiment. A pot culture study was also conducted to assess the growth of amaranthus under different decontaminated conditions. The comparative performance of amaranthus grown in soil under different methods adopted for reducing heavy metal contamination showed that the yield was found to be the highest in the treatment with aerobic compost. The lowest yield was reported for amaranthus grown with phytoremediated material, followed by absolute control. The uptake of major nutrients also followed the same trend as yield. The heavy metal content was higher in the shoots of amaranthus grown with waste material and the accumulation followed the order Cr>Pb>Ni>Co>Hg. In all the treatments under study, the presence of Cr was more dominant in the post harvest soil compared to other heavy metals (Divya Vijayan, V 2015).

Think it over

- ✓ Substitution of K_2O by Na_2O to the extent of 50 per cent applied to the coconut palm was possible without a reduction in the yield, quality of oil and adverse effects of the soil characteristics, under the climatic and soil conditions of Pilicode.
- ✓ For achieving a higher net return from banana cultivation along with.

  other inputs like FYM and mulch, the use of 3/4 level of P and Phospho bacteria inoculation must be considered.
- ✓ Fertilizer application in black pepper gardens must be restricted to a semicircle of radius 30 cm facing the vine irrespective of the type of standard for the maximum utilization of the added inputs.
- ✓ Sub surface zone with high concentration of exchangeable Al existed in laterite soil of the pepper garden and Phosphogysum offerd a potential option for ameliorating the subsoil layers and to promote root growth of black pepper to deeper soil layers.
- ✓ Latex sludge can be used as an alternate and cheap source of P in crop production.
- ✓ The exchangeable aluminium contributed 69 to 86 per cent towards exchangeable acidity and should be taken into account in liming and nutrient management of the laterite soils.
- ✓ The group of 5th to 12th leaves between 19th and 120th day of planting was proved to be the best suited for the foliar diagnosis of N, P and K in ginger.

3. Red soil

These are found mostly in the southern parts of Thiruvananthapuram district and in pockets in catenary sequence along the foot slopes of laterite hills and mounds. These soils are identified in undulating plains of lowland with a general slope of 3 to 10 per cent. These are mostly very deep and homogeneous in nature. The texture of the soil generally ranges from sandy clay loam to clay loam with red to dark red colour. Gravels are rarely noticed in these soils. A variety of crops such as coconut, arecanut, banana, yams, pineapple, vegetables, fruit trees etc., can be grown under proper management.The soils have red colour, which has been attributed to the presence of hematite or anhydrous ferric oxides. The rapid permeability of the surface soils also has been responsible for the characteristic development of these loamy soils, which are very deep and homogeneous without much expression of horizons. They are not fertile due to low organic matter content as well as low essential plant nutrients. These soils are essentially kaolinitic in nature, acidic in reaction and friable.

Genesis, morphology and general characteristics:

"Dynamics of zinc in Typic kandiustults with special reference to nutrition in fodder maize (*Zea mays* L)" was under taken at College of Agriculture, Vellayani. The profile study was done in detail. The various physic chemical properties were determined and reported. The soil of the experimental area was found to be Clayey, Kaolinitic, and Isohyperthermic Typic Kandiustults belonging to Vellayani Series (Thankamoni, 2010).

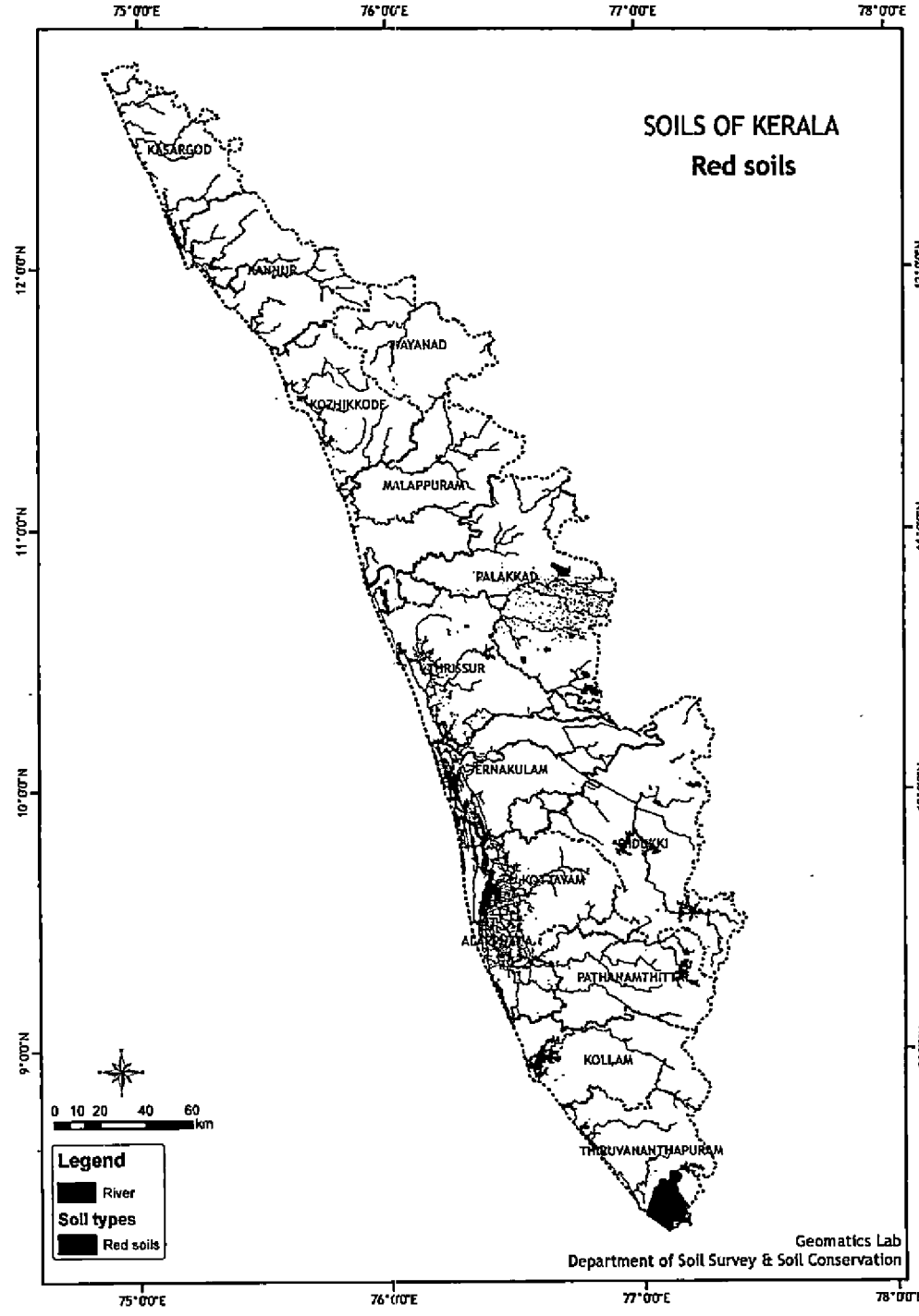
Table2: Physiochemical properties of Red soil (location Vellayani)

Physico-chemical properties	Surface (0-15 cm)	Subsurface (15-30 cm)
Sand (per cent)	73.90	69.50
Silt (per cent)	10.00	12
Clay (per cent)	15.10	18.30
Particle density (Mg m^{-3})	2.36	2.38
Bulk density (Mg m^{-3})	1.28	1.30
WHC (per cent)	38	40.20
Texture	Sandy loam	Sandy loam

Chemical properties		
pH	5.10	5.20
EC (dS m^{-1})	0.12	0.16
CEC (c mol (P+) kg^{-1})	3.59	2.43
Organic carbon (per cent)	0.71	0.69
Available Nitrogen (kg ha^{-1})	271.00	227.50
Available Phosphorous (kg ha^{-1})	22.64	24.3
Available Potassium (kg ha^{-1})	88.92	102.7
Exch. Ca (c mol kg^{-1})	1.42	1.01
Exch.Mg (c mol kg^{-1})	0.45	0.32
Available S (kg ha^{-1})	12.21	10.64
DTPA Fe (mg kg^{-1})	22.60	16.59
DTPA Mn (mg kg^{-1})	8.64	6.80
DTPA Zn (mg kg^{-1})	0.48	0.42
DTPA Cu (mg kg^{-1})	0.84	0.80
Fractions of Zn (mg kg^{-1})		
Ws+Ex-Zn	0.31	0.30
OB-Zn	1.82	0.60
MnO-Zn	0.80	1.01
Am-FeO-Zn	14.10	12.69
CryFeO-Zn	28.94	24.99
Res-Zn	43.63	43.18
Total Zn	89.60	82.50

Nutrient dynamics

An investigation was carried out at the College of Agriculture, Vellayani to evaluate the effect of vermicompost enriched with Rock Phosphate on P availability, yield and quality of cowpea and the feasibility of reducing the inorganic P. The variety used was Kanakamoni. Yield attributes like number of pods per plant, number of seeds per pod and hundred seed weight and total grain yield were significantly


SOILS OF KERALA
Red soils
75°00'E
76°00'E
77°00'E
78°00'E
12°00'N
11°00'N
10°00'N
9°00'N
KASARGOD
KANNUR
WAYANAD
KOZHIKKODE
MALAPPURAM
PALAKKAD
THRISSUR
ERNAKULAM
IDUKKI
KOTTAYAM
ALAPPUZHA
PATHANAMTHITTA
KOLLAM
THIRUVANANTHAPURAM
0 10 20 40 60
km
Legend
River
Soil types
Red soils
Geomatics Lab
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increased by the application of enriched vermicompost. Vermicompost primed with full RP or with half RP produced no significant difference in grain yield. Thus the results revealed that inorganic phosphate for cowpea could be reduced to half of its recommended dose by priming vermicompost with RP. Analysis of plant samples at harvest showed that maximum content of macronutrients except Mg was recorded by enriched vermicompost. It showed its superiority over other treatments for protein and P content of grain. Enriched vermicompost also registered significant increase in soil available N, P and K after the experiment. Uptake of macronutrients was significantly influenced by different treatments (Sailajakumari M. S, 1998).

The research work entitled " Effect of sulphur on yield, quality and uptake of nutrients by cowpea (*Vigna unguiculata* L Walp)" in a Rhodic Haplustox was conducted at Instructional farm, College of Agriculture, Vellayani. The study was undertaken to evaluate the effect of different levels and sources of sulphur application on yield, quality and uptake of nutrients by cowpea using the *var.* Kanakamoni. A 42 percent increaese in yield over control was recorded by 30 kg S /ha as gypsum along with POP recommendations. A significant increase in yield attributes and protein content (25.39 per cent) was also noticed through S fertilization. Uptake of N,P, K, Ca, Mg and S were increased due to S fertilization indicating a synergistic effect. All the growth characters and yield attributes were best correlated with yield. Uptake of nutrients showed positive and significant correlation with yield. Field experiment revealed that S as well as combination of S with organic manures exerted significant effect on most of growth and yield attributing charecters of cowpea. The treatment combination with normal level ofNPK and FYM along with S @ 30 kg ha^{-1} was found significantly superior to other treatments. Gypsum as the source was found to be superior to factamphos (Beena. V. I, 2000).

The study on the dynamics of zinc in Typic Kandiustults with special reference to nutrition in fodder maize (Zea mays.L) was carried out at College of agriculture, Vellayani and the results indicated that the application of Zn @ 15 kg ha^{-1} as soil application along with 120:60:40 NPK kg ha^{-1} + FYM 10 t ha^{-1} for the first crop of fodder maize helped to skip the Zn application for the succeeding crop. From the studies on foliar diagnosis to identify the index plant part of this crop, 3rd leaf lamina from the tip at 25 DAS was selected as the index plant part. The content of Zinc in the 3rd leaf lamina was found to be 21 mg kg^{-1}. Foliar spray @ 0.75percent Zn during the crop growth was recommended on identifying zinc deficiency to the crop. The percentage share of different fractions in the surface soil to the total Zn was as follows i.e, Ws+exch.Zn (0.53-3.99per cent), 0B-Zn(2.15-3.34per cent), MnO-Zn (0.21-0.92per cent), Am. FeO-Zn (17.75-35.30per cent) and Cry-Fe-O Zn

(30.40-59.32per cent) and RS-Zn (16.62-36.91per cent). A path coefficient analysis was also carried out with the different fractions of Zinc on the yield of fodder maize and the results revealed the direct effect of water soluble + exchangeable fraction of soil Zn on the yield of fodder maize (Thankamony K, 2010).

A study regarding "Site Specific Nutrient Management (SSNM) in Chilli (*Capsicum annuum*.L.)" was carried out in Kalliyoor Panchayath of .Kerala. The results derived from the experiment proved the superiority of SSNM over other treatments with respect to the yield, major and micronutrient uptake. High yield target registered a cumulative yield of 17.32 tons, medium yield target registered a cumulative yield of 11.75 tons which was much superior to POP+SNMN that registered a yield of 9.83 tons. Farmers practice registered inferior yield of only 5.2 tons. This technique also provides a scope of increasing the yield without, over application of fertilizers that would result in deterioration of the soil physical and chemical properties in the long run (Priya U. K, 2011).

An investigation entitled Iron and Zinc fortification in amaranthus (*Amaranthus tricolor*) through bioaugmentation has been carried out at the College of Agriculture, Veilayani. The main objective was to study the effect of Fe and Zn application and bioaugmentation of soil with microbial additives on yield and nutrient composition of amaranthus. This was accomplished through a pot culture experiment using laterite soil.From the above experiment, it was concluded that the treatment combination POP x Fe @ zero x Zn @ 10 mg kg^{-1} recorded the highest economic yield and B: C ratio. Considering the nutritional quality and iron and zinc content of economic plant part, the treatment combination K solubilizer x Fe @ zero x Zn as foliar, was found to be the best treatment (Amla Sakthidharan, 2014).

The results of trials undertaken to study the effect of zinc biofortification through mineral fertilization on pod yield and quality of yard long bean (var.Vellayani, Jyothika) showed that foliar application of $ZnSO_4$ at 0.05 percent at branching and flowering stages of the crop increased pod yield and zinc density in the plant while reducing the antinutritional factor, phytate content of the pods. The lowest phytate: Zinc ratio and the highest benefit cost ratio were also for this treatment (Dhanya.G. 2015).

Physical and chemical attributes

The red soils identified for the study were of the Vellayani, Cherniyoor, Bharanikkavu, Beypore, Chirakkal and Kunhimangalam series located in the Trivandrum, Quilon, Calicut and Cannanore districts. Morphological features of the profiles revealed prominent red hues, the intensity of which increased with depth. The profiles were well drained, with ill defined horizons,but they exhibited good

structural development without the presence of coarse fragments. All the soils were sandy in texture with a predominance of the fine sand fractions. There were indications of clay illuviation in all the profiles. Pofiles of Red soils of Vellayani, Bhaarnikavu, Beypoe, Chirakkal and Kunhimangalam series revealed permanent red hues and their intensity increased with depth. All soils were sandy in textue with ill defined horizons. All soils were acidic with low EC and organic carbon. Aailable N and K were low to medium and available P was high (Betty Bastin, 1985).

The physical properties of soil like the bulkdensity, particle density, porosity, volume expansion, surface compaction, moisture retention characteristics hydraulic conductivity, textural properties and soil temperature were found to be not much affected by the continuous use of chemical fertilizers to coconut. The only parameter, which was found to be highly influenced by the long term use of NPK fertilizers, was the structural index *viz.*, the mean weight diameter. With the increase in phosphorus and potassium levels, an increase in mean weight diameter was observed where as there was a decrease in mean weight diameter with increasing levels nitrogen. The yield characteristics of the palms and the physical properties of the subsurface soil were found to be related with each other (Chithra, V.G, 1993).

The study entitled Effect of vermicompost (VC) on the electrochemical properties and nutritional characteristics of variable charge soils has been carried out during 1994-95. From the experiment it was proved that lower doses of vermicompost could be equated with higher doses of FYM and ordinary compost. The major effects were the reduction in P-fixation and increased P solubility in presence of vermicompost. Vermicompost application in combination with chemical fertilizers was proved to be the best among treatments tested. Lower doses of VC (10 t ha^{-1}) with lime and fertilizers were equally effective as higher doses (20 t ha^{-1}) of other organic manures studied. Analysis of plant samples at critical stages of growth also revealed the same effect. Soil analysis data after the pot experiment had further established the superiority of VC over other treatments. This indicated the ability of VC to sustain a higher level of soil fertility for a sufficiently longer period of time (Bijulal. B. I, 1997).

Response to fertilizers

A field experiement was laid out in strip plot with RBD in the Agricultural College Farm, Vellayani, to study the effect of inoculation of blue green algae in conjunction with fairly high doses of nitrogenous fertilizers on the growth and yield of rice. Lime and molybdenum were also included as treatments. An increase in yield of rice corresponding to the addition of 30 kg/ha Nitrogen would be achieved by the inoculation of blue green algae. Application of lime and Mo was not found necessary

for the better performance of BGA under the conditions existed in Vellayani farm. Application of lime and Mo was not found necessary for the better performance of algae under the conditions which existed in the area (Salafudeen. S, 1970).

The middle one third of the total petioles as found to be the best reflect for N, P and Ca and lower to middle one third of either petioles or lamina for K in cassava (Pushpadas. M.V,1968). Neutral normal ammonium acetate is best extractant for available K in soils (Prabhakumari. K, 1981).The lamina of second leaf is recommended as best for foliar diagnosis of NPK in coconut (Gopi. C. S, 1982).The nitrification-inhibition capacity was found to be in the order of neem> mahua> marotty> rubber> karinja cake. When oil cakes are used as nitrification inhibitors, either additional dose of K should be supplied or the time of application of K may be changed for effective uptake of N and K. (Sathyanathan. K.M, 1983).

The optimum level of N,P,K for the Cassava is 100:300:300 kg ha^{-1} and this optimum level with FYM @12.5 t ha^{-1} produced a tuber yield of above 40 tonnes ha^{-1}.(Susan Johan. K, 2003). Liming at 500 kg ha^{-1} increased the yield and yield components of cowpea significantly. (Latha. R, 1984).

Nitrogen fixing process of cowpea continued beyond its maximum harvest stage. Highest residual effect of N fixed by the cowpea obtained a minimum of 60 kg N / ha. Maximum nitrogen gain through fixation, by growing legume crops can be achieved only if the plant is allowed to complete its full growth period. (Indira. M, 1985).

Effect of phosphorus sources on growth and yield of cowpea reported single superphosphate as the best followed by Mussorie phosphate. Mussorie rock phosphate treatment for cowpea followed by a rice crop gained maximum net profit of Rs. 3317/ha (Omana. M, 1986). Urea-neem cake blend increased the N use efficiency of cassava. The maximum benefit was obtained for an application of 75 kg K_2O/ha along with 50 kg N/ha as urea neem cake blend (Manorama Thampatti, 1985).

An investigation was carried out to study the effect of application of Ca, Mg, S and B on the yield and nutrition of groundnut under the agro-climatic conditions of the southern regions of Kerala. A field experiement was laid out in the red loam lateritic soils of Vellayani using different carriers of Ca and Mg, and the combinations therefore, with two levels of Kand B. The different sources of calcium and magnesium were gypsum and magnesite. Two level of K viz., 40 and 60 Kg K/ha, as well as two levels of B, viz., 0 and 10 kg B/ha, as borax, were also included. Dolomite with higher dose of K and gypsum + Magnesium carbonate with lower doses of K increased the yield of ground nut Gypsum application increased the yield and

shelling percentage of groundnut. Ca and Mg (when applied together) as well as Boron enhanced the oil content (Sureshkumar. P, 1985).

A study conducted on the wetlands of Vellayani on the effect of top dressing paddy with phosphorus in the form of ammophos and super phosphate in addition to a basal application on the yield of grain and straw. The result indicated that peak phosphorus absorption by rice occurs at maximum tillering stage and that the phosphate application at or after panicle initiation was not likely to be helpful in bringing about the desired yield increase in rice (Sam Mathew, 1990).

A study was undertaken to assess the effect of application of potassium on the growth, yield and quality of banana cv. Nendran.The maximum bunch yield was recorded at an application rate of 450 g K_2O per plant. From the practical point of K management, the petiole at late vegetative stage (4 MAP)) was considered as the standard reflect for plant analysis for K. Critical K level in the soil at late vegetative stage was determined both statistically and graphically which was 218 kg ha^{-1} for maximum yield and 164 Kg ha^{-1} for economic yield. Linear regression model was developed relating the exchangeable K content of soil at late vegetative stage with different fertilizer doses tried and it may be predicted that 250 g K_2O per plant is to be applied at the late vegetative stage for maximum yield and 118.5 g per plant for economic yield. Considering the economics, application of 450 g K_2O per plant showed superiority in terms of highest benefit/cost ratio of 2.35 (Sindhu. J, 1997).

An investigation was carried out at the Instructional Farm attached to the College of Agriculture, Vellayani in two experiments to find out the effect of soil and foliar application of vermiwash on growth, yield and quality of tomato. Application of vermiwash along with inorganic fertilizers produced marked increase in fruit yield. At higher concentrations (50 and 25 per cent) of vermiwash, inorganic fertilizers could be reduced to half of the recommended dose without any yield reduction. It wasalso observed that at higher concentration, foliar spraying was found to be better whereas at lower concentration soil application was more effective. Vermiwash application through the foliage along with inorganic fertilizers resulted in a higher seedyield. Soil application of vermiwash produced fruits with more shelf-life.The different concentration of vermiwash produced positive influence on the lycopene content of tomato, but no influence on the ascorbic acid and crudefibre content. Nutrient content of plant and fruits were influenced by the vermiwash application. Plant uptake of major and micronutrients were maximum for the highest concentration of vermiwash applied through foliage along with full inorganic fertilizers. The study revealed that vermiwash application in conjunction with inorganic fertilizers could increase the yield and the quality parameters of tomato (Rani Jasmine, 1999).

A field experiment was conducted at the College of Agriculture, Vellayani during August 1999 to June 2000 to study the extent of substitution of K of muriate of potash by Na of common sait in banana cv. Robusta and it was concluded that upto fifty percent of the K requirement of Robusta banana, grown in soils of low K status, couldbe replaced by Na of common salt (Sunu. S, 2001).

In order to achieve maximum yield with minimum fertilizer and to develop an economically viable fertilizer recommendation in banana cv. Nendran, a systematic approach in fertilizer use was experimented in red loam soils of Vellayani, Kerala. The treatments composed of four levels of each fertilizer N (60, 120, 180, 240 g plant), K_2O (80, 160, 240, 320 g plant), Ca (0, 190, 380, 570 g plant^{-1}) and a single level of Mg (120 g plant^{-1}). These treatments were compared with the control and POP recommendations. The treatments T_4 which was the optimum treatment, T_5 with maximum N applied and T_8 with maximum K applied, showed higher values along with POP in growth as well as yield characteristics of the crop. The marked effects of these treatments than the others indicated the significance of systematic approach studies in banana. The optimum treatment T_4, though gave higher yields, showed lower value-cost ratio due to the high cost of Ca fertilizer lime. Though 'systematic approach of fertilizer use could be followed satisfactorily, the crop requirement also should be taken into consideration in the case of heavy nutrient exhausting crops like banana. The insignificant effect of Ca on growth and yield of banana was also proved through this study (Prakashmani, N. 2002).

Fertilizer scheduling for short duration cassava variety *Vellayani Hraswa* was conducted with the objective of studying the influence of NPK fertilizers on the performance of short duration cassava variety *Vellayani Hraswa* and to arrive at a fertilizer recommendation for the same. NPK @ 50: 50: 100 kg ha^{-1} produced maximum tuber yield (47.09 t ha^{-1}). This variety favours a 1:1:3 NPK ratio for higher tuber production. *Vellayani Hraswa* is a good variety of tapioca due to its short duration (about 6 months), high yield (45-50 t ha^{-1}) good cooking quality and moderate fertilizer requirement (50:50:100 NPK ha^{-1}) (Sekar. J, 2004).

A field experiment was carried out in College of Agriculture, Vellayani during September 2003 to January 2004 to study the synergistic effect of Na and K on yield and nutrient uptake in coleus (*Coleus parviflorus* L.). The treatments included were 50 and 100 percent of the recommended dose of K alone and in combination with 50, 75 and 100 percent of Na of common salt to equalize the same amount of recommended dose of K. It can be concluded that a combination of 50 percent K and 50 percent Na is optimum for getting the maximum yield. From the study it was evident that the efficiency of nutrient uptake increased at this combination. By adopting this practice, it was seen that the quality of coleus tubers improved and they became nutritionally richer. This practice was found to be economically more

feasible. From this investigation a synergistic interaction of the two monovalent nutrient ions, K and Na on the growth and yield of coleus was established (Neenu. S, 2005).

The research work entitled impact of organic farming practices on soil health, yield and quality of cowpea [*Vigna unguiculata subsp. sesquipedalis (L.) Verdcort*] was conducted at the Instructional Farm, College of Agriculture, Vellayani. The study was undertaken to evaluate the effect of different nutrient sources (organic, inorganic and integrated) on soil health, yield and quality of cowpea using the variety Sharika. It was concluded that POP recommendation registered the highest pod yield. But concerning environmental safety and quality of products, vermicompost + PSM application was the best (Devi Krishna, 2005).

The effect of application of rock dust at different rates alone as well as in combination with FYM and chemical fertilizers and the resultant effect on growth and yield of Coleus (*Solenostemon rotundifolius*) var. Sreedhara was evaluated by conducting a laboratory incubation study and field experiment at College of Agriculture, Veilayani during 2006- 2007. The results of the incubation study revealed that increasing the rate of application of rock dust resulted in an increase in the available nutrient contents of soil. Application of rock dust in conjunction with an equal quantity of FYM also enhanced the availability of all the major as well as minor nutrients. The pattern of release of available N was found maximum during 30th day of incubation and for P, the highest value was recorded during 120th day of incubation. The release of K was found to increase over time reaching the maximum during the later part of the study. The pattern of solubilisation of micronutrients viz. Fe, Mn and Zn revealed that there was a gradual increase in their concentration from the start of experiment, reaching the highest values during the later stages of incubation. Application of rock dust at a higher rate of.12 t ha $^{-1}$ along with an equal quantity of FYM resulted in the maximum release of almost all the nutrients viz. N, P, K, Fe, Mn, and Zn through out the incubation period. Addition of rock dust along with an equal quantity of FYM resulted the percentage increases from 7 to 17.5, 19.50 to 29.22, 22.95 to 45.38, 10.47 to 14.14 15.58 to 26.36 and 1.3 to 8.6 respectively for available N, P, K, Fe, Mn and Zn when compared to the application of rock dust alone. The results from the field experiment conducted to evaluate the efficiency of rock dust revealed that the plant growth characters like number of branches per plant at 90 DAP and plant spread at 60 DAP showed significant variation due to the application of rock dust @ 10 t ha $^{-1}$ mixed with equal quantity of FYM and kept for 15 days before the field application. Yield component like number of tubers per plant was also increased by 14.81 percent due to the application of rock dust. Application of rock dust @ 10 t ha $^{-1}$ along with equal quantity of FYM and 50 percent of the chemical fertilizers NPK @ 30:30:50 kg

ha $^{-1}$ also produced yield (17.26 t ha $^{-1}$, B. C ratio 2.63) equivalent to POP (19.55 t ha $^{-1}$, B. C ratio 2.39). This treatment also produced the highest number of tubers per plant, dry matter content of plant parts and total dry matter production. The highest yield of 19.55 t ha $^{-1}$ was obtained for POP recommendation. But application of rock dust along with half the recommended dose of NPK and FYM also produced the similar yield as (17.26 t ha $^{-1}$) that of POP recommendation. This shows that partial substitution (50 per cent) of chemical fertilizers with rock dust can be recommended to the farmers where ever it is locally available. Rock dust @ 10 t ha-1 along with equal quantity of FYM resulted in the highest returns per rupee invested (B.C ratio 2.89). It can be concluded from the results of the study that the present recommended dose of in organic fertilizers for coleus can be reduced to half provided it is applied along with rock dust @ 10 t ha -1 . 100 percent substitution of chemical fertilizers with rock dusts 10 t ha -1 and FYM 10 t ha -1 can be recommended for coleus wherever rock dust is locally available (Divya, S. S. Rose. 2008).

An experiment was carried out at College of Agriculture, Vellayani to investigate the interactive effect of nitrogen and sulphur on their release pattern and use efficiency in ferralitic soils with bhindi as the test crop. The experiment consisted of an incubation study and a field experiment. Among the treatments, yield, number of fruits per plant, N Use Efficiency and B: C ratio were highest at the following rate of fertilizer application (80 kg N ha^{-1} + 8 kg P_2O_5 ha^{-1} + 25 kg K_2O ha^{-1} + 15 kg S ha^{-1}) and it was considered as the best treatment combination (Mariya Dainy M. S, 2011).

The research project entitled Biological indicators of soil health as influenced by plant nutrient sources was undertaken to study the changes major biological properties of a soil when the major nutrients to a crop grown on it are supplied organically or inorganically or in their different combinations and to employ them as tools for evaluating the health of that soil. The investigations consisted of laboratory studies and two field trials at the Instructional Farm, College of Agriculture, Vellayani with Amaranthus var. Arun during May 2012 to July 2012 in two soil types of Vellayani, red loam and lateritic. Taking into account the favourable effect exerted on biological properties of soil, yield and yield attributes treatment combination of N and K in organic form and P in inorganic form (oil cake + rock phosphate + wood ash) to supply the recommended dose of major nutrients to the crop was adjudged to be the best treatment for economic production of amaranthus in both red loam soils of Vellayani. Considering quality of the crop, treatment consisting of (Oil cake+ Rock phosphate+ Muriate of potash), which supplied N organically was found to be the best (Mekha. M.G, 2013).

