SOIL RESOURCE INVENTORY OF THE MAIN CAMPUS KERALA AGRICULTURAL UNIVERSITY VELLANIKKARA : PART I - (EAST)

By

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THESIS

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Department of Soil Science and Agricultural Chemistry

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DECLARATION

I, hereby declare that this thesis entitled "**Soil resource inventory of the main campus, Kerala Agricultural University, Vellanikkara Part I East**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other university or society.

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(SEENA)

DEDICATED

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INTRODUCTION

INTRODUCTION

In recognition of the fact that soils are finite resources, these have to be used on the basis of sound principles of resource management, so as to enhance productivity, prevent degradation and pollution and also to reduce the loss of good agricultural lands to non-farm purposes. Nevertheless, agricultural landuse decisions are often framed by arbitrary and subjective judgement mainly due to non availability of reliable database on the soil resources and resource analysis techniques.

Soils are vital natural resources for sustenance of mankind. The need for rational use of the soil resources is more relevant now than ever before. Pressure on land is increasing due to multiplicity of uses to which it is put and the variety of needs it has to satisfy. The pressure on soil resources has resulted in overuse or misuse of these finite resources and thus we find ourselves landed in problems of ecology and environment. Any kind of landuse is executed on the surface soil and it matters much, whether the soil is good or bad. Any fruitful attempt on soil resource management and maintenance of soil health on sustainable basis should be based on the resource potential of soil. Further, crop suitability and productivity are products of fertility capability of the soil. Thus it becomes essential to generate data on soil parameters that will have a bearing on crop production and other uses of the land. The data on soils further help in working out detailed schedule of treatments in respect of land development, tillage operations, agronomic practices, irrigation systems etc.

Conventional inventories of soil resources in India would result in classification of soils into taxonomic units and delineation of their boundaries into soil map units. A typical soil map is a multi-purpose document that can be utilised by all land users. However, a soil map becomes fruitful only when it is interpreted for specific uses. In the context of crop production, detailed investigation of soil fertility parameters and preparation of soil fertility maps at large scales are essential for efficient crop choices and management in terms of nutrients and other soil amendments.

The National Bureau of Soil Survey and Land Use Planning has published a soil map of Kerala at the scale 1:250,000. While this map provides useful data for designing crop production strategies at state level, it seldom helps in farm advisory service. It is cumbersome and expensive to generate soil resource information at farm level for a state like Kerala, where the geomorphology and topo-sequences are so unique that the landscape is often described as a museum of soils.

Nevertheless, the results of experiments from Kerala Agricultural University are extrapolated with sufficient accuracy, to suit various agro-ecological situations prevalent in the state, with the help of available soil information. The present attempt was to augment and update the database on soil resources of various campuses of the University.

A soil map of the main campus of Kerala Agricultural University prepared in 1976 at 1:4000 scale was available for further refinement. This map has series descriptions and records of some permanent features of the soilscape of the campus. A detailed inventory on the fertility of soil resources of KAU campus and its consequent use in conjunction with new technologies generated would facilitate extrapolation of the technologies to other areas of similar soil characteristics within and outside the state. Delineation of the fertility constraints would also help in rational use of fertilizer resources for crop management within the campus.

Fertility Capability Classification would group the soils that have same kind of limitations from the point of view of fertility management. It helps grouping of experimental sites that are expected to respond similarly to soil management practices based on measurements of the top soil and subsoil characteristics directly relevant to plant growth.

Therefore, this programme of research was undertaken with the intention to generate data on the fertility parameters of the soil resources of the Eastern part of the main campus, Vellanikkara and to utilise the data for further analysis of fertility constraints towards crop production.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Soil resource inventories started in India even before independence. Report of Francis Buchanan on the laterites of Angadippuram in Kerala is one of the best examples of soil characterisation in the pre-independence period. Systematic soil surveys were initiated with the establishment of National Bureau of Soil Survey and Land Use Planning (NBSS & LUP), Nagpur and its Regional Centres in different parts of the Nation. In addition, the All India Land Use Survey, State Soil Survey Organisations, Land Use Boards, Research Institutions and State Agricultural Universities are engaged in Soil resource surveys and interpretations. Soil fertility is one major component being investigated all over the world in connection with crop production. Available literature on the areas pertaining to the current study has been scanned and collated hereunder.

2.1 Soil Resource Inventory

Conservation and management of natural resources means their utilisation with least disturbance to the ecosystems prevalent in specific locations. Many a time such considerations are ignored for immediate benefits, especially in agricultural production systems. Soil resource inventories are pre-requisites for gearing up agricultural production through evolution of site specific production technology and alternate crop choices.