A study was undertaken to assess the conjugal effect of manures and chemical fertilizers on the dynamics of major agriculturally significant soil enzymes soil microflora, yield and yield attributes of crop of Bhindi in the red loam soil of Vellayani. Various bioinoculants such as PGPR Mix I, Azosprillum, PSB were used for enriching manures besides neem cake. The treatment, T9 with the application of NPK (50 per cent) as PGPR Mix – I enriched vermicompost along with 50 percent NPK as inorganic fertilizers was found to be best in sustaining soil biological fertility and economic returns. The treatment has also recorded the highest values for soil dehydrogenase, cellulose and protease activities as well as B:C ratio. (Neethu R. Sathyan, 2014).

Soil fertility evaluation

A study entitled "Site specific nutrient management in the bitter gourd (*Momordica Charantia* L)", was conducted in College of Agriculture, Vellayani during 2007-12 with the objective of formulating a site specific nutrient recommendation for enhancing the bitter gourd production in Kalliyur village of Kerala. The study conclusively proved that the present rates of fertilizer recommendation are not at all sufficient for getting maximum yield and profit to farmers. A site-specific nutrient prescription of 123:59:30:40:25:10 kg N, P, K, Ca, Mg, Zn, B ha^{-1} was found to produce 24 t of fruits ha^{-1} and a dose of 123:59:160:30:40 kg N, P, K, Ca, Mg +1 percent Zn foliar + 0.5 percent B foliar ha^{-1} were found to yield 22 t fruits ha^{-1}. The farmers in the area could get a monetary benefit of Rs.601604/- and 542104/-ha^{-1} respectively by adopting these recommendations. Adoption of SSNM prescriptions is advantageous not only from the point of view of increasing profitability to farmers but also minimizing environmental degradation (Neenu.S, 2013).

The study entitled characterization, conversion and evaluation of selected lignocelluiosic biomass was conducted during the period 2013-14 at the Department of Soil Science and Agricultural Chemistry, College of Agriculture, Vellayani. Application of 100 percent N as water hyacinth and composting inoculum was noticed as the best treatment in terms of yield, plant height, number of branches, girth of stem, soil properties viz. water holding capacity, available N, available P, available K, available Mn, available Cu, bacteria population and plant content of micronutrients viz. Mn, Cu, and B. Major enzymes viz. dehydrogenase, urease and aryl sulphatase imposed significance on yield and yield attributes. Application of 100 percent N as compost from water cabbage and Composting Inoculum was found to be good. 100 percent N as compost (water hyacinth + Composting Inoculum) was noticed as the best treatment in pot culture (Anushma. V. 2015).

To assess the impact of providing secondary and micronutrients in the fertilizer schedule for managing the health of Banana Bract Mosaic Virus (BBrMV) affected

plants showed that the application of customized micronutrient formulation (Zn 1percent Mn 0.3per cent, Fe 0.1per cent, Cu 0.1per cent) at triple dose along with primary and secondary nutrients recorded the maximum reduction in the virus titre values along with the maximum yield. (Sangeetha S.S. 2015).

The method and time of application of fertilizers of Mg and B to the yard long bean showed that foliar application was significantly superior to soil application for yield and yield attributes. For obtaining an economic yield, fertilizer applications at first flowering and active flowering stages are good. (Emil Jose, 2015)

Behaviour of various chemicals in soil

The persistence and degradation of chlorpyrifos, a contact insecticide, widely used for the control of soil inhabiting insects were studied in relation to the application of organic manure and lime and also its effect on soil organisms. The experiment was done in field plots at Instructional Farm, College of Agriculture, Veilayani. The insecticide (chlorpyrifos 20 percent EC) was applied @ 3 ml l^{-1} in different treatments. Soil samples were drawn 0, 5, 10, 20, 40 and 60 days after application and after the crop harvest. In the organic manure applied plots the persistence of chlorpyrifos was high due to the adsorption of insecticide in organic matter. The combined application of lime and organic manure cause significant difference in the degradation. Application of chlorpyrifos inhibited the population of bacteria and arthropods, irrespective of the treatment. The bacterial population showed a significant decrease upto 10 days of application of chlorpyrifos and the original count was regained in 75 days. The result also showed that chlorpyrifos application did not affect fungal population. Chlorpyrifos was found to be highly toxic to soil arthropods upto 10 days of application and were not regained till 75 days of application. There was a slight decrease in nodulation in cowpea as compared to control. No residue of chlorpyrifos was detected in the plant parts (pods and grain) from any of the treatment after harvest. Nutrient content on the soil showed an increase in the analytical values due to the treatment effects (Rekha. P. R, 2005).

Soil Quality

An investigation was carried out at the Instructional Farm, attached to the College of Agriculture, Veilayani to evaluate the effect of vermicompost enriched with organic additives viz., neem cake and bone meal on physico-chemical and biological properties of soil, to evaluate its impact on crop performance and the feasibility of substituting farmyard manure and inorganic fertilizer using amaranthus as test crop. The study consist of three parts 1) Preparation and analysis of vermicompost and enriched vermicompost 2) laboratory incubation experiment 3)

Field experiment. On enriching biowastes with neem cake and bone meal, improved the manurial value of vermicompost produced using earthworm species Eudrillus eugeniae. C/N ratio was reduced by enrichment. Microbial population also increased considerably by enriching vermicompost with organic additives. Second part of our investigation was an incubation study and it was conducted to evaluate relative efficiency of enriched vermicompost to release nutrients from soil and its influence on physico-chemical and biological properties of soil. The results revealed that available nitrogen, phosphorus and potassium content of the soil increased upto 45 days of incubation then the availability slowly declined. Organic carbon, pH and EC increased whereas bulk density reduced due to the effects of various organic sources. Application of organic matter had a positive effect on microbial count also. Third part of the study was field experiment, and it was laid out in RBD with 10 treatments and three replications. The biometric observations viz., plant height, number of leaves, number of branches, stem girth, leaf stem ratio all were significantly influenced by different treatments. Significant differences were observed among yield attributing characters like yield per cutting (t ha-1), total yield per plant (g plant-1), total marketable yield (t ha-1), and total dry matter production (t ha-1). Highest yield per cutting was recorded by the treatments T0 (FYM + full NPK), T4 (EVC – NC two percent + full NPK) and T8 (EVC – NC 1 percent + BM 1 percent + full NPK]. With respect to plant contents of nutrients, for nitrogen, highest value was recorded by the treatment T4 (EVC – NC two percent + full NPK), for P, highest value was recorded by T6 (EVC – BM two percent + full NPK) and for K, highest value was recorded by the treatment T8 (EVC – NC 1 percent + BM 1 percent + full NPK). For plant uptake highest values were registered by the treatments T4, T6 and T8 for N, P and K respectively. With respect to quality characters, treatments with organic sources of plant nutrients viz., T8 [EVC- NC 1 percent + BM 1 percent + full NPK) recorded highest value for ?-carotene content in all the three cuttings, for moisture content T3 (VC+1/2NPK) recorded the highest value in all cuttings, for protein T4 (EVC – NC two percent + full NPK) recorded the highest value in all cuttings. For fibre content treatment T1(Full NPK as mineral fertilizer) recorded the highest value and T2 (VC + full NPK) recorded the lowest value. Oxalate content is also influenced by different treatments. Vermicompost enriched with bone meal and treatment received NPK alone recorded highest oxalate content. Post harvest analysis of the soil indicated that organic carbon, available phosphorus, pH, EC and microbial count were increased by applying enriched vermicompost. But available nitrogen and available potassium were slightly decreased. Bulk density was found to be influenced favourably. From the investigation it was proved that enriched vermicompost established its superiority over other organic sources and POP recommendation with respect to soil health and quality of amaranthus. Study

also revealed the feasibility of substituting FYM and inorganic fertilizer with enriched vermicompost by (Sheeba P S 2004).

A detailed investigation entitled Evaluation of latex sludge (Magnesium ammounium phosphate) as a phosphorus source in crop production was carried out at College of Agriculture, Vellayani, with chilli (Capsicum annuum L.) as the test crop. Analytical studies revealed that neutral (pH 6.49) was mainly due to the pH buffering effect of its magnesium phosphate component. The total P content was 35.98 per cent, grading it superior to rock phosphates. Of the total P, 13 percent is water soluble and 36 percent citrate soluble, together accounting for nearly half of the gross P content. Another positive property of latex sludge was the presence of Mg (6.86 per cent) and N (6.05 per cent) in it. Many plants required Mg in about the same quantities as P to increase their photosynthetic efficiency. The present investigation, therefore, undoubtedly proved that latex sludge can be used as an alternate and cheap source of P in crop production. The combination treatment (½ LS + ½ RP) emerged superior on the basis of its direct and residual effects on growth, yield and quality characters of chilli. (Simi Sathyaseelan, 2004).

The research project entitled Development of protocol for quality control of commercial organic manures and their evaluation was conducted at College of Agriculture, Vellayani during 2006-2008. The results of the investigation revealed that none among the forty four commercial organic manures confirmed completely to the quality standards specified by the Fertilizer (Control) Amendment Order, 2006, of the Government of India.. The mathematical models developed for predicting the N, P and K contents of any mixture of bone meal, leather meal and neem cake were, N estimated= 3.62088 BM+ 6.58962 LM+ 1.74407 NC+ 4.74391 (BM)x(LM) + 7.8398 (BM) x (NC) 9.87862 (LM)x(NC), where BM was the proportion of bone meal in the mixture, LM, the proportion of leather meal in the manure and NC, the proportion of neem cake in the mixture. P estimated= 8.41214 BM+ 0.37157 LM+ 0.41953 NC- 2.73548 (BM) x (LM) + 10.15749 (BM) x (NC) 8.72905 (LM) x (NC). K estimated= 0.38543 BM+ 0.01872 LM+ 1.19747 NC+ -0.04393 (BM) x (LM) + 2.98573 (BM) x (NC) 5.64704 (LM) x (NC). The model could be used for finding out adulteration of organic manures with inorganic fertilizers to boost their nutrient contents. The highest yield, total dry matter production, total marketable yield and total yield per plant of the second crop was recorded in (NPK fertilizers +Golden meal) (Gowri Priya, 2008).

A study entitled "Evaluation of aquatic pollution and identification of phytoremediators in Vellayani lake" has been carried out at the College of Agriculture, Vellayani during the year 2009-2011 to assess the extent of pollution and to identify the phytoremediators in Vellayani lake. Samples of water, sediment and macrophytes

found in the lake were collected during pre monsoon, monsoon and post monsoon seasons, from 15 sites within the lake and were subjected to physical, chemical and biological analysis. The physical properties of the lake water viz., colour, turbidity and the amount of suspended solids showed significant variation among seasons and with locations showing higher values during monsoon season. All the chemical properties of lake water were also significantly influenced by the season and location. On evaluating the water as per ISI/WHO criteria, it was found that the chemical characteristics like EC, NO_3-N, K, Ca, Mg, S and Zn were within the maximum permissible limits. P and Cu were not detected in water in any of the seasons. pH of the lake water was within safe limits only during the monsoon season and it was highly contaminated with organic load. The NH4-N content of water exceeded the MPL at certain locations during pre and post monsoon seasons. With regard to the heavy metals, one location was contaminated with Fe, six locations with Cd and eight locations with Pb. During monsoon season, the water quality is generally good. Al content of water was always above the safe limits fixed by ISI/WHO. Hence suitable treatments for improving water quality should be advocated for its use as drinking water/ for domestic purposes. With regard to the microbiological properties, the bacterial count was lowest during monsoon and highest during post monsoon season. Regarding the Coliform count, a gradual increase in number from pre monsoon to post monsoon season was observed. Algal population was seen uniformly distributed in all the 15 sites throughout the three seasons. All the chemical properties of lake sediment were significantly influenced by the season and location. Among the chemical characteristics organic carbon, extractable K, Ca, Mg, S, Fe, Cu, Zn and Pb were higher during pre monsoon season while pH and NH4-N were higher during monsoon season. Most of the chemical characteristics like EC, NO3-N, extractable K, S, Fe, Cu, Zn and Pb recorded their lowest values during monsoon season, while organic carbon, extractable Ca, Mg and Cd were at their lowest during post monsoon. NO_3-N and extractable Al recorded their highest value during post monsoon season. Carbonates and bicarbonates were not detected in the sediment samples. The texture of sediment ranged from sandy to sandy clay loam. Fourteen species of aquatic macrophytes were found within the lake. Maximum number of plant species (12) was found during pre monsoon and minimum (9) during monsoon season. All the macrophytes showed higher elemental composition in shoot compared to root. Among the macrophytes, *Eichhornea crassipes* was found to be a good phytoextractor for N, K, S, Al, Fe, Cu and Cd and *Pistia stratiotes* for N, K, S, Al, Zn, Cu and Pb. *Nymphaea odorata* was found to phytoextract Cu and Cd and Nymphoides indicus for Cd and Pb. For S, *Limnocharis flava* and *Scirpus grossus* can be used as phytoextractors (Kavitha Kamal, 2011).

Detailed investigations consisting of production of biochar from tender coconut husk and its characterization, laboratory experiments viz. Nutrient sorption

desorption studies; carbon dioxide emission studies and a field of experiment to assess the effects of biochar on soil properties, growth and yield of crops using yard long bean (*Vigna unguiculata sesquipedalis*) as the test crop were carried out in Loamy Skeletal Kaolinitic Isohyperthermic Rhodic Haplustult at College of Agriculture, Vellayani during 2011 to 2014. From the investigations it was found that biochar is a rich source of C and all the essential plant nutrients, efficient releaser and adsorber of nutrients, a potential tool for carbon sequestration, one of the best way to utilize biowaste, to protect the environment safely and finally an excellent soil amendment. Combining biochar with organic and inorganic nutrient sources and microbial inoculants can sustain soil health and improve crop yield. (Mariya Dainy, 2015).

A study conducted to evaluate the effect of enriched composts and vermi compost on soil remineralization and crop nutrition revealed that 50 percent N as mineral enriched vermicompost in conjunction with PGPR Mix I helped to increase the yield as well as nutrient uptake of yardlong bean and thus played a vital role in soil remineralization and crop nutrition. The nutrient requirement of yard long bean can be reduced to half the recommended dose if mineral enriched vermicompost is used in conjunction with PGPR Mix I as nutrient source (Sreeja S.V. 2015).

Think it over

- ✓ The optimum level of N, P & K for the cassava was found to be 100:300:300 kg ha^{-1}. This level along with FYM @12.5 t ha^{-1} produced a tuber yield above 40 tonnes ha^{-1}.
- ✓ Phosphogypsum was found to be highly beneficial in increasing the yield and yield attributes of cowpea, by mitigating the adverse effects of soil acidity and aluminium toxicity
- ✓ Upto fifty per cent of the K requirement of Robusta banana and coleus, grown in soils of low K status, could be replaced by Na of common salt
- ✓ Considering quality of the amaranthus, treatment consisting of oil cake, rock phosphate and muriate of potash, which supplied N organically was found to be the best.
- ✓ Chloropyrifos was found to be highly toxic to soil arthropods upto 10 days of application and were not regained till 75 days of application.

4. Coastal and Mixed alluvium

These soils of marine origin are identified along the coastal plains and basin lands as a narrow strip. The elevation of the coastal area is generally below 5m fromMSL. The area has high water table and in some areas it reaches above the surface during rainy season. The soils of the coastal plains are very deep with sandy texture. The texture generally ranges from sand to loamy sand with greyish brown to reddish brown and yellowish red colour. Sand content ranges from 80 percent and clay up to 15 per cent. Even though these soils have high water table, the water holding capacity is poor due to the predominance of sand. Coconut is the major crop in the area. Cashew and other fruit trees are also grown.

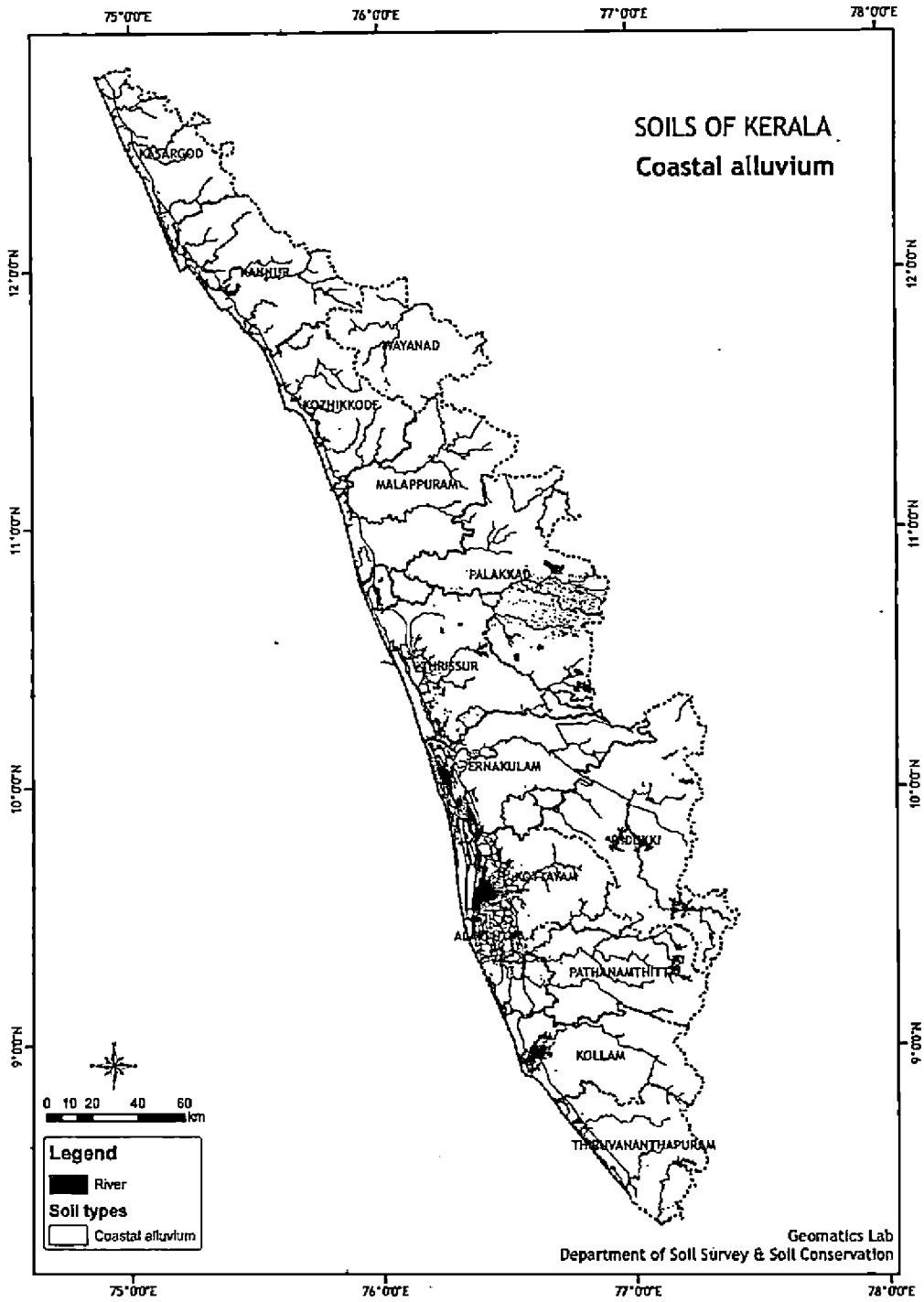
Genesis, morphology and general characteristics

To investigate individual components and bring out their relationship with present land use that would help to maintain the ecological balance while sustaining human needs, two river basins Mangalam-Gayatripuzha and Aralam-Bavalipuzha were selected. Land capability was assessed for each geomorphic unit with minimum degradation to it. It was found that the Mangalam-Gayatripuzha had a mature landscape in comparison with Aralam-Bavalipuzha basin with more diverse geomorphic units. The soil was registered as alluvial in Mangalam-Gayatripuzha basin whereas it is lateritic in Aralam-Bavalipuzha basin. Soil fertility was found to be moderate with no marked variation in both cases. High population density, smaller land holdings and low per capita income had put the land to great stress. Ecologically viable land use based on land capability has become subservient to subsistence land use. Both the basins are susceptible to erosion and this has been aggravated by large scale deforestation and plantation of tuber crops on the hills sides. On the basis of these findings it is recommended that deforestation should be completely stopped and afforestation programmes expedited in order to conserve the ecology of both basins. Soil conservation measures should be taken up on a war footing in the Aralam-Bavalipuzha basin with the entire cost borne by the government. Comprehensive programmes must be formulated to bring the catchment of the rivers under good perennial tree and fodder vegetation.Tapioca cultivation requiring greater tillage on slopes should be discouraged or prohibited. A detailed land capability assessments based on natural land use determinants should be worked out for the two basins since large sections of the people in the hilly areas are poor with no alternative means of subsistence. (Benoy T. Cherian, 1987).

A reconnaissance soil survey of Onattukara region was undertaken to study the extent and distribution of the different soils for soil classification, land capability, irrigability and for subsequent land evaluation. The study revealed that Onattukara region extended over an area of 40,948 ha. The soil map showing the distribution of the identified twenty soil series had been prepared. The climatological data revealed that the soil moisture and temperature regime was recorded as ustic and isohyperthermic respectively. Ten series were classified under Entisols, six under Inceptisols, three under Ultisols and one under Alfisols. Based on the inherent soil characteristics and landscape features, the soils had been grouped into three land capability classes, nine capability subclasses and land capability map was prepared. The soils were classified into five land irrigability classes, eight land irrigability subclasses and land irrigability map was prepared. The soils were evaluated based on principles of land evaluation and rating of productivity parameters. The productivity rating of the soil properties against the productivity index for rice, coconut, sesamum, cassava and banana were made and conclusions was drawn. Productivity rating showed that Kottakakam series was best suited for rice, Palamel, best for coconut and banana, Artuva and Mahadevikad, for sesamum and Palamel and Vallikunnam, for cassava. On the basis of the studies carried out, a land use was proposed for the twenty soil series of Onattukara region based on crop suitability ratings and crop suitability map was prepared for the five crops taken for study (Premachandran, P. N. 1998).

Physical and chemical attributes

An investigation was carried out at Rice Research station, Kayamkulam to study the effect of soil compaction with organic manure and amendments on soil physical properties, nutrient availability, rooting pattern, yield and quality of crops like rice, sesamum, green gram and cowpea under rice based cropping system of Onattukara tract of Kerala. The compaction treatment with four passes of a 400 kg roller significantly improved the soil physical properties, nutrient availability and yield of all the crops. The available water content, microporosity, available N, P and K, root volume and root density significantly increased in compacted treatments for all the crops. Application of coirpith and kayal silt improved the field moisture content in kharif rice. The hydraulic conductivity and infiltration rates decreased in compacted plots. The compacted plots recorded less number of days for 50 percent flowering of sesamum, green gram and cowpea. The rabi crop of rice, sesamum and cowpea recorded the highest grain yields of 2.72 t ha^{-1}, 529.79 kg ha^{-1} and 594.78 kg ha^{-1} in the compacted treatment along with coirpith and farm yard manure (@2.5 t ha^{-1}) combination, where as the kharif crop of rice recorded the highest grain yield of


SOILS OF KERALA
Coastal alluvium
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10°00'N
9°00'N
KASARGOD
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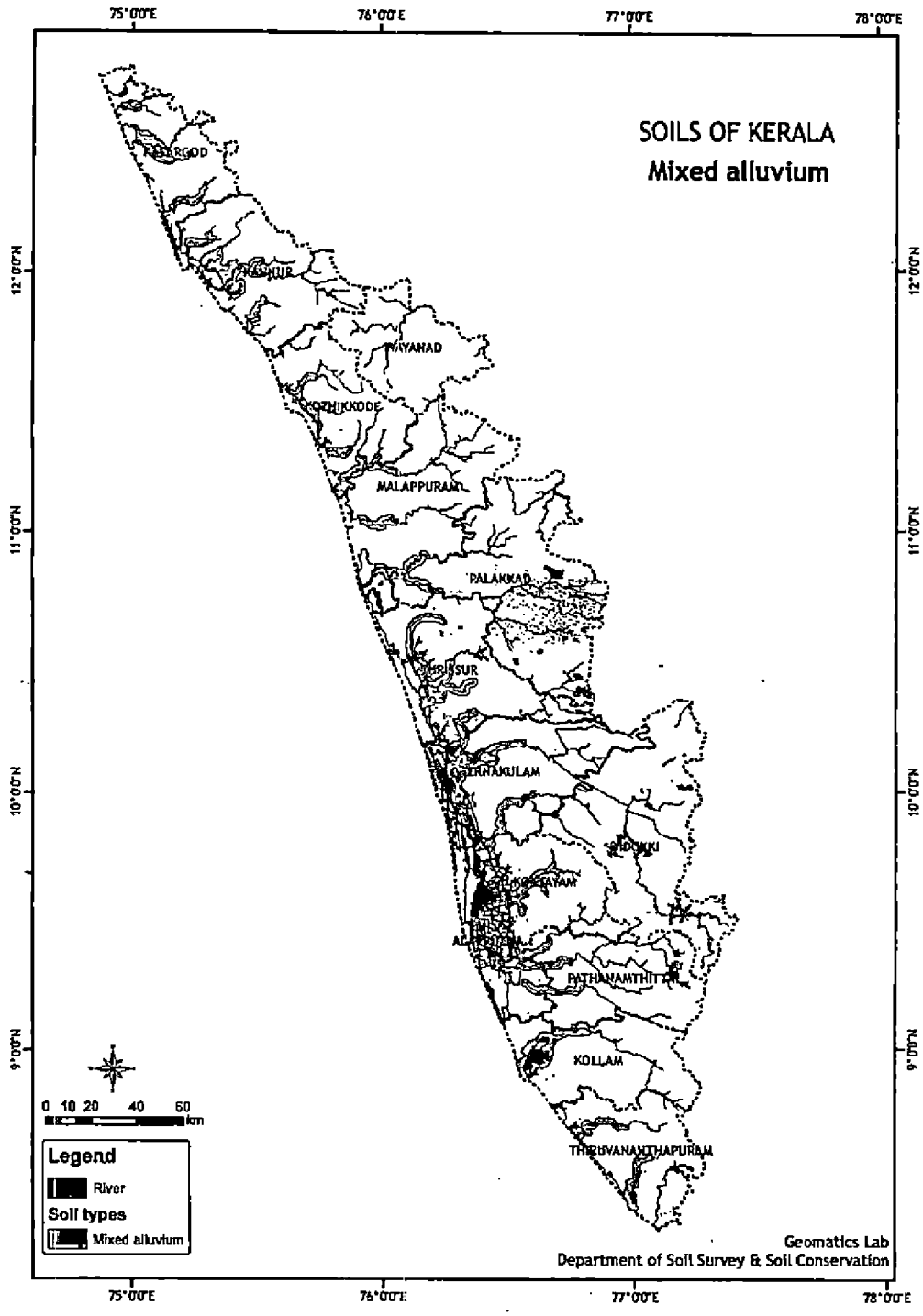
Department of Soil Survey & Soil Conservation


SOILS OF KERALA
Mixed alluvium
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77°00'E
78°00'E
12°00'N
11°00'N
10°00'N
9°00'N
KASARGOD
WAYANAD
KOZHIKKODE
MALAPPURAM
PALAKKAD
THRISSUR
ERNAKULAM
IDUKKI
KOTTAYAM
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KOLLAM
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3.15 t ha^{-1} in the compacted and coir pith treatments along with 5 t ha^{-1} farm yard manure. The seed yield of green gram was highest in compacted and 5 t ha^{-1} farm yard manure treated plots with no amendments. Thus it can be concluded that compaction of coarse textured soils along with the application of 2.5 t ha^{-1} farm yard manure and 5 t ha^{-1} coir pith significantly improved the soil physical properties, nutrient availability and inturn the yeild of different crops under rice based cropping system of Onattukara (Sreelatha A K, 2003).

Response to fertilizers

Available Cu in the alluvial soils of Kerala varied from 0.7 to 4.4 ppm and decreased with depth. The total Zn varied from 15 to 92.5 ppm and decreased with depth. There was significant negative correlation between available and total Zn with pH (George Varghese, 1971). Zn deficiency caused by high levels of P could be corrected by the application of Zn to Vellayani kayal soil. High doses of P produced yellowing in IR-8 due to the low uptake of Zn (Prabha, B, 1971). Zn content of rice increased with increasing rate of Zn application, but lime showed an antagonistic effect on adsorption of Zn (Mariam. K. A, 1975).

The results of the study, differential response of rice cultivators to potash application in the rice soil of Onattukara indicated that, in general, the varietal influences on most of the growth characters in all the four groups were profound. Differential response of K was highly pronounced in all short duration varieties, Ptb23, Ptb29, Cul 7005-6-1, Cul 7004-3-1, and Cul 7006-2-1 giving comparable yields at 22.5 kg K_2O ha^{-1} as that of the POP recommendation. However as this experiment was done in microplots the final recommendation of varieties tolerant to K deficiency could be done only after extensive studies in large plots and in farmers' fields during various seasons (Shaji. K.V, 1996).