A large number of detailed soil inventories at cadestral scales were undertaken in Kerala and is being done for certain watersheds, irrigation projects etc. by different agencies, employing the help of Soil Survey Staff of the Department of Agriculture, Kerala. However, such soil surveys are never interpreted for farm level recommendations on crop management. Soil Survey Staff, Dept. of Agriculture, Kerala (1976) prepared a soil map of the main campus of Kerala Agricultural University at a scale of 1:4000. This map comprises 38 phases belonging to three soil series viz. Vka I, Vka II and Vka III. But their position in soil taxonomical level is not defined. Further, fertility capability classes are also not derived.

A soil map of Kerala was published by the Soil Survey Wing of the Department of Agriculture, Kerala in 1978 (Soil Survey Branch, 1978) where 10 different types of soils were identified and mapped. Detail of the soil types identified in this venture is given in Table 1.

Table 1. Soil Types of Kerala, Classification & Important Characteristics

No.	Soil type	order	sub order	Great soil group	Characteristics
1	Forest loam	Mollisol Alfisol	Udoll Udalf	Hapludoll Tropudalf	Acidic (pH 5.5 to 6.3). Rich in N, poor in bases, heavy leaching
2	Black soils	Vertisol	Udert	Chromudert	Neutral to moderately alkaline (pH 7 to 8.5). High in clay content and CEC. Low N, P & organic matter
3	Riverine Alluvium	Entisol Inceptisol	Fluent Tropept	Tropofluvent Eutropept	Moderate organic matter, N & K. Acidic, poor in P and Lime
4	Coastal Alluvium	Entisol	Psamment	Tropopsament	Acidic, low fertility level, organic matter, clay and CEC. Surface textures are loamy sand & sandy loam
5	Hydromorphic saline	Alfisol	Aqualf	Tropaqualf	Acid; accumulation of salts during summer Undecomposed organic matter found in lower layers.
6	Brown Hydromorphic	Alfisol Inceptisol	Aqualf Aquept	Tropaqualf Tropaquept	Highly acidic, moderate organic matter, N & K. Deficient in P and Lime
7	Red Loam	Alfisol	Udalf	Tropudalf	Acidic. Highly porous, friable. Low in organic matter content and all plant nutrients
8	Kuttanadu Alluvium (Acid Saline)	Inceptisol Entisol	Aquept Aquent	Tropaquept Fluvaquent	Kayal and Kari soils. Serious problems of hydrology, floods, acidity and salinity
9	Onattukara Alluvium (Greyish Onattukara)	Entisol	Orthent	Troporthent	Acidic and extremely deficient in all major plant nutrients
10	Laterite	Oxisol	Orthox	Eutrorthox	pH- 4.52 to 6.2, poor in available N, P & K, low in bases and organic matter content. Poor water holding capacity. 65% of total area, midland and upland regions

One of the best examples of documentation of the soil resources of the Nation was the SRM (Soil Resource Mapping) project of the NBSS & LUP, which resulted in state-wise soil maps of the country at 1:250,000 scale. A soil map of Kerala was prepared by the Bureau at 1:250,000 scale. The printed map at 1: 500,000 scale and accompanying report is now available for state level interpretations (Krishnan *et al.*, 1996). Associations of soil series were considered as map units and 38 such map units are identified in the state. This map now forms the basis for extrapolation of research results of Kerala Agricultural University to specific regions in Kerala.

There are several reports on soil resource characterisation and interpretations from different parts of the country and from abroad. Some of the works are quoted below.

Tamboli and Misra (1969) studied the utility of soil survey and soil testing in increasing the paddy yield in Raipur district of Madhya Pradesh. Soil test summary prepared for each soil series indicated the level of plant nutrients in soils.

Yadava *et al.* (1980) conducted soil and land use survey of seed multiplication farm, Pekhubela in Himachal Pradesh. They classified soil into four series and capability classes. This classification helped to know the nature and limitations of each class of land use and management needs of each class also made according to prevailing problem.

Brar *et al.* (1983) made an investigation to assess the fertility status of Majha tract of Punjab from the data based on the analysis of 27,742 soil samples. Soils were predominantly in light textured and low in organic matter. Available phosphorus was medium and medium to high levels of potassium.

Kumar and Tripathi (1987) investigated the landscape features and soil physical properties related to runoff and soil loss for better land use planning and soil and water conservation measures in mini watershed area in Kafra-bhaura in U.P. Area was classified into four capability classes based on various soil and landscape features.

Sannigrahi *et al.* (1990) carried out an investigation to characterise and classify major soil series occurring in Nilgiri hill areas to help in the proper management of the soil for growing agricultural crops due to favourable climate and good precipitation.

Detailed soil surveys resulting in characterisation of soils upto phase level of soil taxonomy was attempted in Kerala and elsewhere. Deepa (1995) and Sreerekha (1995) characterised the soils of Regional Agricultural Research Station (RARS), Pattambi and Banana Research Station (BRS), Kannara respectively, with respect to taxonomy and brought out fertility constraints for crop management.