Banana cv. Njalipoovan is a popular variety cultivated in homesteads of Kerala. The nutritional requirement of the cultivar has not yet been worked out. Field experiments were conducted at Onattukara Regional Agricultural Research Station, Kayamkulam in Alappuzha district during 1998-99 and 1999-00 to formulate an effective nutrient management schedule for the cultivar in Onattukara soil. In addition to this a soil column study was undertaken separately to assess the leaching losses of nutrients in the soil and retention of applied nutrients at different depths.. The combination of N, P_2O_5 and K_2O applied at 300:300:600g $plant^{-1}$ had appreciably increased the growth characters, yield attributes, and nutrient uptake. It was comparable to that of N, P_2O_5 and K_2O at 200:200:400 g $plant^{-1}$. The bunch yield obtained by the application of N, P_2O_5 and K_2O at 300:300:600 g $plant^{-1}$ was also

comparable with that of 200:200:400 g plant $^{-1}$ However, mineral nutrition of N, P_2O_5 and K_2O at 200:200:400 g plant^{-1} had given the maximum benefit-cost ratio of 1.96. Therefore it can be concluded from the study that application of N, P_2O_5 and K_2O at 200:200:400 g plant^{-1} is beneficial for getting higher yield and maximum economic returns (Indira M. 2003).

A laboratory cum field experiment was conducted to study the effect of S and B on the growth, yield and quality of sesame var. Thilarani and to standardizethe foliar diagnosis of these elements in Onattukara sandy loam soil. The results revealed that the release of S and B was maximum at the 30th DOI. It was observed that application of S and B favourably influenced the yield and yield attributes of sesame. In the case of S, critical nutrient concentration had been standardized as 0.088 percent and for B, it had been found to be 28 mg kg^{-1}. The critical nutrient level in soil was also estimated using the scatter diagram technique and was found to be 23 kg ha^{-1} at 30 DAS for S and 1.4 ppm at 20 DAS for B. Hence the application of S @ 30 kg ha^{-1} and B @ 2.5 kg ha^{-1} could faourably enhance growth of sesame with regard to the growth characters, yield and yield attributes and the quality aspects. (Jeena Mathew, 2010).

A study on the assessment and management of micronutrient deficiencies in Ontattukara soils and development of multi micronutrient mixture for balanced crop nutrition revealed the deficiency of B (77 per cent), Zn (66 per cent) and Cu (53 per cent) in the Onattukara region. Micronutrient fertilizer requirement was computed based on the available micronutrient status of the region and crop requirement and developed a multi micro nutrient mixture having a composition of Zn (9.5 per cent) + B (2.6 per cent) + Cu (1.2 per cent) + Mg (2.4 per cent)+N (0.46 per cent) @ 20 kg ha^{-1}. From the investigation it can be confirmed that foliar application of micronutrient mixture @5 kg ha^{-1} in two splits at 15 DAS was superior to soil application in respect of yield, quality and B:C ratio. The study revealed that micronutrient deficiency is one of the yield barriers which can be broken down by including micronutrient fertilizers in the nutrient schedule of crops. (Mini V, 2015)

Behaviour of various chemicals in soil

An experiement was conducted in the wetlands of the farm attached to the Agricultural College, Vellayani to study the factors that promote H_2S toxicity to the paddy plant and to study in detail the symptoms of the disorders caused by H_2S.Studies were also made to find out the effect of magnesium and silica, as well as the form of nitrogen in controlling or enhancing the production of H_2S toxicity. Application of Magnesium silicate reduced the hydrogen sulphide evolution in rice soils. Among the nitrogen fertilizers, application of ammonium sulphate produced the maximum amount of H_2S (Yogesan Nair. J, 1966).

Soil Quality:

An inventory on the biological characteristics of the major coconut growing soils of Onattukara region in Kerala, showed that the maximum values or the most desirable values on biological properties of soil were recorded in areas receiving organic inputs as nutrient source (Anila T Sasi 2015).

Think it over

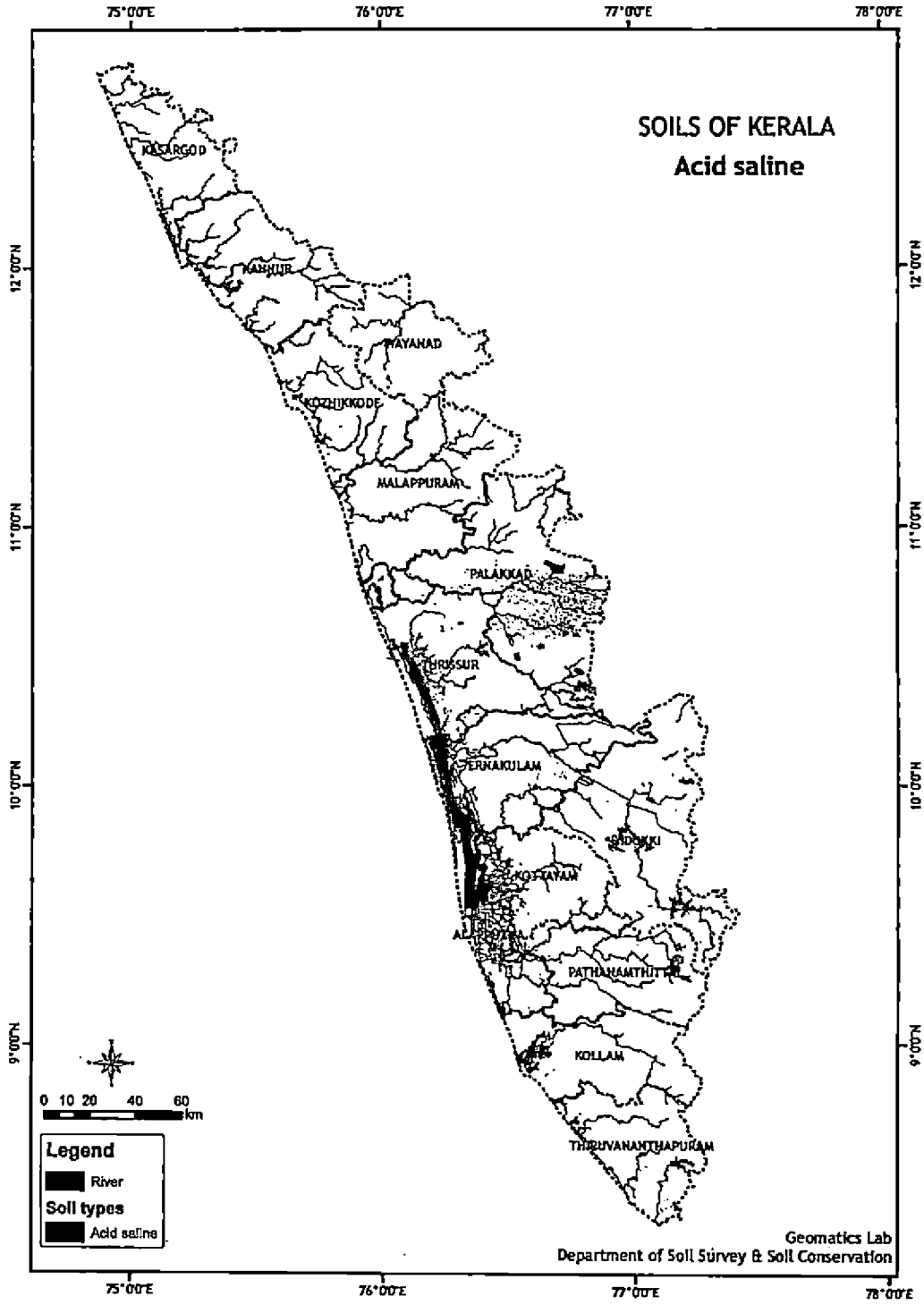
- ✓ Compaction of coarse textured soils along with the application of 2.5 t ha^{-1} FYM and 5 t ha^{-1} coir pith will improve the soil physical properties, nutrient availability and inturn the yield of different crops under rice based cropping system of Onattukara
- ✓ An increase in yield of rice corresponding to the addition of 30 kg/ha N would be achieved by the inoculation of blue green algae
- ✓ Zn deficiency caused by high levels of P could be corrected by the application of Zn to the soils. High doses of P produced yellowing in IR-8 due to the low uptake of Zn
- ✓ Application of N, P_2O_5 and K_2O at 200:200:400 g/plant was beneficial for getting higher yield and maximum economic returns in banana (var. Njalipoovan)
- ✓ Application of S @ 30 kg ha^{-1} and B @ 2.5 kg ha^{-1} could faourably enhance growth of sesame with regard to the growth characters, yield and yield attributes and the quality aspects
- ✓ Application of Magnesium silicate reduced the H_2S evolution in rice soils. Among the nitrogen fertilizers, application of ammonium sulphate produced the maximum amount of H_2S.

5. Acid saline and Kari soils

Acid saline soils are present throughout the coastal area in patches with very little extent. Major area of this soil is identified in the coastal tract of Ernakulam, Thrissur and Kannur districts. The area under these soils comprise of low-lying marshes, waterlogged and ill drained areas near the rivers and streams, which are subject to tidal waves. Sea and backwater tides make these soils saline. During monsoon season, when rainwater and fresh water from rivers enter the fields, salinity is partially washed off. The areas under these soils occur mostly on plains at or below sea level. A wide variation in texture from sandy loam to clay is noticed with dark grey to black colour. Paddy is the only crop that can be cultivated.

The origin, genesis and development of these soils have been under peculiar physiographic conditions. They are, therefore, not comparable with the saline soils occurring in the other parts of the Country. The network of backwaters and estuaries bordering the coast serves as an inlet of tidal waters to flow into these areas, causing Salinity. During the period of March-April the soil is characterised by high salinity, but in June-July they are devoid of salts. Wide fluctuation in the intensity of salinity has been observed. During the rainy season, the fields are flooded and most of the salt is leached out, leaving the area almost free of the salts.These soils are in general brownish and deep. The profile show wide variation in texture, as is common in most of the alluvial soils. This soil is imperfectly drained. In these soils one crop of Paddy is cultivated during August -December.Electrical conductivity of the soil during June-July season ranges from 0.1 to 2.0 ds/m The maximum accumulation of toxic salts is observed during the summer months from March to April when electrical conductivity rises to the range of ds/m. Being developed in areas with relatively high ground water table, these soils show aquic properties. In some areas, undecomposed organic matter is observed in the lower layers, causing problems of acidity. The Pokkali (Ernakulam district) and kaipad (Kannur district) soils come under this category.

The Kuttanad region covering about 875 km^2 is a unique agricultural area in the world. A good portion of this area lies 1-2 m below MSL and is submerged for major parts of the year. The area is susceptible to seasonal ingress of saline water as a result of tidal inflow from the sea. During the monsoons, the rivers and rivulets pour fresh water into the area. As the North East monsoon recedes, seawater again


SOILS OF KERALA
Acid saline
75°00'E
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78°00'E
12°00'N
11°00'N
10°00'N
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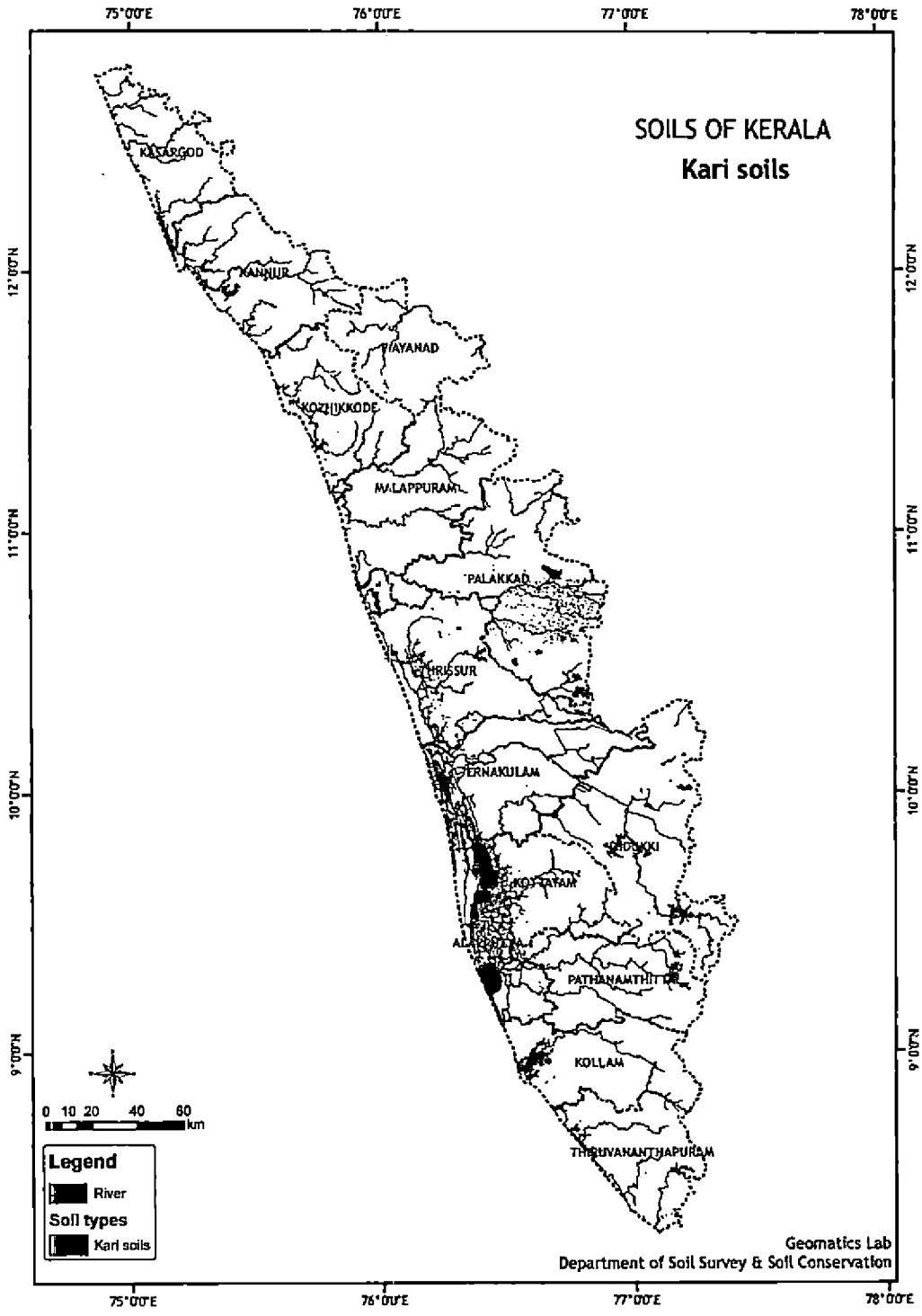
SOILS OF KERALA
Kari soils
75°00'E
76°00'E
77°00'E
78°00'E
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10°00'N
9°00'N
KASARGOD
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Department of Soil Survey & Soil Conservation

enters the Vembanad Lake and the whole area becomes saline. Hence, the soils of Kuttanad area are faced with the serious problems of hydrology floods, acidity and salinity. Consequent to the construction of the Thanneermukkam bund, salinity hazards have been considerably reduced. The soils of Kuttanad form the typical waterlogged soils and are entirely different from normal well-drained soils in their morphological, chemical and physical characteristics.

Area, distribution, genesis, morphology and general characteristics

Illite, montmorillonite and a mixture of hydrous mica were the dominant clay minerals in the peat, marshy and swampy soils of Kerala (Gopalaswamy. V, 1958).

A study was made of the morphological, physico-chemical and microbiological, properties of four typical soil profiles from the Kari areas of Vaikom taluk. The soil were black to dark grey in colour and could be texturally classed as clays or clay – loams. The high CEC of the clay fractions and high silica sesquioxide ratios observed in the clay separates, suggested the presence of 2:1 lattice type of minerals. The top layer of Kari soils was extremely acidic while the lower layers were neutral or alkaline. Even though these soils contain high percentage of all plant nutrients, their availability was low due to low pH, wide C:N ratio and anaerobic conditions These soils have low microbial counts, which increased with depth in the profile. The ammonifying power was more in the top layers due to the predominance of fungi in these layers (Sukumara Pillai, V, 1964).

Kayal soils of Kuttanad were classified under the order entisol, suborder aquent and great group hydroaquent. Organic carbon, C:N ratio, total N and total P were low. Exchangeable hydrogen and aluminium were low compared to Kari and Karappadam soils. Copper was deficient in all the profiles and Zn was deficient in two profiles (Gangadharamenon, P. K, 1975).

Karappadam soils were highly acidic and deficient in P, K and Cu. Acidity of these soils was mainly due to high amount of Al^{2+} and H^{2+} (Santhakumari, G. 1975).

Physico-chemical characteristics of Kole soils are in several respects similar to those of Kari soils of Kuttanad and swamp soils of Kattampally (Abdul Hameed, 1975)

Fifteen soil profiles were drawn from North Kuttanad to study the morphology and physicochemical characteristics of the area. The fertility characteristics were studied by collecting 97 surface soil samples (0-15 cm depth) from 27 padasekharams of the area during rainy and summer seasons (before and after the closure of Thanneermukkom regulator). Toxicity characteristics of the area were studied by collecting bulk soil samples (0-25 cm depth), surface water and ground

water from the above sites during the same period. Morphological and physicochemical properties of the soils showed great degree of variation. Soils were dark brown to black in colour, sticky and plastic, subangular blocky in structure and sandy to clayey in texture, with random deposits of lime shells and humus. Presence of faint to prominent reddish yellow or brown mottles, rice roots and root canals were some of the special characteristics observed in the soil profiles. Soils of the area were highly acidic and mildly saline. Both soil acidity and salinity increased with depth. Organic carbon, CEC and ECEC of the area were higher compared to other parts of Kerala, but the base saturation was comparatively lower. Among the components of exchangeable acidity exchangeable Al^{3+} dominated during rainy season, and exchangeable H^{+} during summer. The overall influence was greater for exchangeable $A1^{3+}$ as evidenced from the higher correlation coefficient (0.862**). The general soil properties and acidity characteristics of the bulk soil samples were similar to that of surface samples, showing a reduction in pH, EC, CEC and available, exchangeable and water soluble cations during summer compared to the rainy season. Among the different fractions of Fe, free and available forms were present in large quantities while exchangeable and water soluble forms were present in negligible quantities. The content of NO_2+NO3-N was comparatively low in soil due to continuous submergence. In water it was not as low as that of soil, indicating a major portion of NO_2+NO3-N retained in water. P content of the area was very low. Its loss through drainage water was nil. A sizeable quantity of K was also subjected to loss through drainage water, though the extent of loss was well below the level of N. Here also highest concentration was noted during additional crop season at the time of basal dressing both in soil and water. The study indicated that the area is subjected to severe pollution due to the accumulation of native toxic factors as well as residues of pesticides and fertilisers. The closure of Thanneermukkom regulator aggravates the situation by restricting the water movement (Manorama Thampatti, K. C. 1997).

An investigation was carried out at College of Agriculture, Vellayani during 2001- 2004 to delineate acid sulphate soils of Kuttanad and to develop sustainable land use plan for the area based on land evaluation and crop suitability rating with the help of GIS technology. The morphological and physico- chemical characteristics of the area showed great degree of variation. The soils were deep with a hue of 7.5 YR to 10 YR, sticky and plastic, angular blocky to sub angular blocky in structure with textural variation from sandy to clayey with random deposits of lime shells and humus. Presence of faint to prominent reddish yellow or brown mottles in most of the soil layers was seen. The soils were extremely acidic with high organic carbon content. The CEC, EC and available nutrients except phosphorous were high for these soils. Due to P fixation, phosphorous deficiency was found to be

widespread. However the base saturation was below 50 per cent. As per USDA classification, the entire study area was classified under the order Entisols, with suborder Aquent, great group Sulfaquent, subgroup Typic Sulfaquent with six soil series viz., Ambalapuzha, Purakkad, Thotapally, Thuravur, Kallara and Thakazhi. As per FAO classification, these soils were included under Thionic Fluvisols. Based on soil mapping of the area it is revealed that acid sulphate soils of Kuttanad covered an area of 14277.51 ha comprising of six soil series. Kallara series occupied the largest area of 6860.17 ha. The soils of the region were deep, poorly drained loamy soils in control section and were very gently sloping with slight erosion. Land capability classification of the area showed five soil series viz., Ambalapuzha, Purakkad, Thuravur, Kallara and Thakazhi covering an area of 13099.60 ha came under the class (IV sw). The Thotapally series was grouped under (III sw). While considering the soil site suitability for paddy, Thotapally and Thuravur series come under subclass (S2 xf) ie these are moderately suitable for paddy cultivation with limitations due to fertility and pH. For coconut cultivation, all the series except Thuravur are grouped under (S2 xf). Soil site suitability for mango cultivation revealed that Ambalapuzha, Purakkad and Thotapally series are moderately suitable with limitations due to excess wetness, low pH and fertility limitations. As per Fertility Capability Classification, the soils belong to the units Lgac, Lgac, LCgac, Cgaics, Lgac and LCgaic respectively for Ambalapuzha, Purakkad, Thotapally, Thuravur, Kallara and Thakazhi series. The modifiers that are relevant to the acid sulphate soil condition were "g" which defined wet land soil, "a" (aluminium toxicity), "i" denotes high P fixation by iron, "c" denotes the acid sulphate soil condition. Socio - economic, cultural and ecological traits were also taken in to account along with land, crop and climatological characteristics of the area for the development of a probable land use model. Based on the study the land use models were suggested for the area with rotational farming involving paddy, fish and livestock (Beena, V. I, 2005).

Physical and chemical attributes

The effects of salinity were less injurious during the vegetative stage than the reproductive stage of rice. The straw of the salt resistant variety Choottupokkali growing in saline soil accumulated high proportions of K, Ca and Cl (Remani. B, 1963).

Pot culture studies using different salts of varying concentrations with rice showed that irrespective of the nature of salt, rice seedlings cannot tolerate a salinity level of more than 12 mmhos cm^{-1}. The tolerance of salts was in the decreasing order of $MgCl_2$ (12 mmhos cm^{-1}) > KCl = $CaCl_2$ (8 mmhos cm^{-1}) > NaCl (4 mmhos cm^{-1}). So EC alone cannot be considered as a factor responsible for injurious effect of salinity in soils (Gopalakrishnan Nair, P., 1963).

The best extractant for extractable Al in these soils was one normal KCl. Increasing the soil: solution ratio resulted in the increase in extractable Al three fold in Kari soil and 2 fold in Karappadam soil. Inundation of Kari and Kaappadom soils prior to cropping period helped to replace the exchangeable Al and washed the soils free of Al (Karthikakutty Amma, M, 1967).

Lime increased the availability of nitrogen by enhancing the mineralization of organic nitrogen. Limimg at full lime requirement level brought the pH to a favourable range in *Kari* soils. In *Karappadam* soils, lime at half the lime requirement brought the pH to favourable level (Kabeerathumma, S, 1969).

The Aluminium hydroxide potential can be taken as valid intensity index for soil acidity for Kole, Kari and Karappadam soils and lime potentials for Kayal soils (Varghese, M. P, 1972).

The electrical conductivity of pokkali soils ranged from 7.7 to 226 mmhos cm^{-1}. These soils were found to be extremely poor in phosphate and rich in potash. Application of liming materials at the time of mounting and subsequent leaching with basement application of phosphate prior to planting increased the yield of paddy (Samikutty V, 1977).

Continuous submergence was found to be disadvantageous to the supply of available Zn to a growing rice crop as it decreased the Zn concentration. In case of Mn, submergence led to toxic concentration. Adsorption- desorption studies of Mn and Zn confirmed that they followed the Langmuir model of adsorption. Maintenance of adequate Mn and Zn either through application of fertilizer, FYM and green leaf ensured maximum production (Rajendran, P, 1981).

The use of steatite and organic materials like cattle manure and green leaves along with lime at recommended level was found to be very effective in suppressing the release of exchangeable Al in Kari soils. Rice varieties identified as tolerant to Al toxicity were those which performed better under acid soil conditions (Alice Abraham, 1984).

Response to fertilizers

Invertase was the most active enzyme in the rhizosphere of rice plant. Basal application of Lindane to the soil @ 2kg ha-1 did not exert any significant effect on microbial population (Krishnaswami, B., 1969). The urease activity in rhizosphere of paddy soils was the highest on 50^{th} day of sowing. The level of urease activity was influenced by the type of fertilizer applied to the soil and in soils which had high level of urease activity, urea could be used for top dressing as the mineralization was fast (Pareethu Bhava Khan, P. M, 1971).

The potassium status of five major acid rice soil groups of Kerala, Viz., Kole, Kari, Kayal, Karapadom and low level latrite, was evaluated by fractionation and fixation studies.The effect of the application of lime on the fixation of potassium was also studied. Kari soils showed highest amount of K fixation. Kari soil contained fairly high amount of total and exchangeable K with high K fixation capacity. The results suggest that the major rice soil groups of Kerala contain fairly high amounts of total and exchangeable potassium. Some of the soils of the State, contrary to earlier belief, are also capable of fixing potassium. This must be an account of the presence of 2:1 type of clay in them (Sreedevi Amma, A, 1972).

Rock phosphate could be made equally or more efficient than super phosphate for supplying fertilizer P to rice grown in the acid soils of Kerala (Madhusoodhan Nair, K, 1978).

A pot culture experiment in a completely randomized design was carried out to study the response of paddy (var Annapoorna) to lime application in four acid soiltypes viz., laterite, kayal, kari and kole.Lime was applied at six levels, viz., no lime, one eighth, one fourth, half, three fourth and full lime requirement levels and calcium acetate at two levels to supply calcium equivalent to one eigth and one fourth lime requirement respectively. The soil samples were analysed at fortnightly intervals. The growth parameters and yield attributes were studied. In Kayal and kole soil, lime at half the LR and in Kari soils full LR recorded the maximum yield of grain. Lime application also minimizeed the Fe and Al solubilization and toxic concentration to paddy (Anilakumar, A, 1979).

With a view to realize the maximum economic yield in rice by optimizing the nutritional status of the soil, a series of experiments were undertaken under the present study entitled 'Yield maximisation in rice (Oryza sativa L.) in the acid sulphate soils of Kuttanad through systematic approach in fertilizer use'. The results thus clearly indicated that the excess application was indicated as a mere waste of economy. The lowest dose of P and K 45 kg P_2O_5 ha^{-1} and K 15 kg K_2O ha^{-1}) along with N 90 kg ha^{-1} was recorded as necessary for optimum yield. The results also indicated that cultivation without fertilizer application was also an economic loss with a BCR of 0.95. Hence the investigation to realize the maximum economic yield in rice through systematic approach in fertilizer use which arrived at a reduced optimum fertilizer dose of 90: 45: 15 kg NPK ha^{-1} for the medium duration rice varieties. (Annie Koruth, 2007).

Soil fertility evaluation

Soils and associated wood fossils contained different forms of S such as free originally combined sulphide and sulphate forms. Sulphur oxidizing and reducing bacteria were present in the soils. It was assumed that there existed a bacterial

cycle in these soils which convert organic forms of Sulphur to sulphuric acid thus formed causes extreme acidity of these soils (Subramoney. N,1958).

An investigation on the physico-chemical characteristics, reductive transformation of iron and sulphate in flooded Kari and karappadom soils of Kuttanad and Pokkali soils of Ernakulam districts were conducted. Forty three soils (15 karappadom soils from Moncompu area, 15 Kari soils from Karumady area in Alleppey Districts and 13 pokkali soils from Kumblalangy, Elamakkra and Panangad areas of Ernakulam District) were used in this study. Transformation of Fe (III) in submerged soils was studied by monitoring NaOAc extractable Fe^{2+} concentration. High concentration was observed in pokkali and Kari soils compared to karappadom soils. A method was developed to study the reduction of sulphate in flooded soils, H_2S, using ^{35}S. The evolution of $H_2{}^{35}S$ was detected from 91.5 h onwards following incubation of flooded soil in N_2 atmosphere. Evolution of $H_2{}^{35}S$ steadily increased upto 211.5 h of incubation, beyond which there was a slight decrease. The total quantity of $H_2{}^{35}S$ evolution during 312.5 h of the experiment was equivalent to the reduction of 6.5 microgram of soil SO_4^{2-}. The reduction of $^{35}S\ O_4^{2-}$ to $H_2{}^{35}S$ commenced when Eh of the flooded soil dropped to -5mV whereas the transformation of Fe^{3+} to Fe^{2+} started at a higher Eh, much earlier to the reduction of $^{35}\ SO_4^{2-}$. (Padmini Amma K.P. 1998)

Soil quality

The present study entitled 'Quality assessment of *Pokkali* soils under different land uses' was undertaken to evaluate the soil and water quality of acid saline *Pokkali* soils under different land uses and to develop geo-referenced database and maps on soil characterization. For this purpose, surface soil samples and water samples were collected from the selected panchayaths representing five land use pattern in the *Pokkali* tracts. The land use patterns under study were i) paddy alone ii) paddy – shrimp iii) shrimp alone iv) fallow and v) mangroves. Analysis of variance revealed that land uses had significant effect on most of the measured attributes except fine sand percent, base saturation percent, content of Mg and Zn, organic carbon and dehydrogenase activity. The statistical analysis resulted in selection of minimum data set which highly influenced the quality of the soil. Indicators in the MDS included available water content, pH, fine sand percent, aggregate stability, silt percent, available Mg, bulk density, available S, microbial biomass carbon, available Mn, organic carbon, base saturation and EC. The highest soil quality index (4.92) was observed in paddy- shrimp land use system in Nayarambalam panchayath and the least value (2.07) was observed in shrimp alone land use pattern in Kottuvally panchayath. The observed soil quality index value was in the order, paddy- shrimp>

paddy alone> fallow> mangrove> shrimp alone. Based on the relative soil quality index value, all land uses were categorized into three groups, ie, poor, medium and good. Paddy- shrimp land use system in Nayarambalam panchayath was the only one land use system coming under the 'good' category. For all the panchayaths and RRS, Vyttila GIS based soil quality index maps were prepared (Chris Joseph, 2015).

Think it over

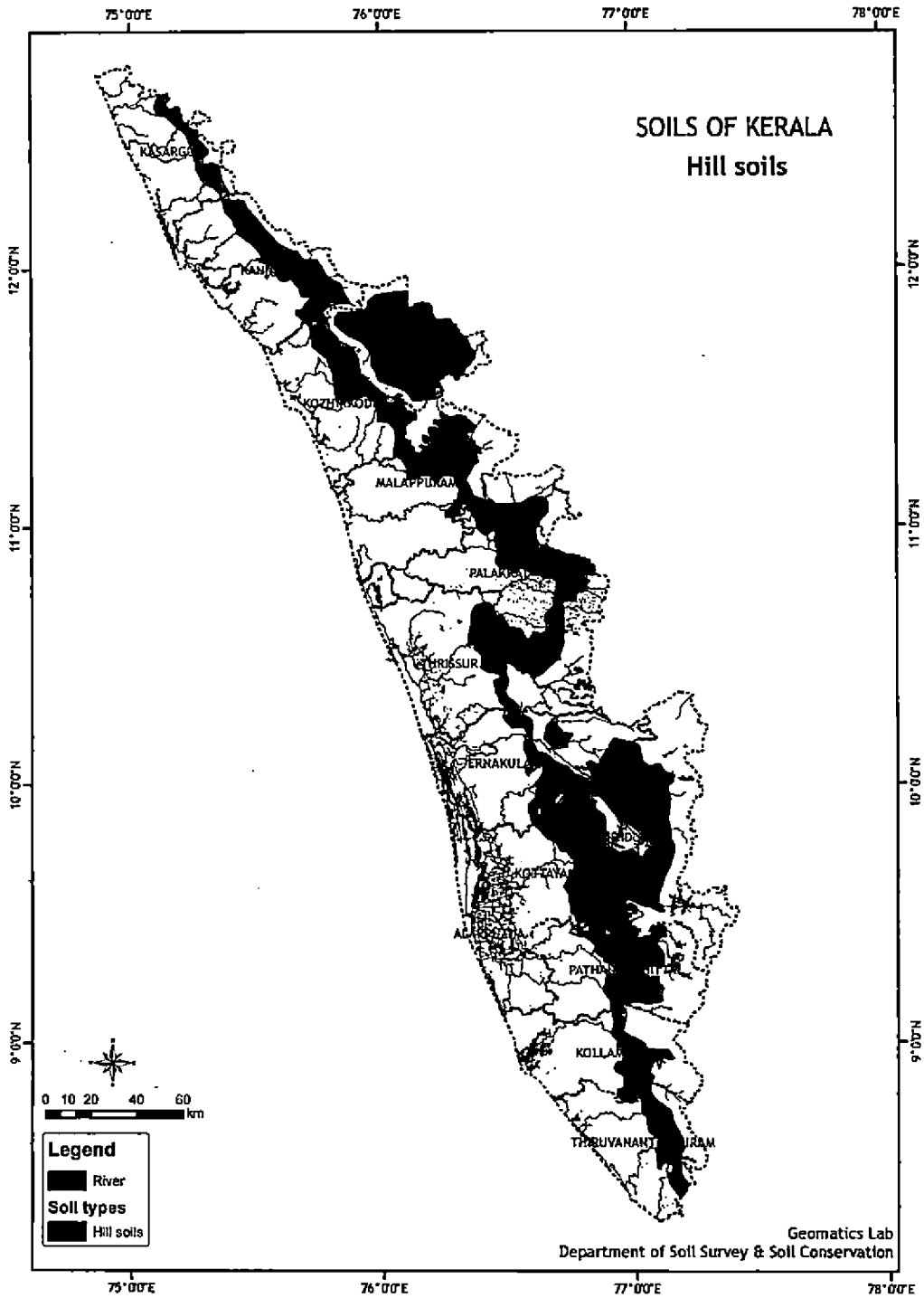
- ✓ Continuous submergence was found to be disadvantageous for the supply of available Zn to a growing rice crop.
- ✓ The effects of salinity were less injurious during the vegetative stage than the reproductive stage of rice.
- ✓ The straw of the salt resistant variety Chettupokkali growing in saline soil accumulated high proportions of K, Ca and Cl.
- ✓ The $Al_3(OH)_2$ potential can be taken as valid soil acidity index for Kole, Kari and Karappadam soils and lime potentials for Kayal soils.
- ✓ The best extractant for extractable Al in these soils was one normal KCl
- ✓ The tolerance of salts was in the decreasing order of $MgCl_2$ (12 mmhos cm^{-1}) > KCl = $CaCl_2$ (8 mmhos cm^{-1}) > NaCl (4 mmhos cm^{-1}). So EC alone cannot be considered as a factor responsible for injurious effect of salinity in soils
- ✓ In Kuttanad soils, the maximum economic yield in rice through systematic approach in fertilizer use is at a reduced optimum fertilizer dose of 90: 45: 15 kg NPK ha^{-1} for the medium duration rice varieties.
- ✓ Rock phosphate could be made equally or more efficient than super phosphate for supplying fertilizer P to rice grown in the acid soils of Kerala
- ✓ In kayal and kole soil, lime at half the LR and in Kari soils full LR recorded the maximum yield of grain
- ✓ The observed soil quality index values of the different land use systems in pokkali lands was in the order, paddy- shrimp> paddy alone> fallow> mangrove> shrimp

6. Hill and Forest soils

These soils are developed from crystalline rocks of Archaean age under forest cover. They occur along the eastern part of the State, generally above an elevation of 300 m above MSL. The area is hilly and mountainous with steep slopes, escarpments, elongated rocky summits and narrow 'V' shaped valleys. The depth of the soil varies considerably depending on erosion and vegetative cover. The soils are generally immature due to slow weathering process. Rock outcrops and stones are noticed on the surface. Gneissic boulders under different stages of weathering are noticed in the subsoil. The texture of the soil ranges from sandy clay loam to clay with reddish brown to very dark brown colour. Forest trees, shrubs and grasses are grown here. They generally show vide variation in depth and are dark reddish brown to black, with loam to silty loam texture. In areas with lesser canopy cover, signs of laterisation have been observed in the profiles. In denuded areas, leaching and deposition of humus in the lower layers are observed. The B-horizon usually contains gneissic gravels and boulders. The soil is quite fertile under forest cover and promotes prolific undergrowth. This soil is often found under vegetation. These soils are generally acidic with pH ranging from 5.5 to 6.3. They are rich in nitrogen; but poor in the bases because of heavy leaching.

Area, distribution, genesis, morphology and general characteristics

A study was carried out at the Kerala Agricultural University and the Kerala Forest Research Institute during 1993-1996 mainly to characterise the reed growing soils of Western Ghats. These soils were classified under Ustic Kandihumult, Ustic Paleohumult, Ustic Haplohumult, Ustic Kanhaplohumult, Typic Kanhaplustult, Ustic Humictropept, Ustoxic Humitropept, Ustic Dystropept, Ustoxic Dystropept, Oxic Ustropept and Lithic Dystropept at sub group level. Reeds were found to flourish on both shallow and deep soils. In pure reed brakes where upper canopy was closed, the undergrowth was completely absent. The content of gravel, especially the secondary gravel, was very low in these soils. In most of the cases the textural make up turned from sandy loam to sandy clay loam from top to bottom of the profiles. Bulk density was found to increase with increase in depth of the profiles while porosity and water holding capacity showed a diminishing trend. These soils were strongly to moderately acid in reaction and in pure reed areas surface soils were


SOILS OF KERALA
Hill soils
75°00'E
76°00'E
77°00'E
78°00'E
12°00'N
11°00'N
10°00'N
9°00'N
KASARGOD
KANNUR
KOZHIKODE
MALAPPURAM
PALAKKAD
THRISSUR
ERNAKULAM
KOTTAYAM
ALAPPUZHA
PATHANAMTHITTA
KOLLAM
THIRUVANANTHAPURAM
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km
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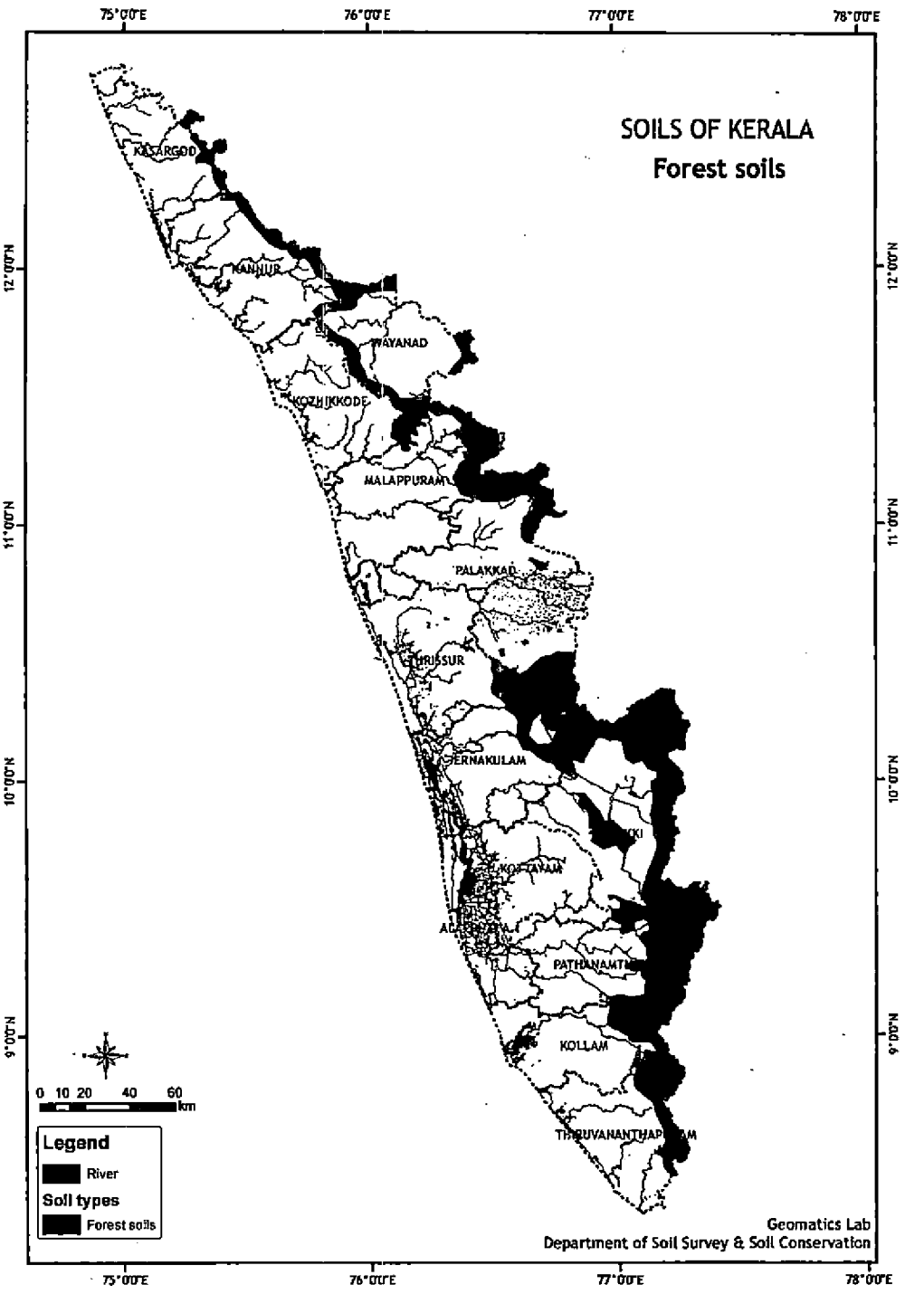
River
Soil types
Hill soils
Geomatics Lab
Department of Soil Survey & Soil Conservation


SOILS OF KERALA
Forest soils
75°00'E
76°00'E
77°00'E
78°00'E
12°00'N
11°00'N
10°00'N
9°00'N
KASARGOD
KANNUR
WAYANAD
KOZHIKKODE
MALAPPURAM
PALAKKAD
THRISSUR
ERNAKULAM
KOTTAYAM
PATHANAMTHITTA
KOLLAM
THIRUVANANTHAPURAM
0 10 20 40 60
km
Legend
River
Soil types
Forest soils
Geomatics Lab
Department of Soil Survey & Soil Conservation

more acid than subsurface soils. In general, exchangeable bases, exchange acidity, cation exchange capacity and percentage base saturation were found to show a diminishing tendency from surface to bottom of the profiles. Distribution of organic carbon, total and available N, total and available P and available K was in a decreasing trend with increase in depth of the profiles while total K was found to be concentrated in lower layers. Results in general reveal that reed bamboo plays a significant role in conserving soil and its fertility. Number of matured culms / ha was found to be a better parameter injudging the growth performance of reed and Class I reed was found to have higher number of matured culms / ha than Class II and Class III. Soils of Class I reed was significantly acidic and contained higher organic carbon but lower available N and K than the class III. Reed growing soils were found to conserve comparatively higher content of soil moisture. Mass loss during decomposition of reed leaf litter was highly influenced by rainfall and the annual decomposition rate constant did not vary significantly (0.229 and 0.234) at two sites studied. Based on the concentration and absolute content, the nutrient mobility from decomposing reed leaf litter was in the order K > N > Mg > Ca > P (Sujatha M P, 1999).

Nutrient dynamics

Morphological and physicochemical properties of denuded forest soils under the influence of oi lpalm plantation was studied and found that in all the layers of denuded forest area, as well as in the plantation, the soils contained appreciable quantities of gravel (George Jose, 1989).

Table 3: Physicochemical properties of denuded forest and Oil Palm plantation soils

	Denuded forest	16 years of oil palm plantation soils
Gravel per cent	50.12	59.47
Coarse sand per cent	21.93	45.82
Fine sand	19.17	9.94
Silt per cent	19.93	11.32
Bulk density g/cc	1.07	1.13
Particle density g/cc	2.11	2.17
Water holding capacity per cent	49.85	48.58
Pore space per cent	49.61	47.35
Volume expansion per cent	8.87	6.42
OC per cent	3.72	1.70

	Denuded forest	16 years of oil palm plantation soils
Loss on ignition per cent	12.31	8.57
Total N	0.36	0.21
C/N ratio	10.2	7.4
Avail. N Kg ha^{-1}	1400	800
Total Phsophorus per cent	0.15	0.11
Avail. P Kg ha^{-1}	6.26	2.16
Total Potassium per cent	0.45	0.37
Exch. K Kg ha^{-1}	80	140
Total Ca per cent	0.22	0.36
Exch. Ca (meq/100 g)	1.22	1.37
Total Mg per cent	0.15	0.12
Exh. Mg	0.87	1.12
Total Fe	13.43	12.89
Exch. Iron (meq/100 g)	0.17	0.08
Total Al per cent	28.56	27.98
Exch. Al (meq/100 g)	0.025	0.002
CEC (meq/100 g)	9.35	8.61
pH	4.82	4.90
Lime requirement (t/ha)	11.48	12.48

Leaf litter collected at monthly intervals showed that highest litter production was in Acacia (9.4 t ha^{-1} $year^{-1}$) followed by natural forest (6.67 t ha^{-1} $year^{-1}$) and Eucalyptus (4.68 t ha^{-1} $year^{-1}$). Chemical analysis of litter samples of plantations and natural forest revealed that with respect to nutrient content fresh and leaf litter of Acacia and Eucalyptus is superior to natural forest whereas litter quality in terms of water soluble components, polyphenols lignin and cellulose were superior in natural forest. Biological activity in terms of earthworm and nematode and microbial content were significantly lower in Eucalyptus and Acacia plantations than that of adjacent natural forest. Low humic acid and fulvic acid content in humus and dominance of fulvic acid over humic acid was also noticed in Eucalyptus plantations. Functional group analysis of humic acid and fulvic acid showed that humic material separated from natural forest contained higher quantity of total acidity contributed by COOH and phenolic group compared to plantation soils, UV, IR, DTA and TGA analysis of humic acid and fulvic acid separated from various plantations showed no variation with respect to natural forest. (Moosa, PP 1997)

The investigation entitled comparative study of the soils of cardamom plantations and virgin forests was taken up at the College of Agriculture, Vellayani, during 1994-1996. The soils of cardamom plantations have higher sand content and lower clay content compared to the soils of adjacent forests. A higher content of the clay in the forest soils compared to cardamom plantation indicates a greater degree of weathering and clay formation. Healthy cardamom plantation soils contained a significantly higher amount of coarse sand and lower content of fine sand than the soils of the location which show a decline in yield. The physical properties such as bulk density, particle density and WHC and exchangeable properties such as CEC, ECEC, and exchangeable acidity were found to be positively influenced by organic matter content of the soils and were more or less similar in all the locations. Total P and K content of soils of the cardamom plantations were low when compared to the adjacent forest indicates inefficient bio-cycling associated with the cardamom plantation and loss of bases from the system by leaching and soil erosion. The content of total nitrogen and available N of the adjacent forest soils was significantly higher indicating a rapid rate of mineralisation of organic matter in the soils of adjacent forest. The total P content of the soils of the healthy cardamom plantations was significantly higher than that of the location which shows a decline in yield. The specific influence of the plantations making more of available P from the unavailable pool is evident. The total and exchangeable potassium status in the soils of the cardamom plantation recorded a lower value than the soils of the adjacent forest. This situation may indicate a lower release as well as greater uptake of this element. The content of micronutrients such as Fe, Mn, Zn and Cu were more or less same in the soils of cardamom plantation and adjacent forest indicating the same parent material and similar climatic conditions prevailed in the locations under study. The analysis of plant leaves showed a higher content of P, K, Ca, Mg, Fe, Mn, Zn and Cu in the leaves of the healthy cardamom plantation. This point to a situation where the soil nutrient factors are not a single factor for declining the yield of cardamom but the plant nutrient factors were also responsible for the decline in yield. (Gladson-D'Cruz, 1998).

An investigation was conducted at the Upputhara panchayath of Peermede taluk, in Idukki district of Kerala with the objective to compare the soil properties, crop nutrient concentrations and quality of cardamom (*Elettaria cardamomum* Maton) under organic and conventional farming. Nine certified organic farms that follow IMO and Skal International certification standards and eight adjacent conventional cardamom farms following recommendations of Spices Board were selected for investigation. Soils of the organic cardamom farms were found to have better aeration than conventional farms, evident from the significantly lower bulk density of soils of the organic farms. Another significant effect of organic agriculture

in cardamom was the improvement of soil electrochemical properties. The rich organic soils of the study area resulted in insignificant difference in organic carbon and organic matter content of the soils of the two farming systems. The ranges of major nutrients in soils were medium to high and hence the difference between organic and conventional cardamom farms with respect to major nutrients was also not consistent. Microbes were proliferating in the organic farms resulting in better decomposition of organic matter with concomitant solubility of major nutrients in the soil. Leaf length, leaf breadth, plant height and number of tillers per clump were significantly low in organic cardamom plants. A reverse trend was seen in the case of petiole length. Panicle length, number of panicles per clump, number of racemes per panicle and number of capsules per raceme were significantly lower in organic farms contributing to lower yields, which of course are expected to improve. Since the morphological make up of the cardamom plants in the organic farms was relatively smaller, the minerals taken up were not diluted resulting in higher concentrations of major nutrients in organically managed plants. The effect of high levels of Ca in the exchange complex is also reflected in low uptake of Fe and Mn by organic cardamom plants (Arun G, 2004).

Physical and chemical attributes

A study was made in the forest soils of Kerala to determine their morphological features, physico-chemical characters and fertility status. Five typical profiles representing the three important vegetational types of the state viz., the tropical evergreen, moist deciduous and shola forest located at different altitudes and of different topography were examined. The data revealed that these soils are the product of long, continued and severe leaching under a hot humid climate. Higher acidity and more clay content were found in moist deciduous forest. (Thomas, K.M, 1964).

A study was made on the effects of deforestation on the content of orgaic carbon, nitrogen, C/N ratio and the total and exchangeable potassium of the soils of two major forest areas of Kerala viz., Chalakudi and Palode which represent the moist deciduous type of vegetation respectively. Four profile were studied from each of the centres, one from the standing forests and the others from areas denuded for 5 , 10 and 15 years. The total and available potassium content of the soils decreased as a result of denudation of forest for 10 and 15 years in the surface layer but increased in lower layers (Mithrachaly, J.I, 1965).

A study was conducted on the forest soils of Nilambur division, Kerala State to determine the extent to which the morphological, physical and chemical characterisatics of the soil are affected by deforestation followed by the maintenance of a pure teak plantation. Profile sites were selected to represent six types of

vegetation viz., natural forests and teak plantations of age 1, 15, 30, 60 and 120 years. Profile pits of depth 180 cm were dug in each of the above areas. Clear felling and planting of teak do not accelerate the process of laterization but may cause a temporary impoverishment of the soil and hardening of the lateritic material originally present (Jose, A.I, 1968).

Studies on the forest soils of Kulathupuzha revealed that the sand and silt content decreased and clay content increased with depth in the profile. A higher content of clay observed in rubber and eucalyptus plantations compared to teak and natural forest indicates a greater degree of weathering and clay formation in them. The C/N ratio narrowed from the surface to lower horizons. Eucalyptus plantation recorded lowest amount of soil N and rubber plantation higher content of soil N. The plantation soils had a higher content of available P. The total K in the soils of eucalyptus plantation recorded comparatively higher values while the values for exchangeable potassium were lowest in them (Premakumar S, 1987).

Behaviour of various chemicals in soil

In order to assess the residue level and to study the extend of pollution due to pesticides, soil and water samples were collected from the cardamom growing plantations of Idukki district. In multi residue method validation, soil samples were spiked at five different levels (0.01 µg g-1, 0.05 µg g-1, 0.1 µg g-1, 0.5 µg g-1, 1 µg g-1) and extraction was carried out using various solvent/ solvent system and the method which gave 70-110 percent recovery with RSD <20 percent was selected. The same procedure was adopted for further estimation of residues from soil samples. The pesticide hot spots were selected mainly in three locations, Kattappana, Pampadumpara and Nedumkandam Panchayath in Idukki district and five farmers were identified randomly from each location. Soil and water samples were collected before and after spraying of insecticides for a period of six months starting from December to May at two different depths at 0-15 cm and 15-30 cm depth from the selected plantations. In the monitoring study, samples collected at 0-15 cm depth were found to contain higher level of pesticide residues. The samples were frequently detected with residues of organophosphorus insecticides like phorate, chlorpyriphos, quinalphos, profenophos, methyl parathion and relatively lower numbers of samples were found to contain residues of endosulphan and synthetic pyrethroids. The samples collected from the lower depth 15-30 cm were contaminated with residues at a lower level. The physico chemical properties of the soil were analysed and it was found that the soils were rich in organic matter content (3.63-3.74 per cent), acidic to near neutral pH (5.72-6.04) and have higher fertility status. The higher organic matter content of the soil favours higher rate of adsorption of the insecticide. Water samples were collected from the selected locations and analysed for the

presence of pesticide residues and it was found that none of the samples were contaminated with pesticide residues. A field dissipation study was carried out with the neonicotinoid group of insecticide, imidachloroprid applied at three different levels (0.05 ml l^{-1}, 0.10 ml l^{-1}, 0.20 ml l^{-1}) in cropped and non-cropped condition. The half life of the chemical calculated under both the situation. The highest half life (4.25 days) was obtained when imidacloprid applied in non- cropped situation at double the recommended dose (0.20 ml l-1) and the lowest half life (2.55 days) was obtained in cropped situation when the insecticide was applied at the lowest dose (0.05 ml l^{-1}). The half life value obtained in cropped condition was lower compared to the non cropped situation. The faster degradation of the chemical under the cropped situation may be due to the higher activity of soil microorganisms and rhizosphere effect in addition to other soil factors like pH and organic carbon content (Siji. N. Nath., 2011).

Soil Quality

Oriculture involves the use of macrophytophagous oribatid mites to bring about biodegradation of plant litter, converting the same into nutrient rich humus which can be utilized as a bio-fertilizer.In oriculture, the oribatid mite species with a proven role in bio processing of plant litter are mass cultured and released into the soil. Success of oriculture lies in the right choice of oribatid mite species based on the particular type of plant litter. Oriculture can thus be treated as the modern method of agriculture with minimum cost of production and maximum yield in a most suitable ecofriendly atmosphere. So the proposed study entitled "Decomposition of leaf litter by Oriculture" was conducted during the period 2014-2015 to envisage the standardization of the methodology for mass multiplication of selected oribatid mites, and to assess the degrading efficiency of soil dwelling oribatid mites on various types of leaf litter and also to evaluate the manurial value of bio processed litter. The experiment to assess the manurial value of decomposed litter was done by factorial CRD with different combinations of two factors, leaf litter of varying C:N ratio and different modes of biotic enrichment (Litter alone, litter+ cow dung , litter+ mites , litter+ cow dung+ mites) as treatments and three replications. The percentage of litter decomposed was assessed and found that jack litter with the biotic enrichment litter+ mite + cow dung found to be the best combination showing the highest percentage irrespective of the litter type. Maximum percentage of litter decomposed was observed for jack litter with the biotic enrichment, litter+ cowdung+ mite and minimum decomposition rate was for cocoa with biotic enrichment litter alone. Effect of different modes of biotic enrichments on the contents of macro and micro nutrients observed to be highest in the treatment combination litter + cow dung+ mites.Influence of litter types on nutrient content

of decomposed litter revealed that highest carbon content (51.26 %) was in cashew litter, N content was in jack litter (3.20 %), P content (0.31 %) was in teak litter and highest K content (0.24%) in cocoa litter. Influence of litter type and biotic enrichment on N, P,K content of the decomposed litter showed that jack litter +cow dung +mites was highest in N content (3.46 %) and teak litter + cow dung +mites was highest in P (0.47 %) and mixed litter + cow dung + mites had highest K(0.21%) content (Nithya Jose, 2015).

Think it over

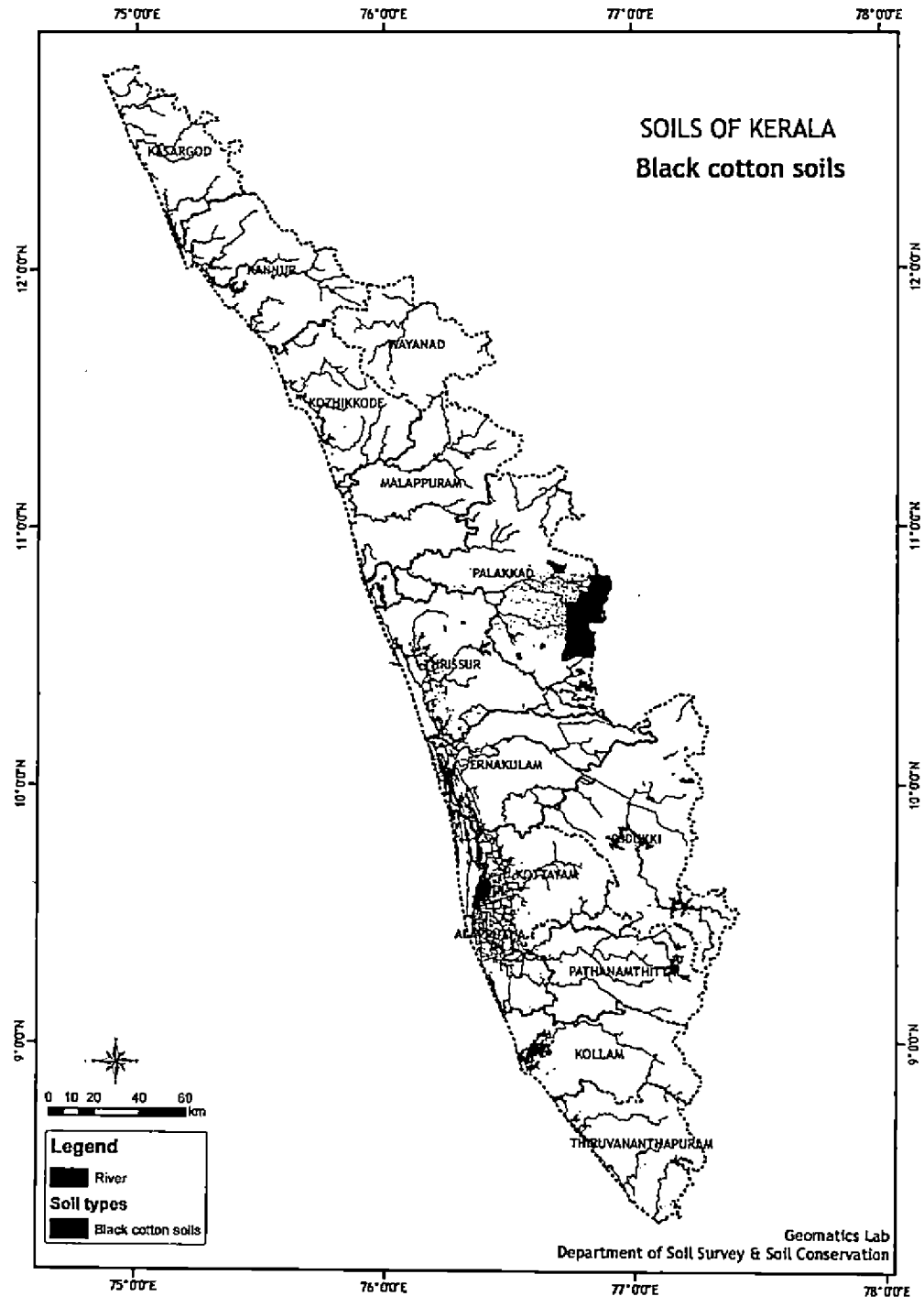
- ✓ Higher acidity and more clay content were found in moist deciduous forest soils.
- ✓ Clear felling and planting of teak did not accelerate the process of laterization but may cause a temporary impoverishment of the soil and hardening of the lateritic material originally present
- ✓ The soil and water samples of cardamom plantations of Idukki were frequently detected with residues of organophosphorus insecticides like phorate, chlorpyriphos, quinalphos, profenophos, methyl parathion and relatively lower numbers of samples were found to contain residues of endosulphan and synthetic pyrethroids.

7. Black Cotton soils

Black cotton soils are restricted to their occurrence to Chittoor taluk of Palakkad district.These soils are identified in alluvial plains, terraces and undulating plains of Chittur taluk in Palakkad district in patches. The elevation of the area ranges from 100 to 300 m above MSL with gentle to moderate slope. These soils are developed on Khondalite suite of rocks traversed by lenticular bands of crystalline limestone and calc-granulites. These soils are very deep, black and calcareous. The texture of the soil ranges from clay loam to clay. They possess high shrink-swell capacity and hence exhibit the characteristic cracking during dry periods. A variety of crops such as coconut, sugarcane, cotton, chilly, pulses and vegetables are grown here. They are found to occur in patches and are considered as extension of the black cotton soils observed in the adjacent Coimbatore district of Tamil Nadu.These soils are dark, low in organic matter, calcareous, neutral to moderately alkaline (PH 7.0 to 8.5) and high in clay content and CEC. Hence they exhibit the characteristic cracking during dry periods. They are usually located in gently sloping to nearly level lands. The levels of potassium and calcium are moderate and those of nitrogen and phosphorus, low. In a relatively small area of 1000 ha. in Chittoor block, a highly dispersed soil termed as "Poonthalpadam" soil, is seen. This soil occurs as a slushy layer to a depth of about 0.5m to 1.5m. A bed of limestone is seen beneath the slushy layer. The physical properties like plasticity, cohesion, expansion and shrinkage are similar to those of the regular soils of the Deccan plateau.

Physical and chemical attributes

A study was undertaken to investigate the physical and chemical characteristics of the Poonthalpadam soils of Kerala. Six soil profiles and fifty two surface samples were included in the study. The texture of the profile samples varied from sandy clay to clay while that of the surface samples varied from loam to clay. In the profiles the clay fraction ranged from 16.35 to 43.25 percent and in surface samples 18.5 to 43.1 per cent. The apparent density of the profile samples ranged from 1.20 to 1.80 Mg m^{-3} and that of the surface samples from 1.16 to 1.36 Mg m^{-3}. A negative correlation existed between clay content and apparent density. The maximum water holding capacity ranged from 30.8 to 45.35 percent in the profiles and from 35.3 to 50.6 percent in the surface samples. The upper plastic limit, lower plastic limit and sticky point moisture were found to be the highest in the surface layers. The pH of


SOILS OF KERALA
Black cotton soils
75°00'E
76°00'E
77°00'E
78°00'E
12°00'N
11°00'N
10°00'N
9°00'N
KASARGOD
KANNUR
WAYANAD
KOZHIKKODE
MALAPPURAM
PALAKKAD
THRISSUR
ERNAKULAM
IDUKKI
KOTTAYAM
ALAPPUZHA
PATHANAMTHITTA
KOLLAM
THIRUVANANTHAPURAM
0 10 20 40 60
km
Legend
River
Soil types
Black cotton soils
Geomatics Lab
Department of Soil Survey & Soil Conservation

the profile samples varied from 6.3 to 8.4. In the surface samples, the pH varied from 6.3 to 8.3 and EC from 0.18 to 0.66 mmhos/cm. The HCO_3 content of the profile samples ranged from 0.03 to 0.60 per cent. The average values of organic matter content in the profiles ranged from 0.01 to 0.13 per cent. In the surface samples total nitrogen ranged from 0.03 to 0.16 per cent. The average values for the C/N ratio of the three layers from the surface were 20.69, 19.89 and 26.96 respectively. The range in the C/N ratios in profile samples was from 6.83 to 59.39 and in the surface samples it was from 6.8 to 55.4. Total P_2O_5 showed a variation of 0.07 to 0.18 percent in all the profiles considered together and from 0.03 to 0.16 percent in surface samples. Available P showed variation from a trace to 25 ppm in the profiles and from a trace to 19 ppm in the surface samples. The CaO content ranged from 0.46 to 5.92 percent in the profiles and from 0.66 to 5.01 percent in the surface samples. The variations in the MgO content in the profiles and the surface samples were from 0.11 to 1.50 percent and from 0.16 to 1.16 percent respectively. The K_2O content of the profiles varied from 0.07 to 0.33 percent and in the surface samples from 0.07 to 0.39 per cent. The total sodium content of the profiles ranged from 0.08 to 0.18 per cent. A positive significant correlation existed between the total sesquioxides and Fe_2O_3 in the profiles. The average values for Fe_2O_3 were 5.75, 5.90 and 6.10 percent and for Al_2O_3 2.50, 1.89 and 1.07 percent respectively in the three layers from the top. The CEC in the surface, intermediate and the third layers of the profiles were 12.1, 12.0 and 10.9 me/100 g respectively. Exchangeable sodium varied from 0.76 to 1.83me/100 g in the profiles. The average values for the surface, intermediate and the third layers were 1.23, 1.15 and 0.83me/ 100 g respectively. The dispersed nature of the clay resulting in the poor physical characteristics of the Poonthalpadam soil might be due to the presence of sodium (Krishnakumar, A. K. 1978).

Thirty eight surface soil samples and their corresponding subsurface samples collected from six villages in the Poonthalpadam tract of Kerala were analyzed for their physico-chemical and mechanical properties.The pH and electrical conductivity were found to be in the optimum range for rice cultivation.In spite of the satisfactory levels of total nitrogen, phosphorus and potassium in these soils, only very small fractions of these elements were in the available form (about 10 percent nitrogen, less than 1 percent phosphorus and 30 percent potassium). This might be due to the process of fixation undergone by these nutrients on their addition, in a soil environment of high pH, free calcium carbonate and clay contents which provided conditions favourable for fixation especially that of phosphorus.When compared to the other problem soils of Kerala, the Poonthalpadam soils have appreciably higher quantities of calcium and magnesium while iron, manganese and sodium levels are low. The ammonium fixing capacity of the soils ranged from 1.12 to 7.24

me/100 g was more in the subsurface soils and was positively and significantly correlated with organic matter, clay and the free calcium carbonate contents. With cation exchange capacity, total sesquioxides and silt contents the correlation is positive while with sand content it is negative. The potassium fixing capacity showing a variation from 1.04 to 7.93 me/100 g was also more in the subsurface samples and is correlated positively and significantly with the clay content only. There was positive, though not significant relationship with organic matter, free calcium carbonate and silt contents and negative relationship with sand and cation exchange capacity. The phosphorus fixing capacity which ranges from 22 to as high as 70 percent, is significantly and positively correlated with free $CaCO_3$ and clay content. With organic matter cation exchange capacity the correlation was found to be negative and with silt and total sesquioxides it was positive. The mechanical analysis of these soils shows that the texture varies from clay to sandy loam. In certain locations, the soils had very high clay contents making cultural operations difficult both under wet and dry conditions. The high content of clay dispersed mostly in the surface layers was the immediate cause of the slushy and puddled nature of the Poonthalpadam soils, aggravated by exchangeable sodium and bicarbonates which brought about a thorough dispersion of the clay. (Sumam George, 1980).

The investigation undertaken, envisaged the characterization of the soil and irrigation water of three sugar cane growing regions namely Vannamada, Meenashipuram, and Attapadi in Palghat district and their relation to nutrient uptake, yield and quality of sugar cane. One hundred and ninety seven surface samples from the regions were characterized for the major physico-chemical properties. Twenty four farmer's field were identified as observation plots to assess the yield, dry matter production and quality parameters of sugarcane juice and the inter relations between these parameters. Samples of irrigation water from four commonly used sources namely bore well, canal, open well and river water used for irrigating sugarcane plots were collected in pre monsoon and monsoon periods for the determination of quality parameters. Soils of three regions were mildly alkaline in reaction. The major texture of the soils was sandy clay loam followed by sandy loam. The water holding capacity and volume expansion of the soils were significantly higher in Vannamada and the lowest in Attapadi regions. None of the physical properties had adverse effect on the growth of sugar cane. Organic carbon and total N, P and K recorded low values in the soils of the three regions. For available P and K, the rating of Vannamada and Meenashipuram regions was medium while for the Attapadi it was high. The micronutrients viz., Fe, Zn, Cu and Mn were above the sufficiency limits. The quality parameters of the irrigation water such as pH, EC, chloride, sulphate, RSC and SAR were within the safe limits for the irrigation of the sugarcane. Juice quality parameters were significantly and positively correlated with N, P, K and Na (Visveswaran, S. 1995).

Response to fertilizers

A study was undertaken to investigate the effect of direct application of rockphosphate in combination with amendments in the black soils of Palakkad. There were two experiments, an incubation study to investigate the relative efficacy of various amendments in releasing soluble P from rockphosphate and a pot culture experiment to study the comparative efficiency of rock phosphate with amendments. Incubation experiment showed an increase in P fractions like saloid-P, occluded-P, reductant-P, Fe-P, Al-P and Ca-P upto 45 days which decreased subsequently with the advancement of time. In the pot culture experiment growth as well as yield character of crop were significantly influenced by treatments receiving rockphosphate amended with direct acidulation and pyrite application at all levels. Rajphos @ 45 kg ha^{-1} with 50 percent acidulation was found to be on par with the treatment receiving Rajphos @ 30 kg ha^{-1} with 50 percent acidulation. Rajphos treated with acid performed equally well as SSP and the results were comparable. The grain and straw yield and uptake of nutrients were significantly superior for treatment consisting of acidulated rockphosphate. Chemical amendment like iron pyrite and microbial inoculation with phosphobacterin was also found to be efficient but the effect was not significant statistically (Vyas, N. G, 2002).

Soil fertility evaluation

A field experiment was carried out to find out the best nutrient management system suited for sustainable rice production in black soils of Chittur, Palakkad district. It can be concluded that black soils of Chittur were fertile. But the productivity of these soils are constrained by factors like high content of basic cations such as calcium and sodium and subsequent low uptake of major nutrients. High plant content of Fe was also observed during the maximum tillering and panicle initiation stage of rice. The content of Si in soil as well as uptake of Si by the crop was also comparatively less. So management practices have to be adopted to reduce the soil content of the basic cations as well as nutrient imbalances in soil and plants by drainage, leaching and incorporation of FYM, crop residues and rice husk (Danish Tamuly, 2011).

Soil Quality

A study intended for "Characterization of soil and water of Palakad eastern plains in relation to growth and nitrogenase content of *Azolla spp.*" was undertaken in the Department of Soil Science and Agricultural Chemistry, College of Horticulture, KAU, Vellanikkara during 2013 – 2015. The objectives of the study were to conduct a survey of *Azolla* spp. in the rice growing tracts of Palakkad eastern plains and to

identify soil and water quality parameters congenial for the growth and nitrogenase content of *Azolla* spp. Nitogenase enzyme actitvity quantified was profoundly affected by the location. The amount of ethylene produced extended from 192 to 236 mole ethylene $g^{-1}h^{-1}$. It showed a significant negative correlation with soil pH and EC.The study had given valuable information on the influence of soil and flood water quality parameters and locations on *Azolla* which could be used for further investigation on its nutrient dynamic (Bhavyasree, K.T., 2015).

Think it over

- ✓ In slightly alkaline reaction, presence of carbonates and bicarbonates of Na may be responsible for desorption of large amount of K in the soil
- ✓ Chemical amendment like iron pyrite and microbial inoculation with phosphobacterin were found to be efficient
- ✓ Management practices such as drainage, leaching and incorporation of FYM, crop residues & rice husk are necessary to reduce the content of the basic cations as well as nutrient imbalances in soil.

8. Comparative studies on different soil types of Kerala

Pedology

One representative soil profile from each of the following research stations were selected and classified as per soil Taxonomy (USDA, 1975). (Bindukumari A). The details are furnished as follows :

Table 4: The main features of the soil profiles of different soil types of Kerala

	Profile I	Profile II	Profile III
Location	A block CRS Balaramapuram	College of Agriculture, Vellayani, rubber garden	Terraced land of NARP Special station, Sadanandpuram, Vettikavala, Kottarakkara
Parent material	Lateritic alluvium	Lateritic alluviam, residual material igneous rock derived from coarse acid	Lateritic alluvium on biotite genesis and charkonite
Physiography	Alluvial basin	Leveled experimental land	Mid slop of a middle level lateritic hill
Relief	Nearly flat	Gently slopy	Gently slopy towards west
Slope	1-2 percent	1-3 percent	2-4 percent
Elevation	More than 50 MSL	50 m above MSL	600 m above MSL
Drainage	Moderately well drained	Moderately well drained	Moderately well drained
Climate	Humid tropical, Annual Rainfall-1646.92mm, Mean Annual Temperature- 27.5°C	Humid , tropical, Mean annual rainfall 1646.1mm, Mean annual temperature 27.5°C	Humid tropical climate mean annual rainfall – 2500 mm, Mean annual temperature – 24°C
Vegetation	Coconut	Rubber	Mango garden with few grasses
Limitations effecting plant growth if any	Low fertility, low water holding capacity	Low fertility, low water holding capacity	Moderate water holding capacity, erosion

Table 4 : Continued

	Profile IV	Profile V	Profile VI
Location	Experimental plot of sugarcane research Station, Thiruvalla	Cardamom Germplasm collection plot of CRS Pampadumpara, Idukki, Kerala	AMPRS, Odakali, lemon grass cultivated experiemental land behind the office building.
Parent material	Alluvium	Laterite alluvium	Lateritic alluvium over resudial laterite
Physiography	Toe slope of hill leveled	Toe slope of hill lock	Side slope of a laterite mount
Relief	Gently slopy	Slopy	Gently slope
Slope	1-2 percent	15-30 percent	3-5 percent
Elevation	20 m above MSL	520 m above MSL	50 m above MSL
Drainage	Moderately well drained to well drained	Well drained	Moderately well drained
Climate	Humid tropical climate Mean annual rainfall – 2500 mm, Mean annual temperature 27 °C	Humid tropical climate, mean annual rain fall 3000mm, Mean annual temperature 24°C	Humid tropical, Mean annual rainfall 2300 mm Mean annual Temperature 27°C
Vegetation			Lemon grass cultivated experiemental plot
Limitations effecting plant growth if any			Medium fertility, low water holding capacity, less effective soil volume

Table 4: Continued

	ProfileVII	Profile VIII	Profile IX
Location	BRS Kannara	Terraced land near playground of COH	Dissected cut of a hill crest on the side of instructional farm of KCAET, Thavanur Malapuram
Parent material	Biolite gneiss	Biolite gneiss	Biolite/gneiss
Physiography	Rolling midland	Rolling midland	Petroferric hill crest
Relief	Gently slopy	Gently slopy	slopy
Slope	2-3 percent	2-3 percent	2-5 percent
Elevation	150 m above MSL	150 m above MSL	80 m above MSL
Drainage	well drained	well drained	Ill drained
Climate	Humid tropical Mean annual rainfall 2800mm Mean annual Temperature 28°C	Humid tropical,, Mean annual rainfall 2800mm Mean annual Temperature 28°C	Humid tropical, Mean annual rainfall 2800mmMean annual Temperature 27.5°C
Vegetation	Banana cultivated	Barren land with few grasses	Nil with few grasses
Limitations effecting plant growth if any	Low medium fertility, low water holding capacity, partial reduction during post rainy season	Low effective soil volume, low fertility, medium water holding capacity, errosion	Shallow soil and hard petroferric contact.

Table 4: Continued

	Profile X	Profile XI	Profile XII
Location	CWRDM Calicut, Terraced forest patch behind the main office cum laboratory building of CWRDM, Kunnamangalam, Calicut	Mango garden RARS Ambalavayal, Wayanad	New land with cashew acquired by RARS Pilicode
Parent material	Lateritic alluvium	Lateritic alluvium on residual weathered quartizitic gneiss	Lateritic alluvium on residual laterite
Physiography	Side slope of a lateritic mount	Summit of hill	Low laterite mount
Relief	Slopy	Gently slopy towards west	Slopy
Slope	10-12 percent	2-4 percent	5 – 10 percent
Elevation	80 m above MSL	600m above MSL	100 m above MSL
Drainage	Moderately well drained	Moderately well drained	Moderately well drained
Climate	Humid tropical climate Mean annual rain fall –2960 mm, Mean annual temperature – 27°C	Humid tropical climate Mean annual rainfall – 2500 mm, Mean annual temperature – 24°C	Humid tropical, Mean annual rainfall 2900mm, Mean annual temperature 27°C
Vegetation	Grasses, Shrubs and trees	Mango garden with few grasses	New land with cashew acquired by RARS Pilicode
Limitations effecting plant growth if any	Low fertility, Low water holding, capacity less effective soil volume	Moderate water holding capacity, Erosion	Lateritic alluvium on residual laterite

Four subwatersheds namely Kallupalamthode, Ayithithode, Thuruthithode and Attingalthode were selected in Aruvikkara watershed of Nedumangad Taluk, Thiruvananthapuram District, Kerala, for assessing the erodibility of the soils, productivity potential, fertility capability classification and soil classification. It was observed that only two soil series occur in the study area, namely Palode and Nedumangad series, which were placed under the order Ultisols. Palode series occured in the upper physiographic positions namely crest and upper sideslope, while Nedumangad series occur on the lower physiographic positions.The major problem identified in the watershed areas is soil erosion. In Kallupalamthode, Ayithithode and Thuruthithode watersheds, more than 80 percent of the area had already been brought under soil conservation measures, whereas in Attingalthode watershed, no soil conservation measures had been adopted so far. But the soils in all the four watersheds showed high values of erodibility indices, revealing their susceptibility to erosion. In the lower sideslope sites in all the catenary sequences, it was observed that these sites have high productivity potential for rubber. The FCC grouping showed that all the soils were either loamy or clayey in the surface and substrata and were favourable for the cultivation of coconut, tapioca, banana, arecanut, rubber, mango, jack and pepper. The adverse effect of more than 35 percent gravels was more pronounced in the loamy than in clayey soils. (Anup, V, M, 2004).

Soil Classification

A study was conducted to identify the micromorphology and mineralogy of the soil of major land resource areas of Kerala (AnupV.M, 1996).

Table 5 : Mineralogy of the soils of major land resource areas of Kerala

SSI No.	MLRA unit	Profile site	Clay mineralogy (Decreasing order of abundance)	Classification (USDA 1975,1994)
1	Southern Dissected terri plain	Vellayani	Kaolinite> mixed clay minerals> feldspars and geothite	Fine lomy mixed isohyperthermic Rhodic Haplustox
2	Southern low land laterites	Thiruvanantha-puram	Kaolinite> mixed clay minerals>Mica>Smectite> feldspars and geothite	Fine kaolinitic isohypothermic plinthic Kndiustults
3	Southern Coastal plane	Kazhakuttom	Kaolinite> Smectite= mixed clay minerals>Mica quartz> geothite	Sandy mixed is ohypothermic Ustic Quartipsaments
4		Kayamkulam	Kaolinite> Smectite> mixed clay minerals>Mica quartz> geothite	Sandy mixed isohyperthermic tropic fluvaquents

Table 5: Continued

5	Southern Dissected mid land laterites	Nedumangad	Kaolinite> mixed clay minerals>Mica>Smectite> feldspars> gibbsite> geothite	Fine skeletal Kaolinitic plinthic haplustults
6		Kottarakkara	Kaolinite> mixed clay minerals>Mica>Smectite> feldspars> gibbsite> geothite	Lomy skeletal Kaolinitic isohyper-thermictypic plinthustults
7	Southern Foot hills	Palode	Kaolinite> mixed clay minerals, goethite> feldspars	Fine Skeletal mixed isohyperthermic typic hapludolls
8	Kuttanad coastal Basin	Karumadi	Kaolinite> Smectite, mixed clay minerals>illite	Fine mixed isohyperthermic histic sulfaquents
9		Moncompu	Kaolinite> Smectite, mixed clay minerals>illite	Fine mixed isohyperthermic histic sulfaquents
10	Central back water basin	Viyatill	Kaolinite> Smectite, mixed clay minerals>illite> gibbsite	Fine mixed isohyperthermic histic sulfaquents
11	Central dissected mid land laterite	Vellanikkara	Kaolinite>mixedclay minerals>mica>Smectite> Feldspar>gibbsite> goethite	Fine loamy skeletal isohyperthermic typic Plinthustults
12	Palakkad gap	Eruthenpathy	Smectite> Kaolinite>mixed clay minerals>illite>mica> gibbsite>Feldspars	Fine montmorilloni-tic isohyperthermic petrocalcic chromusterts
13	Northern dissected mid land laterite	Angadipuram	Kaolinite>mixedclayminerals> mica>Smectite> Feldspar> gibbsite>goethite	Fine loamy skeletal isohyperthermic typic Plinthustults
14		Kunnamangalam	Kaolinite>mixedclay minerals>mica>Smectite> Feldspar>gibbsite> goethite	Fine skeletall kaolinitic isohyperthermic typic Plinthustults
15	Pilicode		Kaolinite>mixed clay minerals>mica>Smectite> Feldspar>gibbsite> goethite	Fine skeletall mixed isohyperther-mic Plinthustults
16	Wyanad plateau	Ambalvayal	Kaolinite>mixedclay minerals> mica>illite> gibbsite, goethite	Fine loamy mixed isohyperthermic typic ustorthents

Nutrient dynamics

Phosphorus uptake of rice was favoured by high pH values, moderate amounts of exchangeable and water soluble Fe and high conductivity of soil solution Fe. Iron phosphate was the predominant form of phosphate in the rice soils of Kerala (Padmanabhan Nair, S., 1965)

The distribution of total Mo in the soils of Kerala ranged from 0.7 to 2.6 ppm. The red soils contained maximum amount of total Mo and forest soils, the minimum. The black soils contains the maximum amount of reducible Mo (400 ppm) and in red soil, it was minimum (2ppm). (Rajagopalan, V, 1969).

Application of lime or dolomite in acid soils improved the uptake of K in rice soils (Usha, C.1966). The fractionation procedure of Chang and Jackson has to be suitably modified to determine the various inorganic fractions including thorium phosphates and rarer phosphate (Gopinathan, G., 1969).

Application of sagar (manure supplement prepared from sea water) with NPK resulted in maximum uptake of all nutrients except P and a slight increase in the pH of the soils (Chinnamma, N. P, 1975).

The organic P fractions varied from 15.3 to 52.4 percent of total P in major soils of Kerala. The average C: N, C: P and N: P ratios for the surface samples were 13, 214.1 and 17.7 respectively (John, P. C., 1971).The double acid consisting of 0.05 N HCl and 0.025 N H_2SO_4 is a suitable extractant for available P in Kerala Soils (Mohan. R. K., 1978)

The economic response for P beyond 30 kg can be obtained only for varieties Thriveni, Rohini, Annapoorna, Mashoori, IR-8 and Aswathy. The optimum economic dose was 42 Kg P per hectare. Identification of varieties which are poor in response to P suggest that in a rice-rice cropping system, alteration of responding and non-responding varieties enable the skipping of P atleast in alternate season (Mahendran, P., 1979). Nutrient status of the 3rd leaf petiole of the 3rd flush period (February) is suitable for foliar diagnosis of N, P and K in cocoa (Annie Koruth, 1982).

In three permanent manurial experiment (PME), two at Pattambi and one at Kayamkulam, the continuous application of treatments for thirty one seasons had brought about maximum variation of 0.7 pH unit at Kayamkulam while at Pattambi the variation in old PME was 0.2 and in new PME 0.4 pH unit. The continuous application of organic matter has resulted in a significant built up of micronutrient status, especially of Zn and Mn (Sam T. Kurumthottical, 1982).

Studies on the phosphorus fixation studies in rice soils of Kerala showed that the coastal sandy alluvium recorded the lowest and Kari soils recorded the highest P fixing capacity . (Harikrishnan Nair,K, 1986).

The study, entitled "Studies on exchangeable equilibria and its prediction on some acid soils of Kerala" was conducted in three soil types, viz., Kari, laterite and redloam soils, differing in their texture and organic matter content. From studying on the effect of different electrolyte concentration of aluminium on aluminium-potassium, aluminium-calcium, aluminium-magnesium exchange, an increasing aluminium adsorption was observed with an increase in electrolyte concentration of aluminium. The adsorption of aluminium was maximum in soils with high organic matter content.The normalized exchange isotherms of aluminium for different cationic systems and soils lay above the diagonal, suggested the preferential adsorption of aluminium over other cations. Except the Gapon selectivity coefficient, all the other coefficients (K_{KOD}, K_V and K_N) increased upto a certain value of base saturation and then decreased. The value of K_G increased with increase in base saturation. Among the various selectivity coefficients, K_N was found to be the most dependent one and K_G the least dependent. The dependence followed the order $K_N > K_V > K_{KOD} > K_G$.The negative values of free energy change for different cationic systems suggested the preferential adsorption of potassium, calcium and magnesium over aluminium. Among these cations, potassium was found to be adsorbed with more energy, followed by calcium, magnesium and then by aluminium. The values of free energy change showed the following order of preference for the competing cations, K>Ca>Mg>Al. From the study it can be concluded that potassic fertilizers can be used in acid soils of Kerala because of its high retention and minimum leaching loss. Compared to potassium, calcium and magnesium were adsorbed with less bond energy and hence to maintain a higher concentration of these cations in the soil exchange complex, a considerable amount of calcium and magnesium should be supplied by frequent application of lime (Swarnavi, S.1988).

Boiling nitric acid extractable K estimated for Trivandrum, Kazhakuttom and Kotoor series revealed that 71, 46 and 51 percent of K determined by this method was available to crops (George Joseph, 1993).

The important acidity contributing factors identified in the wetland rice soils of Kerala were organic matter clay minerals, CEC, exchangeable hydrogen, exchangeable Al, Fe, Mn, S and total soluble salts. Path coefficient analysis of important acidity contributing factors and the correlation and regression analysis of soil characteristics indicated that exchangeable aluminium was the best parameter for measurement of soil acidity. High dose of lime application causes reacidification of soil at a faster rate especially in soils having high potential acidity. Studies on submergence showed that wetland rice soils of Vellayani, Karamana, Karapadam, Kole, Kaipad, Pattambi, Kattampally and Wyanad did not require lime to raise the pH for rice cultivation because all these soils attained a pH value of 5.5 within 2

weeks of submergence and available N, P, Ca, Mg, Na, Fe, Mn and Si were increased. Al and S were reduced to very low values by submergence. Zinc and Cu were found to decrease by prolonged submergence. By draining the field and aerating it, zinc availability could be increased. Cu deficiency occured in peat soils like Kari because solubility of Cu decrease 100 fold for each unit increase on pH and stronger complexation of Cu with organic ligands and higher stability of these complexes. (Usha P.B, 1995)

A study was done at the College of Agriculture, Vellayani during 1994-95 to quantify the different forms of potassium and to investigate the inter-relationships of these forms with other soil fertility parameters. Soil samples were collected from ten locations each, of the two major wet land rice soils of Kerala viz., lateritic alluvium of Pattambi (brown hydromorphic) and Onattukara sandy soil (greyish Onattukara) of Kayamkulam. Incubation studies were also carried in both soil types, with and without applied potash, for a period of two months. The study revealed that considerable variation existed in the physico-chemical properties of the two soils. The lateritic alluvium of Pattambi was clayey, high in chloride, organic matter, active iron, CEC, ECEC, exchangeable Ca, Mg and sum of bases and was low with respect to coarse sand and available phosphorus contents and was less acidic as compared to the Onattukara sandy soils of Kayamkulam. The latter was loamy sand in texture with a high content of coarse sand fraction, more acidic, high in phosphorus content and low in clay, chloride, organic matter, active iron, CEC, ECEC, exchangeable Ca, Mg and sum of bases in comparison to the former. Fractionation studies revealed that the Pattambi soils had a higher content of total K, HNO_3K and fixed K as compared to that of Kayamkularn soils. The high positive correlation of exchangeable K with the available K fraction in both the soil types justifies the existence of a dynamic equilibrium between the two fractions. The negative correlation of exchangeable and available fractions of K with active iron observed in Pattambi soils was contrary to earlier observations in this regard. Though comparatively high in organic matter, the effect of soil reaction on the available K status was not considerable in Pattambi soils as compared to Kayamkulam soils. This led to the conclusion that management of organic matter in tropical soils is important to maintain the available K status for sustainable farming. The positive inter correlation obtained between lattice K and total K indicated that the major portion of soil potassium existed in the lattice form. The positive and significant association of other forms of potassium was indicative of the existence of a dynamic equilibrium between these forms of K. Potassium fixation was found to be a constraint in Pattambi soils especially with the addition of potassic fertilisers. Hence this should be given due consideration while formulating cost-effective and efficient potassium management strategies since the major chunk of potassic fertilisers are imported in our country (Naveen Leno 1997).

Representative surface samples (0-20 cm) of eight soil types each from three locations (total 25 samples-including one additional sample from Kuttanad) covering nine agro-ecological units representing the major rice growing tracts of the state were collected for the study on "Availability indices of boron in major soil groups of Kerala". The agro-ecological units (AEU) included were Kuttanad (Kuttanad, AEU 4), Kole (Kole lands, AEU 6), Pokkaii (Pokkali lands, AEU 5), Black cotton (Palakkad central plains AEU 23 and Palakkad eastern plains, AEU 10), Onattukara (Onattukara sandy plains, AEU 3), Palakkad rice soil (North central laterite, AEU 10), Laterite soils from Kozhikode, Vellanikkara and Pattambi (Midland laterite, AEU 11 and North central laterite, AEU 10)and Wayanad Plateau soils (Northern High hills, AEU 15 and Wayanad central plateau, AEU 20). Among the 25 soils, 15 soils showed acute boron deficiency chances (Critical limit: <0.5 mg kg^{-1} soil). Fractionation of soil boron was done to separate the different forms of boron existing in soil viz. nonspecifically adsorbed plus water soluble B (NSA-B), specifically adsorbed B (SPA-B), manganese oxy-hydroxide bound B (MOH-B), B occluded in amorphous Fe-Al oxides (AMO-B), B occluded in crystalline Fe-Al oxides (CRO-B) and residual boron. Amount of boron existed in different fractions was in the following order, Residual > CRO-B > AMO-B > MOH-B > SPA-B > NSA-B. Among these fractions, MOH-B and NSA-B contributed to available B directly as well as indirectly through each other. Electrical conductivity or rather salinity is the single most important factor influencing B availability.Adsorption studies were conducted with all the soils to study the adsorption pattern of B in the above soils. The data obtained from boron adsorption experiments were fitted into different adsorption isotherms like Freundlich, Langmuir and Tempkin isotherms. 22 soils followed Freundlich adsorption pattern where as only one each of Black cotton soils (Black cotton 1) and Onattukara soils (Onattukara 2) fitted with Langmuir and Tempkin as well. Onattukara 1, the soil which recorded the lowest available B of 0.04 mg kg-1 was used to conduct a pot culture experiment using rice as test crop with three levels of B (0, 10 and 20 kg ha^{-1}) with and without 5 t of FYM per hectare. The data on soil as well as plant analysis at panicle initiation and harvest stages indicated that available B status improved with increasing levels of B. Grain and total DM yield increased with the increase in boron doses without FYM. It was also noted that FYM alone could meet the B requirement. FYM with borax was found to have antagonistic effects with respect to yield as well as the nutrient contents in rice. (Anu George, 2011).

A study on the profile of ferralitic alluvial paddy soils under long term differential fertilizer application was formulated with the objective of studying the variations in the important biological properties of ferralitic alluvial soils under long term fertilizer experiments with rice-rice cropping sequence and the relationship of these properties with yield and yield attributes were recorded. Soils of three long term fertilizer experiments at RARS, Pattambi *viz.*, 1) Permanent Manurial Trial with tall

indica rice variety (PMT- Tall), 2) Permanent Manurial Trial with dwarf indica (PMT-Dwarf) & AICRP on long term fertilizer experiments (LTFE) formed the study material. In nutshell for sustenance of soil health and maximum yield, treatment (10 kg N ha-1 as GL+ 10 kg N ha-1 as CM + NPK @ 20:20:20 kg ha-1) was adjudged to be the best for (PMT- Tall). For (PMT- Dwarfl), (22.5 kg N ha-1 as GL + 22.5 kg N ha-1 as CM + NPK @ 45:45:45 kg ha-1) was the best treatment and {100 percent NPK + FYM @ 5 t ha-1 (to Kharif crop only)} for LTFE (Nikhil. K, 2014).

Physical and chemical attributes

Organic matter influenced the amount and distribution of water soluble, exchangeable, reducible and active forms of Fe in rice soils of Kerala. Water logging contributed as one of the controlling factors in the solubilization and mobilization of Fe, which increased with depth (Narayana Pisharody, P., 1965).

Studies on the physical properties of the major soil groups of Kerala revealed that particle density was highest (2.88) in laterite soils and the lowest in riverine alluvium and forest loam (2.34). Bulk density was highest for brown hydromorphic and forest loam groups (1.03 and 1.01) (Antony, P.C, 1982).

A simple linear equation for calculating total nitrogen based on organic carbon content of the soil was worked out as N percent = 0.0803 OC percent + 0.38. The mean C:N ratio for low, medium and high organic carbon were 8.19, 9.68 and 11.26 respectively. The percentage of humic acid, fulvic acid and humin in the soil organic matter were 28.3, 36.5 and 35.2 respectively (Usha, P. B, 1982).

Aggregate size distribution and its relationship to physical and chemical properties of some typical soils of Kerala was undertaken by (Ushakumary. K, 1983) and the salient findings sumarised as follows.

Table 6: Aggregate size distribution and physical properties of some typical soils of Kerala.

Soil type	Depth (cm)	Coarse sand per cent	Fine sand per cent	Slit per cent	Clay per cent
Laterite soil	0-15	57.8	10.8	2.4	29.0
Black soils	0-15	20.8	8.5	17.9	52.8
Red loam	0-15	45.35	16.4	4.1	34.04
Riverine alluvium	0-15	4.8	31.5	36.2	27.5
Coastal alluvium	0-15	59.9	17.6	6.1	16.5

Table 6 (Continued)

Soil type	Depth (cm)	Mean particle density (g/cm3)	Bulk density (g/cm3)	Porosity per cent
Laterite	0-15	2.77	1.69	39.10
Black	0-15	2.60	1.17	55.00
Red loam	0-15	2.63	1.35	48.70
Riverine alluvium	0-15	2.52	1.16	54.00
Coastal alluvium	0-15	2.50	1.43	42.80

Liming the rice soils coupled with washing was found to significantly increase the mean pH values and decrease the exchangeable H^+ and $Al3^+$. Soil acidification increased with increased levels of lime (Mary Kutty, K.C, 1986).

Studies on the comparative effect of different mulches on soil temperature and soil water retention revealed that any type of mulching materials could reduce the evaporational loss of water. The sawdust mulch could hold comparatively higher moisture percentage and the soil temperature recorded was low. Influence of dry leaves on various factors was on par with sawdust (Jayasree, P 1987).

Onattukara soil recorded the highest leaching loss of applied nitrogen (56.1 per cent) Kayal soil showed the lowest leaching percentage of 24.21. The highest runoff loss was also in Onattukara soil with 40.41percent and the least in Karappadam soil, 15.7 percent (George T Abraham, 1995).

A study on the effect of coir pith on physico-chemical and moisture retention properties of selected soil groups of Kerala *viz.*, coastal sandy, laterite and red soils as influenced by the application of different levels of coir pith was conducte. An incubation study for the period of one year was conducted to evaluate the physico-chemical properties and an *in vitro* study for six months using cocoa seedlings as an indicator plant for the water retention property of coir pith. Samples were collected from the pots at quarterly intervals and analysis was done for various physico-chemical properties like volume-mass relationship, moisture retention at tensions of 30, 500 and 1000 and 1500 kPa and organic carbon. At the end of one year after incubation water stable aggregates and CEC were analysed. Application of the coir pith significantly improved the bulk density, maximum water holding capacity and percent pore space. There was a significant increase in the moisture retention at different tensions. The percent aggregate stability, the mean weight diameter, structural coefficient and stability index showed significant increase with

increasing levels of coir pith. Soil moisture retention at different tensions was significantly influenced by the addition of coir pith (Venugopal. R ,1995).

Six prominent physiographic units, present in Wayanad, Malappuram, Thrissur, Kottayam and Pathanamthitta districts were selected for the study. In each physiographic unit, three soil profiles were cut one each from the top, middle and bottom of the catena of a hill to ascertain the impact of the slope on the soil properties. Soils were characterised and classified according to the norms of soil taxonomy. The soils from the above soil profiles were characterised for fertility capability classification. An attempt was made to introduce a local modifier 'm' to denote the status of available Mg, using 0.08 cmol kg^{-1} in the FC classes identified. In this experiment the soils studied for taxonomic classification were subjected to numericali classification using Euclidean distance measure. In Thrissur district 14 sites were selected for studying the soil-plant relationships. Soil samples were collected at bimonthly intervals between November 96 and September 97 to understand the influence of weather on the availability of nutrients. Plant girth and height were recorded simultaneously while collecting soil samples. Soils were analysed for pH, organic carbon, total nitrogen, exchangeable Ca, Mg, K, Na, Al and DTPA extractable Fe, Mn, Cu and Zn. An attempt was made to relate the dynamics of nutrient availability to the plant growth. Two rubber estate areas, one in Thrissur and the other in. Kottayam districts were selected for studying the spectral signature of rubber. Satellite data pertaining to different dates were procured for studying temporal variations in reflectance. The reflectance of rubber along with teak and mixed forest was studied in individual bands, false colour composite and normalised difference vegetation index images. A supervised classification was performed in the images of both the study areas. The effects of various soil properties on growth performance were disentangled into direct and indirect effects in the path analysis. It was observed in general that the path model could explain variability in plant growth to a sufficiently larger extent emphasizing the role of soil parameters and also highlighting the interaction effects on plant growth. While attempting to test the agronomic utility of soil taxonomy and fertility capability classification, it could be noticed that the soil taxonomy could give a general order of ranking based on plant growth among different taxa. It was also seen that studies on temporal changes in spectral behaviour of rubber might help in separating it from teak as well as mixed forest. It could be drawn from the data that mean reflectance of above 60 percent in band 4 might indicate the vegetative cover of rubber. Similarly, the image pertaining to the period when complete canopy is developed would help in delineating rubber from teak and mixed forest in these study areas (Nageswara Rao, D. V. K., 2000).

Response to fertilizers

Application of Si and Mg @ 100 lb of Mg and 25 lb of Si in the form of magnesium carbonate and sodium silicate respectively could increase the grain and straw yield of paddy (Padmaja, P.1964).

Of the different forms of inorganic soil P, iron phosphate constituted the most predominant fraction, followed by aluminium phosphate, calcium phosphate and occluded forms of P. The red and laterite soils which contained a high percentage of the most of the resistant forms of occluded Fe and Al phosphate can be considered as the most weathered and matured soils. The uptake of P by rice was favoured by high pH values, moderate amounts of exchangeable and water soluble Fe and high conductivity of soil solution Fe. Iron phosphate was the predominant form of phosphate in the rice soils of Kerala (Sundraesan. Nair. P, 1965).

No interaction was observed between Cu and Zn and thereby showing that uptake of Cu was not affected by Zn by IR-8 and vice versa in Kerala rice soils (Balakrishnan Nair, C. 1970)

Nitrogen balance studies in major rice soils of Kerala revealed that loss of N occurred from all the soil types. Ammonia volatilization and denitrification from the different soils were studied (Meera, K.1985). Studies on the phosphorus fixation studies in rice soils of Kerala showed that the coastal alluvium recorded the lowest and Kari soils recorded the highest P fixing capacity. (Harikrishnan Nair. K, 1986).

Soil fertility evaluation

Most of the soils in Kerala are rich in total S. The maximum amount of sulphates was found in Kari and Pokkali soils (Jacob, C. I, 1966).

The silica content of rice plant varied from 4 to 12 per cent. On an average, Kerala soils contain 600-700 kg available silica/ ha and irrigation water contribute about 30 kg/ha per crop of rice. An average rice crop in Kerala removes about 250 kg of silica/ha (Kumaran Nair, P. 1966).

Sandy soils of Kerala recorded the lowest CEC of 1.5 meq/100 g and black soils recorded the highest value of 49.6 meq/100 g. The exchangeable cations of different soils decreased in the order Ca> Mg>K> Na. Black soils recorded full base saturation and sandy soil recorded the lowest. (Venugopal, V. K, 1969).

The antagonistic relationship between Ca and B was more marked in B deficient plant. Availability of B in the soil is mostly governed by the organic matter content of the soils. The study on boron status of the four soil types viz forest, red, laterite and sandy soil revealed that forest soils (0.86 ppm) having the highest content of available boron as compared to other soil types (Suresh, P. R, 1985).

The occurrence and distribution of the micronutrient elements in the rice soils of south Kerala was conducted by Mariam Jacob, 1989 at College of Agriculture, Vellayani.

Table 7: Distribution of micronutrients in rice soils of Kerala

Depth in cm (0-20)	Fe	Mn	Zn	Cu mg kg^{-1}	Mo	B
Coastal sand /alluvium	26.6	0.91	0.79	0.84	0.27	0.18
Lateritic allu	306.49	40.8	3.34	1.15	0.82	0.15
Kari soil	321.7	6.51	9.5	1.73	0.56	0.35
Karappadam	393.01	30.64	2.63	4.53	0.62	0.38
Kayal	283.16	24.89	3.72	2.78	0.41	0.30

The pattern of distribution of different forms of iron studied varied significantly among the six soils, viz. lateritic alluvium, Kkari, Kayal, Karappadam, Kole and Pokkali. Total iron was highest in Kole and lowest in Karappadaom soils (K.P. Harikumar, 1989)

Table 8: Studies on the dynamics of different forms of soil Fe in the acid soils of Kerala during submergence

Water soluble form of fe Exchangeable form of Fe Active form of Fe Free oxid form of Fe Total amorphours form of Fe Amorphous organic form of Fe	Forms maximum in kari soil
Crystalline iron	Maximum in the lateritic alluvium
Amorphous inorganic form of iron	Maximum in Kole soils
Water soluble iron	Minimum Kole of lateritic alluvium
Exchangeable and crystalline iron	Minimum on Karappadom soil
Active, free oxide, total amorphous and amorphous inorganic forms of iron	Minimum in pokkali soil
Amorphous organic iron	Minimum in the lateritic alluvium

Influence of form of organic matter on the mineralization of applied phosphorus in submerged rice soils was studied and it was revealed that in general, submergence of soil increased the transformation of both native and added P into Fe-P, Al-P, Ca-P and saloid – P. Reductant – P and occluded – P fractions decreased with progressive submergence. Organic matter addition suppressed the transformation of native and added inorganic phosphorus into different inorganic P fractions (Fe-P, Al-P, Red – P, Occluded – P and Ca-P) and maintained higher amount of added P in the soil in available form during the initial 75 days of submergence.(Nageeb, P H, 1989)

A study has been made to determine the different forms and distribution of sulphur and its relationship to relevant soil parameters in the major upland soils of south Kerala representing sandy, redloam, laterite midupland and forest soils. The soils in general were not deficient in this element. The content of different forms of sulphur was maximum in the forest and minimum in sandy soils. Sulphur content decreased from forest to sandy soils through laterite upland, laterite midland and redloam soils. Organic sulphur registered more than 90 percent while sulphate sulphur less than 10 percent of the total sulphur in all the soils. In all the soil types both total and organic sulphur decreased with increasing depth. Except for sandy soils sulphate sulphur also showed the same trend in distribution in all the soils. Accumulation of sulphate form in the subsurface layers of sandy soils may be attributed to its coarse textured nature.Of the four extractants used for the determination of available sulphur in soils; Morgan's reagent was proved to be the best extractant followed by neutral ammonium acetate, normal hydrochloric acid and water in the descending order in all the soils. Sulphur uptake as determined by Neubauer technique recorded the highest value in forest and lowest in sandy soil, laterite upland, laterite midland and redloam coming in between in the descending order. Neubauer values and available sulphur determined by the different extractants was also established. The different forms of sulphur were positively and significantly correlated with the soil characteristics viz., silt, clay, and organic carbon, total contents of nitrogen, phosphorus, calcium, magnesium and sesquioxides and negatively correlated with soil pH. The relationship among the various forms of sulphur was also found to be significantly positive (Sheeba S, 1991).

The humified fraction of soil organic matter is maximum in Karappadam soils (72.8 per cent) followed by Kayal (60.4 per cent), Kari (56.2 per cent) and lateritic alluvial soils (53.1 per cent). Humic acid content of the humified organic matter is maximum in Karappadam soils followed by Kayal and Kari soils. The lateritic alluvial soils contained the lowest quantity of HA. The fulvic acid content of humified organic matter is maximum in Kayal soils and minimum in lateritic alluvial soils with Kari and Karappadam soils showing intermediate values (Sreedevi, K., 1996)

Table 9: Internal relationship of humus and its fertility components of major wetland soils of Kerala

	Kayal	Kari	Karappadam	Lateritic alluvial soils
pH	4.2	4.2	4.4	5.6
WHC per cent	80.8	69.3	71.8	44.4
CEC cmolkg^{-1}	18.1	19.0	15.4	7.0
Total OMper cent	8.03	7.58	6.81	2.24
Lime requ t ha^{-1}	30.7	30.1	26.7	19.7
Total N per cent	0.32	0.28	0.32	0.22
Total P_2O_5 per cent	0.143	0.044	0.077	0.117
Total K_2O per cent	0.42	0.22	0.29	0.07
Total Ca per cent	0.52	0.35	0.22	0.09
Total Mg per cent	0.15	0.14	0.16	0.03
Available N Kg ha^{-1}	441.8	469.9	421.6	434.4
Available P_2O_5Kg ha^{-1}	1.49	3.29	5.12	54.06
Available K_2O Kg ha^{-1}	358.4	236.2	164.9	118.3
Ex.Ca Cmol kg^{-1}	4.71	3.56	3.82	2.39
Ex.Mg Cmol kg^{-1}	1.68	1.42	1.11	27.9

An investigation was carried out to assess the total and available micronutrients in soils of selected major land resource areas (MLRAs) of' Kerala. The micronutrients investigated in the present study were iron, manganese, zinc, copper and boron. The study was intended to establish the pattern of the distribution of micronutrients both vertically and spatially in eight MLRAs viz, Palode, Vellayani, Trivandrum, Mannar, Kottarakkara, Thakazhy, Ramankary and D-Block soil series of Kerala. From the results obtained, it was observed that micronutrients like iron and manganese were well supplied in all the profiles studied. The micronutrients were found to decrease with depth except in Ramankary, D-Block and Thakazhy series where it showed an irregular trend with depth due to the peculiar hydrologic and oxidation-reduction conditions existing in these soil series. The available and total micronutrients content in the surface soils from places around the profile sites did not show any significant variation among places. In almost all the samples very high iron content was recorded (Sathyanarayanan R, 1997).

Analysis of soil samples collected from the experimental plots of five permanent manurial trials distributed in the coastal, midland and mid-upland regions of Kerala revealed drastic differences in the activities of five major soil enzymes, viz., urease, phosphatase, protease, dehydrogenase and cellulase. It is evident that considerable suppression of the enzyme activity was observed consequent to the application of agrochemicals though they rendered relatively harmless over a period of time within the life span of the crop. Among the various amendments used, treatment involving the application of organic amendment as vermicompost in combination with lime and fertilizers was found to be significantly superior. All the five enzymes thus registered the highest value in this treatment irrespective of the stage of the crop (Aparna, B, 2000).

Behaviour of various chemicals in soil

Modeling of carbofuran movement and sorption in soils was undertaken in the soils that exhibited wide variation in the major physico-chemical properties.Concentration of carbofuran in the leachate showed the highest values for the Inceptisol of Chengannur followed by the Entisol of Kayamkulam, both having low CEC, OM and clay content.The Ultisol of Malappuram with high OM, CEC and clay had given the lowest value for carbofuran in the leachate. Persistence of carbofuran was maximum in Mollisol of Nedumangad with high OM, clay content and CEC. Persistence was poor in the Inceptisol of Chengannur and Entisol of Kayamkulam which are low in OM, clay content and CEC. The only transformation product identified was 3 – Keto carbofuran observed in the surface soil of Ultisol of Malappuram and Mollisol of Nedumangad at 80 days after application (Moosa P. P, 1993).

An attempt was made to assess the behaviour of 2,4-D in the three major rice soils of Kerala *viz.,* Palakkad, Kuttanad and Kole lands. A variation of 3.44 to 10.76 days was noticed in the half life of 2,4-D in the major rice soils of Kerala. The lowest half life was recorded by Karumudy sample of the Kuttanad region and the highest by Moncompu of the same region. The degree of adsorption increased with concentration of 2,4-D in the soil solution i.e. adsorption of 2,4-D in the rice soils of Kerala followed Freundlich isotherm of the form xm = KCn. The major part of the 2,4-D (more than 50 percent of the applied 2,4-D) remained in the 0-10 cm depth and less than 36 percent remained in the 10-20 cm soil layer. Ten percent of the applied 2,4-D leached up to a depth of > 20 cm in some soils of Kole region (Cherpu and Anthikkad) which had higher rates of percolation of water. However, no 2,4-D residue was available in the leachate of any soil at the lowest level of application of herbicide *i.e.,* 1.0 kg ha^{-1}. 2,4-D residues of drinking water at concentrations greater than 0.0001 µg was considered to be toxic to human beings and animals. The

findings of the study emphasized the need for restricting the 2,4-D application to 1.0 kg/ ha, particularly in the sandy soils of Kerala. At the recommended level of 1.0 kg ha^{-1} 2,4-D residues persisted in paddy field for less than 30 days. Residues of 2,4-D in the soil were not detectable at 60 days even if the rate of application was increased to 4.0 kg ha^{-1}. The results of the study revealed the key role of fungi in the degradation of 2,4-D in the paddy field under investigation. 2,4-D residues in the grain and straw samples were very much lower than the maximum residue limits. The findings of the present investigation made it clear that the recommendation of 2,4-D at the rate of 1.0 kg ha^{-1} for weed control in rice does not cause any adverse effect in the soil or crop produce. (Durga Devi, K. M, 2002).

A study entitled "Zinc and boron availability in soils and impact of carriers on crop productivity" was carried out at College of Agriculture, Vellayani 2003-2005 to monitor the effect of moisture levels with and without FYM on the availability of B and Zn in three types of soil viz., red, laterite and Onattukara sandy and the influence of carriers of Zn and B on tomato. Two kg of each type of soil was taken in earthern pots of uniform size and incubated for two months at three moisture levels viz., air dry, field capacity and full saturation with and without FYM. The experiment was laid out in CRD with six treatments. From the incubation study, it can be seen that B availability was more at full saturation condition than at air dry and field capacity moisture regimes in all the three soils. It was minimum at air dried state of soil. Available Zn recorded maximum value at air dried state than at field capacity and full saturation moisture regimes. The influence of B and Zn on the growth, yield and quality of tomato can be clearly understood from the pot culture experiments. Plant height and number of primary branches showed significant increase with B and Zn application. Yield, B : C ratio and quality parameters were higher in the treatments which comprise B/Zn along with FYM. Available K in soil after pot culture increased with increase in levels of application of boron. The same trend was shown by DTPA-extracted Zn and Cu. Available Fe and Mn decreased by B application. Soil B increased with increase in level of B application. Plant content of these nutrients showed the same trend as that of soil content. Available P, Fe, Mn and Cu decreased with increase in levels of Zn application in the pot culture experiment with Zn. Soil available Zn increased with increase in level of application of Zn. Plant nutrient content showed considerable variations. There was an increasing trend for uptake of nutrients from T1 to T8 as there was an increase in total dry matter production in both the experiments. From the results cited above it can be confirmed that B and Zn fertilization has an important role in improving yield and quality of tomato. The highest yield, quality and B : C ratio were obtained when B was applied @ 1.5 kg ha^{-1}. This indicates that further experiments may be conducted by raising the level of B above 1.5 kg ha^{-1} to verify its effect on contributing to further increase in yield. In

the experiment with Zn, though the yield was the highest in T8, the B : C ratio was higher in T7 than in T8 . This indicates that economic yield was obtained when Zn was at 5 kg ha^{-1}. For the purpose of formulating recommendations on application of B and Zn, more field studies need to be conducted (Jyolsna, V. K. 2005).

Three locations from seven agro ecological units dominated by rice crop were identified namely, Onattukkara sandy soil (AEU 3), Kuttanad (AEU 4), Pokkali (AEU 5), Kole (AEU 6), north central laterite AEU 10), Palakkad central plains (AEU 22) and Palakkad eastern plains (Black soils) (AEU 23). Geo-referenced soil samples were collected at three stages, before cropping season, at active tillering and visual panicle initiation. Plant samples were also collected during the above stages and analyzed for nutrient contents.Submergence resulted in increase in pH both under wet and dry analysis. On the basis of wet analysis, pH was higher than that by dry analysis. On dry analysis pH gave higher values than by wet analysis. The $(C:N)_1$ ratio (based on total carbon and total nitrogen) varied from 9.32:1 in Onattukara sandy soil to 18:1 in Kuttanad on the basis of wet analysis. Analysis after drying recorded a $(C:N)_1$ ratio ranging from 10.84 in Palakkad central plains to 22.00 in Kuttanad. Comparison of wet and dry analysis of other available nutrients indicated that higher values were recorded for P, K, Ca, Mg and Fe in wet analysis while the values for available S, Mn, Zn and B were higher in dry analysis. Data on analysis after drying, recorded significant negative correlation of pH with organic carbon (-0.36**) and available S (-0.37**) due to accumulation of organic acids and ions under aerobic condition. Antagonistic interaction of available P with available Ca was attributed to significant negative correlation obtained between them on dry analysis. Wet analysis gave significant positive correlation of pH with available Ca (0.35**) and significant negative correlation with available S (-0.28*). All the C: N ratios computed on the basis of, total carbon and total nitrogen $(C: N)_1$, total carbon and available nitrogen $(C: N)_2$, organic carbon and total nitrogen $(C: N)_3$ and organic carbon and available nitrogen $(C: N)_4$ were significantly correlated with total and available nitrogen at different stages both under wet and dry analysis. Four soil types namely, Onattukara sandy, Kuttanad, North central laterites and Palakkad eastern plains were used for an incubation study to unravel the pattern of decomposition of added organic matter and to identify the C:N ratio at equilibrium. Changes in pH and redox potential during submergence indicated slight increase in pH after 7 days of submergence and redox potential was constantly decreasing with increasing period of submergence. The $(C:N)_1$ ratio was found to stabilize at 9.6:1 after 3 months of incubation with organic matter while it was stabilized at 7.6:1 without organic matter in Onattukara soil. In Kuttanad soils it was 18.3:1 and 17:3 respectively. In Chittor soils it stabilized at 10:1. (Irene Elizabeth John, 2014).

Soil quality

Status and impact of heavy metals in selected soils and crops of Kerala were estimated. A critical analysis of the total content of these heavy metals in the soils studied were revealed that Cu and Cd are existing beyond the critical level in some of the samples. In the wetland soils, content of all heavy metals was at the lowest level of phytotoxicity and food safety in all the samples from absolute control plots of rice Permanent Manurial Experiments at Pattambi, Moncompu and Kayamkulam. The highest levels of heavy metals were registered in samples from plots receiving maximum quantity of organic manures and inorganic fertilizers. The DTPA extractable form was found to be only a very minor part of their total content. The heavy metal load of the commonly used P fertilizers in Kerala was found to be highly variable. Zn was recorded as the highest contaminant followed by Pb, Ni, Cd and Cu. With respect to manures commonly used in Kerala, Zn was registered in the most abundant, among the five elements studied, followed by Cu. Retention of heavy metals was found to be more in the roots of all plants compared to the above ground portions except Zn in amaranthus. The grain, straw and root of rice plants collected from PME plots which were receiving organic manures and inorganic fertilizers continuously for several years had a distinctly higher content of all heavy metals compared to the samples obtained from absolute control plots. The content of Cu in rice samples and that of Zn and Cu in the fodder samples from sewage farm exceeded the critical level to express phytotoxicity. In some of the samples of amaranthus and cowpea, content of Zn, Pb and Cd exceeded the food safety standards prescribed in Germany. Studies on the pattern of retention of applied Cd and Ni in undisturbed soil columns of important soil types of Kerala showed that retention of Cd and Ni was more in the top than in the bottom layers. Higher retention and lower leaching loss of applied Cd and Ni was observed in the columns not treated with FYM. Pot culture studies have shown a significant reduction in yield of rice, sesame and cowpea at various levels of Cd and Ni with and without FYM. Nutrient content of seed, shoot and root showed variations but did not reveal any specific pattern in various crops. In cowpea, low levels of Cd and Ni in the absence of FYM stimulated nodulation and nitrogen content. Intake of Cd and Ni in various plant parts of rice, sesame and cowpea was in the order root> shoot> seed. It was more in the presence of FYM than in its absence. The toxic effects of Ni on growth and yield parameters were of lesser magnitude compared to Cd especially in rice and cowpea. Maximum accumulation of Cd in edible portions was recorded by sesame with no ill effect on germination. However a moderate accumulation of Cd in rice seeds resulted in significant reduction in germination. An alarming observation obtained from the study was that almost all samples of rice grains exceeded the food safety standard of 1 mg Cd kg^{-1} indicating that rice, the staple

food of the people of Kerala is contaminated with Cd, the most hazardous heavy metal for human health. (Usha Mathew,1999).

An investigation entitled 'Utilization of dairy industry solid waste as an organic waste in soil productivity' was carried out at College of Agriculture, Vellayani to study the feasibility of using dairy industry solid waste (dsw) as an organic source for improving soil productivity. The dairy waste collected from TRCMPU Ltd. at Ambalathara, Thiruvananthapuram was used in the present study. Vermicomposting was carried out in pits of size 1 m x 0.5 m x 0.5 m using vegetable wastes, ground dsw and cowdung in the ratio 5:3:1 by the activity of earthworm *Eudrillus eugeniae*. Incubation study was conducted at the laboratory to monitor the nutrient release pattern and changes in physical properties and microbial population in soil. Analysis of physico-chemical and microbial properties of dsw revealed that it had a near neutral pH (6.5) and it contained 37.5 percent organic carbon, 5.80 percent N, 2.04 percent P, 0.71 percent K, 1.69 percent Ca, 1.58 percent Mg, 1.71 percent Fe, 159 mg kg 1 Mn and 1084 mg kg 1 Zn. Population of bacteria, fungi and actinomycetes in dsw were 13.3 x 106, 11.6 x 104 and 1.3 x 104 respectively. The results of the study revealed that vermicomposting can be successfully done in dsw using *Eudrillus eugeniae*. Vermicompost with a C : N ratio of 11.12 was obtained after 60 days of composting. The final compost contained 3.12 percent N, 1.97 percent P, 1.81 percent K, 2.05 percent Ca, 3.55 percent Mg, 0.80 percent Fe, 230 mg kg-1 Mn, 408 mg kg-1 Zn and 44 mg kg¬-1 Cu. Number of bacteria, fungi and actinomycetes in the compost at maturity stage were 42.6 x 106, 38.6 x 104 and 21.3 x 10^4 respectively. . All nutrients except Cu were more on cdsw applied treatment in the initial period. Bulk density of soil decreased in all treatments except T0 upto six weeks of incubation followed by a gradual increase in 8 and 12 weeks. Treatment in which cdsw was applied at higher dose showed the lowest bulk density. Upto six weeks the highest water holding capacity was noticed in cdsw applied treatments, after that fym applied treatments showed highest water holding capacity. Bacterial and fungal population reached the peak in sixth week and then declined. Upto eight weeks the effect of treatments was non significant with respect to actinomycete population. The pot culture experiment indicated the influence of cdsw on growth, yield and quality of amaranthus. Biometric and yield observation have proved the superiority of cdsw over FYM. Beta-carotene content was more in cdsw applied treatments. Total yield and B:C ratio were the highest when cdsw was used as a partial substitute for FYM. Physicochemical properties of soil after the pot culture experiment revealed that pH, EC, organic carbon and available nutrients increased in ail treatment except in T_0 compared to the initial soil. pH, EC, organic carbon, available P, Ca and Fe were the highest in T_2 which received cdsw at higher dose while the available N, K, Mg, Mn, Zn and Cu were the highest in T_1 which received FYM. From the results it can be

concluded that effective biomanagement of dsw can be carried out using *Eudrillus eugeniae*. Better availability of nutrients especially nitrogen from cdsw compared to FYM immediately after application as evidenced by incubation study is advantageous for short duration leafy vegetables. Use of dsw can reduce the use of FYM partially or fully in amaranthus. Fertilizer N can also be reduced to the extent of 1/3 of POP recommendation (Indu B, 2004)

Think it over

- ✓ Accummulation of heavy metals in the plant produce due to the application of fertilizers and organic matter is a concern for human health.
- ✓ The optimum dose of herbicides like 2,4-D may be strictly adhered inorder to prevent the build up of residue in rice plants.
- ✓ Liming the rice soils coupled with leaching was found to be significantly increasing the mean pH values and decreasing the exchangeable H^+ and Al^{3+}. Soil acidification decreased with increased levels of lime.
- ✓ Compared to potassium, the cations,calcium and magnesium were adsorbed with less bonding energy and hence to maintain a higher concentration of these in the soil exchange complex by frequent application of lime.
- ✓ Aggregates of size larger than 0.25 mm were found in appreciable amount in laterite, black, red loam, riverine alluvium and coastal alluvium soils of Kerala. Black soil had distinctly superior aggregation as compared to other soils
- ✓ A simple linear equation for calculating total nitrogen based on organic carbon content of the soil was worked out as N% = 0.0803 OC % + 0.38
- ✓ The continuous application of organic matter had resulted in a significant build up of micronutrient status, especially Zn and Mn in permanent manurial experiments
- ✓ The C/N ratio was found to stabilize at 9.6:1 after 3 months of incubation with organic matter while it was stabilized at 7.6:1 without organic matter in Onattukara soil. In Kuttanad soils it was 18.3:1 and 17:3 respectively. In Chittor soils it stabilized at 10:1.
- ✓ On an average, Kerala soils contain 600-700 kg available silica ha^{-1} and irrigation water contribute about 30 kg/ha per crop of rice. An average rice crop in Kerala removes about 250 kg of silica ha^{-1}

9. Agro-ecology of Kerala

Agro ecological zoning involves the inventory, characterization and classification of the physical environmental resources which are meaningful for an assessment of the potential agricultural production systems. The physical resources include components of climate, soil and land form, basic for the supply of water, energy, nutrients and physical support

The analysis of agro-ecology of the Kerala State based primarily on climate, geomorphology, land use and soil variability resulted in delineation of five agro-ecological zones and twenty three agro-ecological units and ninety eight agro-ecological subunits. The state has been divided into five agro-ecological zones (AEZ's). Twenty three agro-ecological units (AEU's) have been delineated for the state based on climatic variability, landform and soils.

AGRO-ECOLOGICAL ZONES

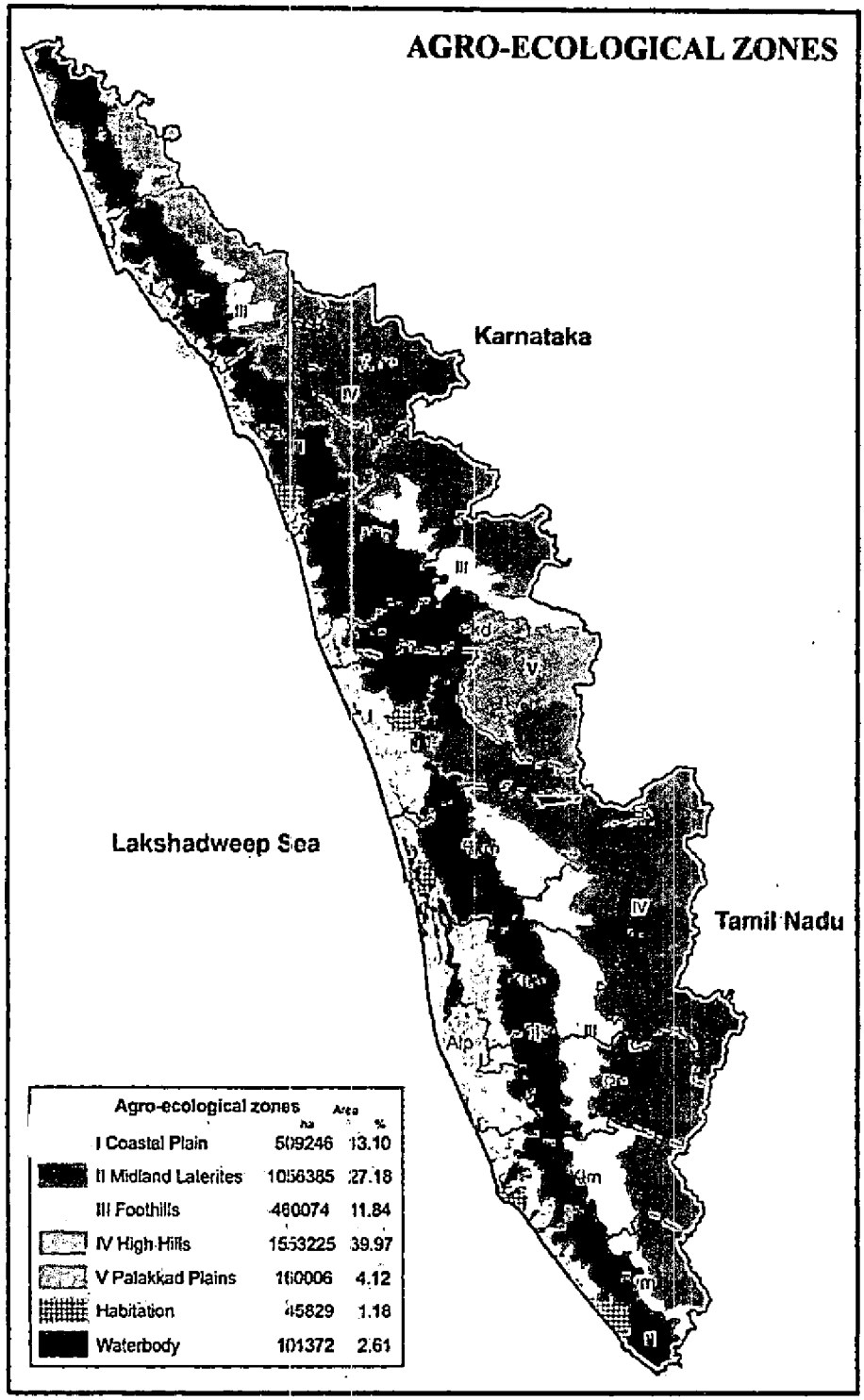
The state has been divided into five agro-ecological zones (AEZ's).

Coastal Plain

The Coastal Plain agro-ecological zone comprises the nearly level to gently sloping lands along the coast at elevation below 30 metres and lying between the sea and the midlands. It includes sandy beaches, sandy plains, coastal laterites, and lowlying areas such as estuaries, backwaters, submerged lands, swamps, marshes, *kayal lands*, and broad valleys. The zone covers an area of 5,09,246 ha (13.10 %) in the state.

Midland Laterites

Midland Laterites, an agro-ecological zone which comprises undulating to rolling lands interspersed with narrow valleys between the coastal plain on the west and foothills and hills on the east, extending from the southern end to the northern end of the state. The elevation ranges from 30 to 300 metres. The zone covers an area of 10,56,385 ha (27.18 %) in the state.


AGRO-ECOLOGICAL ZONES
Karnataka
Lakshadweep Sea
Tamil Nadu
Agro-ecological zones
Area
ha
%
I Coastal Plain 509246 13.10
II Midland Laterites 1056385 27.18
III Foothills 460074 11.84
IV High Hills 1553225 39.97
V Palakkad Plains 160006 4.12
Habitation 45829 1.18
Waterbody 101372 2.61

Foothills

The undulating to rolling lands and low hills between the midland laterite on the west and high hills on the eastern side constitute the Foothills, the agro-ecological zone. The terrain has only very narrow valleys. The elevation ranges from 300 to 600 metres. The zone covers an area of 4,60,074 ha (11.84 %) in the state.

High Hills

The hilly region comprising Western Ghats and plateaus extending from south to north constitute the High Hills agro-ecological unit. The Western Ghats and highland plateaus rise 600 metres above mean sea level, with a number of peaks well over 1800 metres. The Western Ghats comprise Central Sahyadri, the Nilgiris and South Sahyadri. The mountains are essentially plateau remnants of two or three altitudinal zones. Slopes of hill ranges can be as high as 80 per cent. The zone covers an area of 15,53,225 ha (39.97 %) in the state.

Palakkad Plain

The Palakkad Gap, resembling an inland plain with low elevation, is a prominent physical feature along the valley of the Bharathapuzha river. The gently sloping lands of Palakkad, east of Kuthiran hills, flanked on the south and north by Nelliyampathy hills and Attappady hills, respectively and merging to Tamil Nadu uplands through the gap in Western Ghats constitute the agro-ecological zone, covering an area of 1,60,006 ha (4.12 %) in the state.

AGRO-ECOLOGICAL UNITS

Twenty three agro-ecological units (AEU's) have been delineated for the state based on climatic variability, landform and soils.

AEU 1: Southern Coastal Plain

The Southern Coastal Plain is delineated to represent the nearly level coastal lands where sands are the dominant soil type. The unit comprises 42 panchayats along the coast from Thiruvananthapuram to Ernakulam district. The climate is tropical humid monsoon type (rainfall 2360 mm; mean annual temperature 27.6 °C). Dry period (duration of soil moisture deficit) is nearly 4 months. Coconut plantations on uplands and rice in lowlands are the major land use. The unit covers an area of 56,782 ha (1.46 per cent) in the state.

AEU 2: Northern Coastal Plain

The Northern Coastal Plain represents the coastal plain, north of Ernakulam district and comprises 77 panchayats along the coast from Thrissur till the northern end of the state. The unit with tropical humid monsoon climate (rainfall 3133 mm; mean annual temperature 28 °C) has dominantly sandy soils on nearly level lands. It is similar to the southern counterpart, except for the longer dry period of nearly six months. Coconut plantations on uplands and rice in lowlands are the major land use. The unit covers an area of 1,22,970 ha (3.16 per cent) in the state.

AEU 3: Onattukara Sandy Plain

The special agro-ecological unit Onattukara Sandy Plain is delineated for the sandy plains extending into the midlands from coast and covering 43 panchayats in Kollam and Alappuzha districts. Climate is tropical humid monsoon type (mean annual temperature 27.6 °C; rainfall 2492 mm) and soils are sandy. Length of dry period is 4 months. Coconut plantations on uplands and rice in low lands are the major land use. The unit covers an area of 67,447 ha (1.74 per cent) in the state.

AEU 4: Kuttanad

Kuttanad is a special agro-ecological unit delineated to represent the waterlogged lands spread over 69 panchayats of Alappuzha, Kottayam and Pathanamthitta districts. Large parts of these lands are below, at or just above sea level. Climate is tropical humid monsoon type (mean annual temperature 27.6 °C; rainfall 2,746.1 mm). Hydromorphic soils, often underlain by potential acid-sulphate sediments and unique hydrological conditions characterize the unit. Seawater ingress into Kuttanad is controlled through bunds and barrages to facilitate rice cultivation. Coconut is grown on the uplands and bunds of the unit and rice in lowlands. The unit covers an area of 1,26,931 ha (3.27per cent) in the state.

AEU 5: Pokkali Lands

Pokkali Lands, another special agro-ecological unit, is delineated for the lowlands, often below sea level, in coastal areas of Ernakulam district and extending to parts of Thrissur and Alappuzha districts. The unit covers 34 panchayats. Climate is tropical humid monsoon type (mean annual temperature 27.6 °C; rainfall 3,049 mm). Hydrology and soils are similar to those in Kuttanad. However, seawater inundation is not controlled and hence soils are acid-saline. Coconut is raised on uplands and a special kind of rice cultivation, locally known as *Pokkali cultivation,* is done in lowlands. The unit covers an area of 39,765 ha (1.02 per cent) in the state.

AEU 6: Kole Lands

The Kole lands agro-ecological unit, spread over the coastal part of Thrissur district and extending to southern coastal parts of Malappuram district covers 40 panchayats. Climate is tropical humid monsoon type (mean annual temperature 27.6 °C; rainfall 2,902 mm). These lands too are, for most part, below sea level. Seawater ingress into these lands is controlled through barrages and weirs to facilitate rice cultivation. The soils are hydromorphic acid clays, often underlain by potential acid-sulphate sediments. Coconut is grown on the uplands of the unit and bunds and rice in lowlands. The unit covers an area of 71,142 ha (1.83 per cent) in the state.

AEU 7: Kaipad Lands

The Kaipad Lands agro-ecological unit occurs along the coast of Kozhikkode, Kannur and Kasaragod districts as isolated stretches of waterlogged lands. The unit covers only 16 panchayats. Climate is tropical humid monsoon type (mean annual temperature 27.3 °C; rainfall 3,254 mm). The lowlands, often below sea level, do not have any protection against sea water inundation. The hydromorphic, acid-saline, clay soils are often underlain by potential acid-sulphate soils. Coconut is grown on the uplands of the unit and bunds and rice in lowlands. The unit covers an area of 24,209 ha (0.62 per cent) in the state.

AEU 8: Southern Laterites

The Saouthern laterites agro-ecological unit spread over 24 panchayats in south-western part of Thiruvananthapuram district is delineated to represent the uniqueness of climate and soils. The area with tropical moist subhumid monsoon climate receives low rainfall compared to the other areas of midland laterites (mean annual temperature 27.1 °C; rainfall 1,884 mm). However, the well-distributed rainfall from both SW and NE monsoon restricts the dry period to just three months in a year. The soils, though acid and having low-activity lateritic clay, unlike in other

parts of laterite terrain, are practically free of gravel and plinthite. Coconut on uplands intercropped to a variety of annual and other perennial crops and rice, tapioca, banana and vegetables on lowlands are the major land uses. The unit covers an area of 38,727 ha (1.0 per cent) in the state.

AEU 9: South Central Laterites

The South Central Laterites agro-ecological unit is delineated to represent midland laterite terrain with typical laterite soils and short dry period. The unit covering 161 panchayats of midlands extends from Thiruvananthapuram to Ernakulam district. The climate is tropical humid monsoon type (mean annual temperature 26.5 °C; rainfall 2827 mm) with dry period around three and half months. Unlike the southern counterpart, the strongly acid, lateritic clay soils are gravelly and often underlaind by plinthite. The lowlands have strongly acid, low-activity, non-gravelly clay soils with impeded drainage conditions. Mono-cropped rubber and coconut intercropped to a variety of annual and other perennial crops is the major land use on uplands and rice, tapioca, banana and vegetables on lowlands. The unit covers an area around 3,65,932 ha (9.42 per cent) in the state.

AEU 10: North Central Laterites

The North Central Laterites agro-ecological unit is delineated to represent midland laterite terrain with longer dry period than its southern counterpart, but less than the one in the North. The unit is spread over 62 panchayats, 3 municipalities and a corporation in Thrissur and Palakkad districts. The climate is tropical humid monsoon type (mean annual temperature 27.6 °C; rainfall 2795 mm) with dry period of around four and half months. The uplands have strongly acid, gravelly, lateritic, low-activity, clay soils, often underlain by plinthite. The lowlands have strongly acid, non-gravelly clay soils with impeded drainage. Coconut intercropped to a variety of annual and other perennial crops is the major land use on uplands and rice, tapioca, banana and vegetables on lowlands. The unit covers an area of 1,71,469 ha (4.41 per cent) in the state.

AEU 11: Northern Laterites

The Northern Laterites, an agro-ecological unit which is delineated to represent midland laterites from Malappuram to Kasaragod districts experiencing long dry period. It is spread over 163 panchayats and 6 municipalities. The climate is tropical humid monsoon type (mean annual temperature 27.3 °C; rainfall 3217 mm). Though the rainfall is higher than in other agro-ecological units of the midlands, dry period is around 6 months in a year. The uplands have strongly acid, gravelly, lateritic, low-activity, clay soils often underlained by plinthite. Laterite duricrusts are also frequent in the unit. Coconut intercropped with a variety of annual and other perennial

crops is the major land use on uplands and rice, tapioca, banana and vegetables in lowlands. Cashew plantations are also extensive on uplands. The unit covers an area around 4,80,257 ha (12.36 per cent) in the state.

AEU 12: Southern Foothills

The Southern Foothills, an agro-ecological unit which is delineated to represent the undulating lands with low hills, between midland laterites and the high hills of Western Ghats. It covers 90 panchayats from Thiruvananthapuram to Thrissur districts. The climate is tropical humid monsoon type (mean annual temperature 27.5 °C; rainfall 3462 mm) with dry period of around two and a half months. The strongly acid, gravelly, lateritic, low-activity, lateritic clay soils are rich in organic matter. The narrow valleys have similar but non-gravelly soils with impeded drainage conditions. Shorter dry period, absence of plinthite layer in soil and higher soil organic matter distinguish the foothills from midland laterites. Plantations of rubber, coconut, pepper and coffee abound in the unit. The unit covers an area of 3,15,893 ha (8.13 per cent) in the state.

AEU 13: Northern Foothills

The Northern Foothills, an agro-ecological unit which represents foothills from Thrissur to Kasaragod and differs from its southern counterpart for longer dry period. It covers 27 panchayats of Palakkad, Malappuram, Kannur and Kasaragod districts. The climate is tropical humid monsoon type (mean annual temperature 27.5 °C; rainfall 3462 mm) with dry period of around four months. The strongly acid, gravelly, lateritic, low-activity, clay soils are rich in organic matter. The narrow valleys are similar, but non-gravelly soils with impeded drainage conditions. Shorter dry period, absence of plinthite layer in soil and enhanced levels of organic matter distinguish the foothill soils from north central and northern midland laterites. Plantations of rubber, coconut, pepper and coffee are the major land use. The unit covers an area of 1,44,181 ha (3.71 per cent) in the state.

AEU 14: Southern High Hills

The Southern High Hills, an agro-ecological unit extending from Thiruvananthapuram to Nelliyampathy in Palakkad district has elevation more than 600 metres. Besides elevation, the steep slopes of the terrain and lower temperatures distinguish the high hills from the foothills and midlands. Thirty panchayats in Thiruvananthapuram to Palakkad district constitute this unit. The climate is tropical humid monsoon type, but lower temperatures than in coastal plain and midlands (mean annual temperature 21.6 °C; rainfall 3602 mm). Length of dry period is only two months. The steeply sloping hilly terrain has deep, well drained, strongly acid, organic-matter-rich clay soils. While forests cover major part of the unit, plantations

of rubber, coconut, pepper, tea and coffee are not uncommon. The unit covers an area of 6,72,675 ha (17.31 per cent) in the state.

AEU 15: Northern High Hills

The Northern High Hills, an agro-ecological unit extending from Thrissur to Kannur is similar to its southern counterpart except for the longer dry period. The unit comprises 61 panchayats spread over the northern districts. The climate is tropical humid monsoon type (mean annual temperature 26.2 °C; rainfall 3460 mm) with dry period of nearly four months, much longer than in the southern counterpart. The hilly terrain has deep, well drained, strongly acid, organic-matter-rich, clay soils. The valleys have deep, imperfectly drained, acid clay soils. While forests cover major part of the unit, plantations of rubber, coconut, pepper and coffee are not uncommon. The unit covers an area of 5,28,434 ha (13.60 per cent) in the state.

AEU 16: Kumily High Hills

The Kumily High Hills, an agro-ecological unit which is delineated to represent low-rainfall parts of the High Hill zone. The unit differs from Southern High Hills not only in the lower rainfall, but also the extensive occurrence of very deep, non-gravelly clay soils. Thirteen panchayats distributed in Peerumedu and Udumbanchola taluks of Idukki district constitute this unit. The climate is tropical humid monsoon (mean annual temperature 22.5 °C; rainfall 1809 mm) and dry period is nearly three months. The soils are very deep, well drained, acid, non-gravelly, low-activity clay soils. They are rich in organic matter. The highland valleys in the unit are similar, except for impeded drainage conditions. Plantations of cardamom, tea, coffee, and pepper are the major land use. Forest cover is also substantial. The unit covers an area of around 1,50,984 ha (3.81 per cent) in the state.

AEU 17: Marayur Hills

The Marayur Dry Hills, an agro-ecological unit which is delineated to represent the low rainfall region (rain-shadow) of the high hill zone and comprises only three panchayats of Idukki district. The climate is tropical humid monsoon type (mean annual temperature 23.7 °C; rainfall 1276 mm) and dry period is nearly three months. The unit distinguishes itself from other AEU's of high hill zone by the lower temperatures, low rainfall and soil qualities. The fertile, deep, clayey soils rich in organic matter with favourable soil reaction (slightly acid to neutral) are well supplied with bases. Land use, besides forest, comprises temperate fruit trees, potato, sugarcane, temperate vegetables and rice. The unit covers an area of 28,968 ha (0.75 per cent) in the state.

AEU 18: Attappady Hills

The agro-ecological unit, Attappaddy Hills, spatially distributed as a narrow strip of land along the valley in central part of the hills in North Palakkad, represents land areas of comparatively low rainfall. It comprises parts of Sholayar, Puthur and Agali panchayats. The climate is subhumid tropical monsoon type (mean annual temperature 24.3°C; rainfall 1482 mm) and dry period around four months. Besides the climate, the other distinguishing feature of the unit is the fertile, near neutral to slightly alkaline clay soils rich in organic matter and bases. Land use is mainly coconut plantations, banana, vegetables, maize and rice. The unit covers an area of 8,872 ha (0.23 per cent) in the state.

AEU 19: Attappady Dry Hills

The Attappady Dry Hills unit which represents land areas of very low rainfall and dry period around eight months in a year. This unit in the north-eastern corner of Palakkad district comprises parts of Puthur, Agali and Sholayar panchayats. The climate is tropical dry subhumid to semi-arid type (mean annual temperature 24.7 °C; rainfall 856 mm). Much of the rainfall is received from the NE monsoon and the dry period is around eight months in a year. The hilly terrain has shallow, slightly acid or neutral, stony and gravelly clay soils. Thorny shrubs with occasional trees are the dominant land cover. Cultivation is confined to limited areas of valley lands and around tribal hamlets. The unit covers an area of 18,495 ha (0.48 per cent) in the state.

AEU 20: Wayanad Central Plateau

The Wayanad Central Plateau, an agro-ecological unit which represents highland plateau with low temperature and high rainfall. The unit covers 11 panchayats in Wayanad district. Climate is tropical humid monsoon type (mean annual temperature 22.6 °C; rainfall 2659 mm) with dry period around three months. Upland soils are deep, acid clays and are fairly rich in organic matter. Valley soils are similar, but suffer from impeded drainage conditions. Plantations of coffee, tea, coconut, arecanut and pepper are the dominant land use on uplands and rice and banana in lowlands. Forests cover a significant area. The unit covers an area of 74,471 ha (1.92 per cent) in the state.

AEU 21: Wayanad Eastern Plateau

The Wayanad Eastern Plateau, an agro-ecological unit which represents parts of the high land plateau with lower rainfall. The unit comprises 6 panchayats, one in Mananthavady taluk and rest in Sulthan Bathery taluk of Wayanad district. The climate is tropical subhumid to humid monsoon type (mean annual temperature

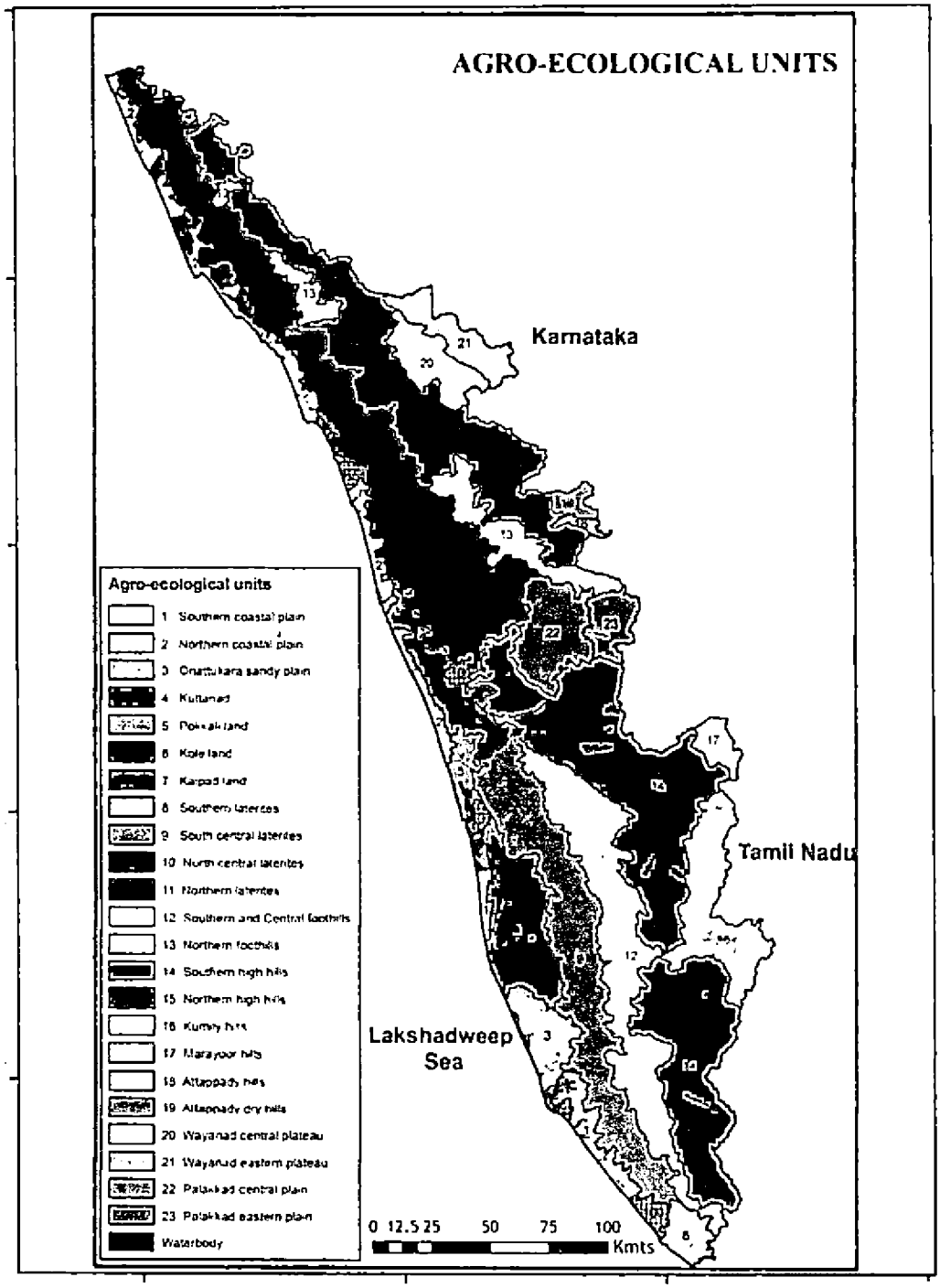
22.6 °C; rainfall 1394 mm) with dry period around four months. The unit differs from central plateau in having lower rainfall and longer dry period. Besides, the soils in this part have favourable soil reaction (slightly acid to neutral), and are well supplied with bases. Plantations of coffee, tea, coconut, arecanut and pepper are the dominant land use on uplands and rice and banana in lowlands. Forests cover a significant area. The unit covers an area of 70,325 ha (1.81 per cent) in the state.

AEU 22: Palalakkad Central Plain

The Palakkad Central Plain unit which is delineated to represent the land areas of moderate rainfall and dry period around five months in the Palakkad plain. It is transitional to the drier eastern plain and humid western parts (AEU 10). The unit comprises 37 panchayats spread over Alathur, Chittur and Palakkad taluks and the Palakkad Municipality. The climate is tropical subhumid to humid monsoon type (mean annual temperature 27.6 °C; rainfall 1966 mm) with dry period around five months. The deep, well drained upland soils are non-gravelly loams and clays. Soil reaction is slightly acid or neutral and the soils are well supplied with bases. The valley soils are similar, but with impeded drainage conditions. Coconut intercropped to a variety of annual and perennial crops is the major land use on uplands and rice in lowlands. The unit covers an area of 1, 12,957 ha (2.91 per cent) in the state.

AEU 23: Palakkad Eastern Plains

The Palakkad Eastern Plain, an agro-ecological unit which is delineated to represent the drier parts of Palakkad plain in the gap region of Western Ghats, having low rainfall, long dry period and fertile soils. The unit comprises 11 panchayats in eastern Palakkad. The climate is tropical dry subhumid monsoon type (mean annual temperature 27.6 °C; rainfall 1340 mm) and dry period around six months. The unit has slightly acid or neutral red clay soils well supplied with bases and plant nutrients. Lower parts of the uplands and lowlands have alkaline swell-shrink clay soils. The fertile soils are rich in bases and plant nutrients. Lowlands have impeded drainage. Coconut, arecanut and mango are the major plantation crops. Annual crops include groundnut, cotton, banana, maize, jowar and sugarcane. The unit covers an area of 47,049 ha (1.21 per cent) in the state.


AGRO-ECOLOGICAL UNITS
Karnataka
Tamil Nadu
Lakshadweep Sea
Agro-ecological units
1 Southern coastal plain
2 Northern coastal plain
3 Onattukara sandy plain
4 Kuttanad
5 Pokkali land
6 Kole land
7 Karpad land
8 Southern laterites
9 South central laterites
10 North central laterites
11 Northern laterites
12 Southern and Central foothills
13 Northern foothills
14 Southern high hills
15 Northern high hills
16 Kurisy hills
17 Marayoor hills
18 Attappady hills
19 Attappady dry hills
20 Wayanad central plateau
21 Wayanad eastern plateau
22 Palakkad central plain
23 Palakkad eastern plain
Waterbody
0 12.5 25 50 75 100
Kmts

Appendix (i)

List of theses in chronological order

Sl. No.	Thesis title	Research Scholar	Year
1	2	3	4
1.	Studies on the fertility status of some peaty, marshy and swampy soils	Gopalaswamy, V.	1958
2.	Chemical and mineralogical studies in the acid peats of Kerala	Subramoney, N.	1958
3.	Role of *Beijerinckia* in the fertility of acid soils	Barooah, P. P.	1962
4.	Studies on the formation, morphology and chemistry of Kerala soils	Koshy, M. M.	1962
5.	Contribution of cowpea to the nitrogen economy under different utility pattern	Varghese, P. Y.	1962
6.	Studies on the salt-affected rice soils of Kerala	Gopalakrishnan Nair, P.	1963
7.	Studies on the fractionation of soil phosphorus and the adsorption and retention of Ammonium nitrogen in Kerala soils.	Narayanan Nambiar, P. K	1963
8.	Influence of salinity on the germination and growth characteristics of rice.	Remani, B.	1963
9.	The influence of Calcium and Magnesium in increasing the efficiency of fertilizers for rice and calcium and magnesium status of some typical rice soils of Kerala.	Thomas Varghese	1963
10.	Effect of elevation and rainfall on forms of principal plant nutrient elements in Kerala Soils	Vijayachandran, P. K.	1963
11.	Studies on induced mutation in *Azotobacter*	Kesava Nithiyanandan	1964
12.	The influence of variety and the form and level of Nitrogen on the growth, yield and nutrient content of rice.	Kochappan Nair, K.	1964

1	2	3	4
13.	The effect of calcium, magnesium and silicon on the productive factors and quality of rice.	Padmaja, P.	1964
14.	Physico-chemical and microbiological studies on some Kari soils of Kerala.	Sukumara Pillai,V.	1964
15.	Studies on some forest soils of Kerala	Thomas, K. M.	1964
16.	Studies on the effect of deforestation on the organic carbon, nitrogen and potash status of some forest soils of Kerala.	Mitrachali, J. I.	1965
17.	Forms and distribution of iron and manganese in the rice soils of Kerala.	Narayana Pisharody, P.	1965
18.	Phosphorus uptake by plants and readily extractable phosphorus in some rice soils of Kerala in relation to their important chemical characteristics.	Padmanabhan Nair, S.	1965
19.	Studies on the effect of silica fertilization on the uptake of nutrients by rice plant at different stages of growth.	Sadanandan, A. K.	1965
20.	Studies on the seasonal variations in pH, water - soluble salts and bacterial population in the Kari soils of Kerala.	Suseela Devi, L.	1965
21.	Influence of different forms and levels of magnesium on the growth, yield and nutrient uptake by rice	Ayyappan Nair, M.	1966
22.	Nitrogen enrichment of soils of Vellayani by Monsoon rains	Babukutty, K.	1966
23.	Sulphur status of Kerala soils	Jacob, C.I.	1966
24.	Status of available silica in the rice soils of Kerala State	Kumaran Nair, P.	1966
25.	Potash nutrition of rice with regard to the effect of calcium, magnesium and silicon	Usha, C.	1966
26.	Studies on the hydrogen sulphide injury on paddy plants	Yogesan Nair, N.	1966
27.	Studies on extractable aluminum in the rice soils of Kerala.	Karthikakutty Amma, M.	1967

1	2	3	4
28.	Studies on the effect of phosphorus on the growth, yield and nutrient uptake of two newly introduced rice varieties Tainan 3 and TN-1)	Mohankumar, B.	1967
29.	Studies on the effect of nitrogen on the growth, yield and nutrient uptake of two newly Introduced rice varieties (Tainan 3 and TN-1)	Prema, M. K.	1967
30.	Studies on the effect of potassium on the growth, yield and nutrient uptake of two newly introduced rice varieties (Tainan 3 and TN-1)	Ramankutty, N. N.	1967
31.	Effect of different forms and levels of phosphorus on the growth, yield and composition of three high yielding varieties of rice (IR 8, TN-1 and Culture 28).	Jagadeesh Chandran Nair, M. P.	1968
32.	A study of the morphological, physical and chemical characteristics of soils as influenced by teak vegetation.	Jose, A. I.	1968
33.	Estimation of loss of nitrogen from different nitrogenous fertilizers when applied to different soils under waterlogged conditions.	Krishnakumari, M.	1968
34.	Studies on the uptake of nutrients and response of rice (var IR-8) at different levels of nitrogen, phosphorus and potassium.	Krishnan, P.	1968
35.	Studies on foliar diagnosis, yield and quality of tapioca (Manihot utilissima Pohl) in relation to potassium and calcium.	Pushpadas, M.V.	1968
36.	Studies on foliar diagnosis, yield and quality of tapioca (Manihot utilissima Pohl) in relation to nitrogen and phosphorus.	Vijayan, M. R.	1968
37.	Effect of nitrogen fertilization on the yield and chemical composition of grasses and consequent changes in the nitrate content of foliage.	Abdul Wahid, P.	1969
38.	Studies on the inoculation of blue green algae under field conditions for nitrogen enrichment and its effect on certain soil chemical characteristics.	Aboobaker, V. O.	1969

1	2	3	4
39.	Effect of elevation and rainfall on the physico-chemical properties of the soils of the High Ranges of Kerala.	Chandrasekharan Nair, K.	1969
40.	Studies on the efficacy of bacterization with phospho-bacterin on the availability and uptake of phosphorus in relation to the growth and yield of rice, variety IR-8.	George Philip	1969
41.	Studies on the phosphorus status of the sandy soils of Kerala State.	Gopinathan, G.	1969
42.	Effect of liming on exchangeable cations and availability of nutrients in acid soils of Kuttanad.	Kabeerathumma, S.	1969
43.	Studies on the activities of certain enzymes naturally occurring in the rice soils of Kerala and in the rhizosphere of rice plants under different treatments.	Krishnaswamy, B.	1969
44.	Studies on the influence of graded levels of phosphorus on the uptake of zinc, copper and manganese and on the phosphorus induced chlorosis in IR-8.	Pushkala, S.	1969
45.	Distribution of manganese and molybdenum in the soils of Kerala and the effect of molybdenum on the growth of cowpea	Rajagopalan, V.	1969
46.	Cation exchange studies in Kerala soils	Venugopal, V. K.	1969
47.	Studies on the lack of response of phosphatic fertilizers to rice in the laterite soils of Kerala.	Akbar, A.	1970
48.	Studies on copper and zinc status of Kerala rice soils and the response to these elements by IR-8	Balakrishnan Nair, C.	1970
49.	Studies on the effect of liming on the activity of certain enzymes occurring in the rhizosphere of cowpea (*Vigna sinensis Savi*).	Joseph, K.V.	1970
50.	Distribution of copper and zinc in the soils of Kerala.	Ravikumar Praseedom	1970

1	2	3	4
51.	Studies on the inoculation of blue green algae under field conditions in relation to the nitrogen economy of the rice soils of Kerala.	Salafudeen, S.	1970
52.	The influence of different levels of calcium and phosphorus on the growth, yield and composition of two high yielding varieties of rice, Padma and Jaya.	Sivan Nair, P. N.	1970
53.	Studies on the nutrient status of the alluvial soils of Kerala with special reference to the distribution of copper and zinc.	George Varghese	1971
54.	Studies on the organic phosphorus status of Kerala soils.	John, P. C.	1971
55.	Studies on urease activity in the paddy soils of Kerala State in relation to nitrogenous fertilizer treatment.	Pareed Bava Khan, P. M.	1971
56.	Studies on the effect of zinc on rice (Var. IR-8) as influenced by levels of phos-phorus in Vellayani kayal soil.	Prabha, B.	1971
57.	Potassium status of some rice soils of Kerala.	Sreedevi Amma, A.	1972
58.	Changes in water soluble and exchangeable iron in paddy soils receiving ammonium sulphate.	Usha, N. Nair.	1972
59.	Studies on the status and distribution of copper and zinc in two soil series of Trivandrum district.	Valsaji, K.	1972
60.	Studies on the lime potential and aluminium hydroxide potential of the acid soils of Kerala State.	Verghese, M. P.	1972
61.	Distribution of copper and zinc in the acid peat (Kari) soils of Kerala	Gopinath,V.	1973
62.	Studies on the fertility status of the red soils of Kerala and the effect of adding nitrogen in combination with MnO_2 on the growth, yield and composition of rice.	Harikrishnan Nair, K.	1973

1	2	3	4
63.	Studies on the utilization of sunflower (*Helianthus annus*)	Jacob Mathew	1973
64.	Morphological and physico-chemical properties of the acid peat (Kari) soils of Kerala.	Varghese, V. P.	1973
65.	Fertility investigation on the kole soils of Kerala.	Abdul Hameed	1975
66.	Studies on a manure supplement containing secondary and trace elements prepared from sea water (Sagar) on the growth, yield, quality and absorption of nutrients by rice.	Chinnamma, N. P.	1975
67.	Morphological and physico-chemical properties of the Kayal soils of Kuttanad, Kerala State.	Gangadhara Menon, P. K.	1975
68.	Chemistry of low productive acid laterite and acid sulphate soils and their amelioration for growing rice(*Oryza sativa. L*)	Kabeerathumma,S.	1975
69.	Studies on the effect of zinc in combination with lime on the growth, yield and absorption of nutrients by rice.	Mariam, K. A.	1975
70.	Morphological and physico-chemical properties of Karapadom soils of Kuttanad region of Kerala State.	Santhakumari, G.	1975
71.	Fertility investigations on the laterite soils of Kerala State.	Hassan, M. A.	1976
72.	Performance of slow Release Nitrogen sources on growth, yield and nitrogen uptake of rice	Oommen, M	1976
73.	Investigations on the salinity problems of *pokkali* and *kaipad* areas of Kerala state	Samikutty, V. A	1977
74.	Studies on the rice growing soils of Wyanad.	Saratchandran Nair, P.	1977
75.	Investigations on the use of Mussoori rock phosphate in the acid soils of Kerala.	Sundaresan Nair, C.	1977
76.	Use of indigenous sources of Magnesium silicate as a soil amendment.	Vijayakumar, K.	1977
77.	Study of physico-chemical characteristic of the *poonthalpadam* soils of Kerala	Krishnakumar, A. K.	1978

1	2	3	4
78.	Studies on increasing the efficiency of rock phosphate in Kerala soils.	Madhusoodanan Nair, K.	1978
79.	Soil test-crop response studies of soil phosphorus in Kerala	Mohan, R. K.	1978
80.	Studies on the persistence of Carbofuran in soil.	Rajagopal, K.	1978
81.	Studies on the laterite and red soil asso-ciations in certain locations in Kerala.	Subramonia Iyer, M.	1978
82.	Studies on the response of paddy to lime application in the acid soils of Kerala	Anilakumar, A.	1979
83.	Investigations on the possible reasons for the lack of response to phosphorus in Kerala.	Mahendran, P.	1979
84.	Evaluation of available phosphate reserve of soil by chemical methods	Mathew Jacob, K.	1979
85.	The utility of an indigenous source of magnesium silicates for rice in *Kuttanad* soils.	Karunakara Panicker, N.	1980
86.	Studies on the effect of varying levels of zinc on the growth and yield of rice.	Krishnan Namboodiri, K.	1980
87.	Effect of lime, phosphorus and rhizhobium inoculation on the growth, yield and chemical composition of cowpea.	Samuel Mathew	1980
88.	Pedogenic studies on lateritic catenary sequences occurring in Kerala	Venugopal, V. K.	1980
89.	Efficiency of rice varieties in their utilization of native and applied P with a view to locate varieties tolerant to P deficiency levels in soils	George, C. A.	1981
90.	Foliar diagnosis, yield and quality of ginger (*Zingiber officinale*) in relation to nitrogen, phosphorus and potassium	Johnson, P. T.	1981
91.	Evolving suitable agro technique for sesames in *onattukara*	Krishna Kumar,V.	1981
92.	Soil testing methods for Potassium in relation to cassava	Prabhakumari, P.	1981

1	2	3	4
93.	Manganese and zinc status of rice soils of Kerala.	Rajendran, P.	1981
94.	Foliar diagnosis, yield and quality of turmeric (*Curcuma longa* L) in relation to nitrogen, phosphorus and potassium	Saifudeen, N.	1981
95.	Potash nutrioperiodism in rice (*Oryza sativa* L.)	Shehana, R. S.	1981
96.	Fertility investigations in the *poonthalpadam* soils of Kerala	Sumam George	1981
97.	Studies on the genesis, morphology and physico-chemical characteristics of the lateritic soils of Kerala	Thomas Varghese	1981
98.	The relationship between soil nutrient status and foliar analysis of cocoa of different age groups in the various soil types of Kerala	Annie Koruth	1982
99.	Studies on the physical properties of the major soil groups of Kerala with special reference to the effect of salinization and desalinization	Antony, P. C.	1982
100.	Studies on biodegradation of cellulose materials	George Kavalam	1982
101.	Foliar diagnosis in coconut (*Cocos nucifera Linn.*) to nitrogen, phosphorus and potassium	Gopi, C. S.	1982
102.	Nutrient dynamics and residual effect of permanent manurial experiment with rice.	Sam, T. Kurumthottical	1982
103.	Increasing Nitrogen use efficiency in upland soil	Sathyanathan, K. M.	1982
104.	Physico-chemical investigations on the crop hazards due to industrial pollution in the sandy soils of Trivandrum.	Sumam Susan Varghese	1982
105.	Foliar diagnosis, yield and quality of pepper (*Piper nigrum* L) in relation to nitrogen, phosphorus and potassium	Sushama, P. K.	1982
106.	Characterisation of soil organic matter in different soil types of Kerala	Usha, P. B.	1982

1	2	3	4
107.	Nutritional status of soil and plant in relation to the incidence of *Chenthal* disease of cardamom	Dileepkumar, K. N.	1983
108.	Effect of potassium nutrition on the yield and quality of cassava (*Manihot esculenta Crantz*)	Gopalakrishna Nair, P.	1983
109.	Yield prediction in coconut based on foliar nitrogen, phosphorus and potassium	Krishnakumar, N.	1983
110.	Increasing nitrogen use efficiency in upland soils.	Sathyanathan, K.M.	1983
111.	The nature of acidity in upland and rice fallows in relation to response of pulse crop to liming.	Sudharmai Devi, C. R.	1983
112.	Aggregate size distribution and its relationship to the physical and chemical properties of some typical soils of Kerala.	Ushakumari, K.	1983
113.	The release of aluminium in soils under sub-merged conditions and its effect on rice.	Alice Abraham	1984
114.	Effect of lime and different forms of phosphorus on the growth, yield and chemical composition of cowpea.	Latha, R.	1984
115.	A comparative micromorphological and physico chemical study of the upland and mid upland laterite soils of kerala	Sankarankutty Nair	1984
116.	Physico-chemical characterization of red soils in different regions of Kerala	Betty Bastin	1985
117.	Influence of applied nutrients and stage of harvest on the yield and physicochemical properties of essential oil of palmarosa (*Cymbopogan Martini Stap F Var. Motia*)	Chinnamma, N. P.	1985
118.	Nitrogen fixation by cowpea as influenced by the stage of growth and duration of crop.	Indira, M.	1985
119.	Studies on the root activity pattern of black pepper *(Piper nigrum* L) employing radiotracer technique	Jayasree Sankar, S.	1985

1	2	3	4
120.	Potassium utilization in cassava *(Manihot utilissimum* Pohl) as influenced by neem cake-urea blend	Manorama Thampati, K.C.	1985
121.	Suitability of rock phosphate for direct application in the acid rice soils of Kerala.	Regi, P. Mathew	1985
122.	Role of boron in plant nutrition in Kerala in relation to its content in soils.	Suresh, P. R.	1985
123.	Evaluation of the role of elements Ca, Mg, S and B in the nutrition of groundnut with reference to monovalent (K) to divalent (Ca+Mg) cationic ratios.	Sureshkumar, P.	1985
124.	Evaluation of available phosphorus and potassium in soil using common extractant	Durga Devi, K. M.	1986
125.	Investigations on the causes of the poor productivity of the rice soils of 'Pazhanchira Ela' in Chirayinkil taluk.	Girija, V.	1986
126.	Assessment of the factors governing response to phosphorus in the rice soils of Kerala.	Harikrishnan Nair, K.	1986
127.	Factors governing response of rice to liming in Kerala soils	Marykutty,K.C.	1986
128.	Relative efficiency of rice varieties for absorption and utilization of soil and fertilizer phosphorus	Mashar Velapurath	1986
129.	Nitrogen balance studies in the rice soils of Kerala.	Meera, K.	1986
130.	Use of cheaper and efficient sources of phosphatic fertilizer for cowpea in rice fallows	Omana, M.	1986
131.	Effect of submergence on the soil testing parameters of paddy soils.	Usha Mathew	1986
132.	Fertility investigations on the soils of South Kerala in relation to their physiographic positions.	Wilfred Godwin, G.	1986
133.	Chemistry of coconut rhizosphere	Anilkumar, K.S.	1987
134.	Environmental planning of two selected river basins of Western Ghats based on investigations on land use planning and land capabilities	Benoy T Cherian	1987

1	2	3	4
135.	Effect of different mulches on soil temperature and soil water utilization in relation to seedling emergence & crop growth	Jayasree, P.	1987
136.	Continuous use of municipal sewage effluents on soil physical and chemical properties	Karunakaran Nair, G	1987
137.	Exchangeable aluminium as an index of liming for the acidic upland soils of Kerala	Meena, K.	1987
138.	Effect of sodium chloride on soil characteristics, yield and quality of coconut grown in laterite soil	Prema, D.	1987
139.	Nutrient recycling under monoculture conditions in the tropical forest eco-systems	Premakumari, S.	1987
140.	A comparative micromorphological and physico- chemical study of the upland and mid upland laterite soils of Kerala.	Sankarakutty Nair, R.	1987
141.	Characterisation of laterite soils from different parent materials in Kerala	Stella Jacob	1987
142.	Possibilities of using unsymmetrical dimethyl urea as urease nitrification inhibitor for increasing the efficiency of nitrogenous fertilizers	Asha Varghese	1988
143.	Physico-chemical and biological properties of high elevation soils with reference to tea	Elizabeth Chacko	1988
144.	Characterization of Kerala soils into fertility classes with respect to available P and K extracted by a common extractant	Kamalam, P. V.	1988
145.	Horizontal and vertical movement of potassium in the Neyyattinkara – Vellayani soil association from a long term fertilizer experiment under coconut	Premkumar, S	1988
146.	A comparative study of the nature of acidity in the upland and low land soils of state Kerala	Raveendran Nair, A.	1988
147.	The distribution, fixation and availability of P in the *kole* soils of Kerala	Sheela, S.	1988
148.	Nutritional status of soils in relation to foliar nutrient levels in oil palm	Solomon Chacko	1988

1	2	3	4
149.	Studies on exchange equilibria and its prediction in some acid soils of kerala	Swarnavi, S.	1988
150.	Nitrogen losses from the rice soils of Kerala with special reference to ammonia volatilization	Anilakumar, K.	1989
151.	Nutrient management model for compensating spatial soil variability in rubber plantations in Amboori area	Anilkumar, J. R.	1989
152.	Impact of Eucalyptus and Acacia plantations on soil properties in different pedogenic environment in Kerala	Byju, G.	1989
153.	Sulphur status of the *kuttanad* soils of Kerala	Cicy P. Mathew	1989
154.	Physico-chemical characteristics, genesis and classification of soils from forest ecosystems in Kerala	Elsy, P. A.	1989
155.	Morphological and physico - chemical properties of denuded forest soil under the influence of oil palm plantation.	George Jose	1989
156.	Standardization of index leaf/ leaves to assess the nutritional status of clove (*Eugenia caryophyllus*) in relation to soil fertility	Gnanadas, D.	1989
157.	Studies on the dynamics of forms of soil Fe in the acid soils of Kerala during submergence	Harikumar, K. P.	1989
158.	Influence of water and specific anions and cations on physico chemical and biological properties of soil	Jaya,V.	1989
159.	The occurrence and distribution of the micronutrient elements in the rice soils of south Kerala	Mariam Jacob	1989
160.	Influence of forms of organic matter on the mineralization of applied phosphorus in submerged rice soils	Nageeb, P. H.	1989
161.	Studies on the solubilisation of Fe in submerged soils and methods to minimize its solubility and toxic concentration to paddy	Ramasubramanian,P. R.	1989

1	2	3	4
162.	Heavy metals in fertilizers in relation to their accumulation in soils due to continuous fertilizer use.	Sathya Prakasan, S.	1989
163.	Comparative morphology and physico chemical properties of some forest and deforested soils of Kerala	Sivadasan, N.	1989
164.	Micro meso and micromorphology and mineralogy of acid sulphate soils of Kerala	Subramoniya Iyer, M.	1989
165.	Nutrient Dynamics in the rice based cropping system	Sundaresan Nair, C.	1989
166.	Microbial mobilization and immobilization of nutrients in red loam soils	Susan John, K.	1989
167.	Potassium supplying capacity of Neyyattinkara Vellayani soils association and its relationships with the potash nutrition of major crops on them.	Valsaji K	1989
168.	Efficiency of potassium in mitigating the effect of shade in intercrops	Jayaraj, P.	1990
169.	Efficiency of potassium under different levels of irrigation in summer vegetable ash gourd	Muraleedhara Menon, P. G.	1990
170.	Quality of oil of Ocimum as influenced by stages of harvest and shade	Rekha Pillai	1990
171.	Yield prediction in cashew based on foliar nutrient levels	Rosily Mathew	1990
172.	Effect of top dressing with complex fertilizer on the yield of rice	Sam Mathew	1990
173.	Comparative effect on different phosphatic fertilizers in rainfed *Nendran* Banana	Sheeja, V. G.	1990
174.	Influence of soil texture on potassium availability, fixation and uptake by rice in laterite soils	Jessymol, A. S.	1991
175.	Taxonomy and fertility assessment of the soils in command area of Edamalyar Project	Krishnakumar, P. G.	1991
176.	Nutrient uptake effect of Cassava (*Manihot esculanta Crantz* as influenced by vesicular arbuscular micorrhizal (VAM) association and rock phosphate application	Narayanan, S.	1991

1	2	3	4
177.	Sulphur status of major uplands of south Kerala	Sheeba, S.	1991
178.	Surface charge characteristics and phosphorus availability in selected oxisol and ultisol of Kerala	Sreekala, S	1991
179.	Clay mineral characterization of the major soil series of Trivandrum Dt.	Asharaf, M	1992
180.	Fractionation of organic and inorganic nitrogen in important soil types of Kerala	Mini, E. R.	1992
181.	Response of rice to application of micronutrients	Muraleedharan, P.	1992
182.	Effect of long term application of manures and fertilizers on soil properties, utilization efficiency of nutrients and quality of rice	Padmom, M. K.	1992
183.	Secondary and micronutrient interaction in continuously fertilized coconut palms	Prabhakumari, P	1992
184.	Status' availability and transformation of magnesium in acid soils of Kerala	Prema, D .	1992
185.	Evaluation and suitability rating of ten major soil series of the command area of Kallada irrigation project	Premachandran, P. N.	1992
186.	Electro chemical properties of selected Oxisols and Ultisols of Kerala with special reference to charge characteristics and surface mineralogy	Rajendran, P	1992
187.	Growth and nutrition of black pepper as influenced by decaying litter materials in soil	Sivakumar, C.	1992
188.	Suitability of magnesite as a source of magnesium in acid rice soils of Kerala	Susan Varghese	1992
189.	Management of acidity by combined application of lime and gypsum in low activity clay soils of Kerala	Tessy Jacob, K.	1992
190.	Efficiency of rock phosphate in the acid rice soils of Kerala	Visakha, L	1992

1	2	3	4
191.	Soil temperature and moisture characteristics as influenced by inter-cropping of fodder crops in coconut garden.	Asok, P. I.	1993
192.	Classification of upland soils of Kerala	Bindhukumari, A.	1993
193.	Behavior of potassium in selected soil series of Thiruvananthapuram district.	George Joseph	1993
194.	Soil fertility of coconut root zone as influenced by long term inorganic fertilizers	Joemon Joseph	1993
195.	Decomposability and mineralisation pattern of coir pith in latosols	Jothimoni, S.	1993
196.	Modeling of carbofuran movement and sorption in soil with varying physico-chemical properties.	Moosa, P. P.	1993
197.	Toxic hazards of the industrial atmospheric pollutant SO_2 on tree crops	Rani, B.	1993
198.	Evaluation of methods to improve the nitrogen use efficiency of urea in rice	Sapheena. K.S.	1993
199.	Influence of iron toxicity on growth, yield and plant composition of major rice varieties cultivated in Kerala	Sheela, R.	1993
200.	Potassium dynamics in Neyytattinkara soil series under coconut cultivation	Sreelatha, A.K.	1993
201.	Classification of wetland soils of Kerala for placement in soil taxonomy	Unni Krishnan, S	1993
202.	Behaviour of phosphorus in selected soil types of Kerala	Vijayan, A. P.	1993
203.	Effect of long term fertilizer application on the soil physical properties in coconut garden	Chithra,V.G.	1994
204.	Quality and fatty acid composition of coconut oil in relation to variety variation and mineral nutrition	GeethaKumari, V.S.	1994
205.	Potassium release and exchange characteristics of the selected wetland rice soils of Kerala	Louis Joseph	1994

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215.	Partial substitution of Muriate of potash by common salt for cassava (*Manihot esculanta* Crantz) in Oxisols of Kerala	Sudharmai Devi	1995
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250.	Effect of vermicompost enriched with rock phosphate on cow pea (*Vigna unguiculata L. Walp*)	SailajaKumari, M. S.	1998

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280.	Yield maximization in Cassava (*Manihot esculanta* Crantz) through 'Systematic approach in fertilizer use'	Susan John, K	2003
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296.	Standardisation of production and enrichment of vermi wash	Thankamoni, K.	2005
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317.	Characterization of the soils of Koliyoor micro water shed using geographical information system	Appu, M.G.	2012
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319.	Production and evaluation of proteinaceous earthworm meal	Fasila, E. K.	2012
320.	Biological indicators of soil health as influenced by plant nutrient sources	Mekha, M.G.	2013
321.	Site specific nutrient management in the bitter gourd (*Momordica Charantia* L)	Neenu, S.	2013
322.	Effect of integrated plant nutrient system (IPNS) on soil biological regimes in red loam soil	Neethu, R. Sathyan	2013
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329.	Silicon and boron nutrition of rice (Oryza sativa L.) in laterite derived paddy soils of northern Kerala	Sainath Nagula	2014
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340.	Nutrient dynamics and transformation in aerobic and flooded systems of rice in lateritic soils of kerala	Geetha, P.	2015
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