Vasudevan *et al.* (1997) made an attempt to assess the fertility status of Kanjamalai hills of Tamil Nadu. They revealed that the soils are neutral in reaction, 69% low in nitrogen, low in phosphorus, 58% low in potassium. But the soils were supplied with Cu, Mn and Fe.

Kumar *et al.* (1998) characterised the soils of Punjab Agricultural University, Regional Research Station for Kandi area, Ballowal Saunkhri. They classified soils into three soil units. Based on the morphological, physico-chemical and mineralogical characterisation, classification of soil was done and management practices were formulated for good crop production.

Mukhopadhyay *et al.* (1998) conducted detailed soil survey of Punjab Agricultural University Nucleus Seed Farm, Naraingarh. Characterisation of soils helped to improve production management and multiplication of seeds and generation of transferable agro technology.

Tamgadge *et al.* (1999a) conducted an investigation regarding soil resource inventory of Madhya Pradesh and they established soil-physiographic relationship of the area. Tamgadge *et al.* (1999b) also investigated about the cropping system and soil degradation of soils of Madhya Pradesh and have done the land use capability classification. They used the results of interpretation of soil data for various applied purposes and its effect on crop yield efficiency and crop production systems.

2.2 Soil Survey Interpretations

Soil surveys and resulting soil maps are designed according to the purposes for which they are to be interpreted. The soil map indicate the extent of kinds of soils having typical characteristics and of groups of soils having differing characteristics but occurring in a geoclimatic setting. It locates the kinds of soils with reference to interpretation that are important in their proposed use.

Interpretative classifications of soils are necessary for rational use of soil resources. Several kinds of land evaluation techniques are applied in different locations and also for different purposes.

Ratnam *et al.* (1970) conducted a soil survey of paddy growing soils of the Thanjavur district of Tami Nadu and found that all the soils are low in plant nutrients. They identified eight soil series and recommended soil test based recommendation and adoption of improved agricultural practices for sustained yield and to maintain fertility.

Interpretation of soil survey carried out in Borai sub-catchment, Bilaspur district, Madhya Pradesh, under Mahanadi Catchment have been discussed with regard to the land capability, soil and land irrigability, and paddy soil classifications (Biswas, 1977). The total area was grouped into fifteen land capability units.

Detailed soil survey of selected villages in Gubbi Taluk was taken up with the objective of evaluation of land for crop planning at the micro level of villages (Rao, 1985). These included field research consisting of identification and characterisation of soil classes, preparing a legend for identification of soil classes and their phases through verification of soil based observations in the field to delineate their boundaries.

Janakiraman *et al.* (1997) carried out soil survey interpretation for land use planning in *Theri* soils of Tamil Nadu and four soil series were identified. Various constraints were assessed and interpreted for better land use planning.

A detailed soil survey and evaluation of soils in Tamil Nadu Agricultural Farm, Coimbatore, was carried out for land use interpretative grouping (Mayalagu *et al.* 1998). Based on this six series were identified and mapped.

The manifold advantages of the soil information systems such as ease of handling of voluminous data, reproduction of maps derived suitability and other interpretative maps, easy linkage with other geo-referenced coverages to generate new composite overlays, cost effective and time saving periodic up-datation of maps/information and capabilities of quick monitoring and impact assessment measurers make it a useful tool for generating action plans and its implementation for land resource management of a region (Das, 1999).

2.2.1 Land Capability Classification

A general evaluation based on limitations of land characteristics, is best illustrated in the USDA land capability classification (Klingebiel and Montgomery, 1966). The system though general in approach is made primarily for agricultural purposes. Even though this system can delineate areas suitable for agriculture with different degrees of limitations, it cannot provide site specific soil management recommendations.

Cultivable soils are grouped according to their potential and limitations for sustained production of commonly cultivated crops. Lands suited to cultivation are grouped in class I to class IV according to the degree of limitations. Lands in class V to class VII are suited to silviculture and pasture. Class VIII lands is suited neither to agriculture nor to forestry.

Murthy *et al.* (1968) conducted a survey in Madras state regarding Kundah project for the sound management of watershed. They identified seven series and land capability classification leads to nine classes and subclasses. This classification gave information on proper land use and adoption of soil conservation measures on each class of land, which will be helpful in the formulation of plans for watershed management in Kundah project.

Patil *et al.* (1991) did a detailed soil survey and land capability classification of Agriculture College Farm, Nagpur. The land capability classification leads to six classes and sub classes. Suitable measures have been suggested for soil conservation and proper land use planning according to prevailing programme.

Mayalagu *et al.* (1992) investigated the morphological characters and productivity ratings of Subramaniapuram series in saline tracts of Ramanathapuram taluk in Tamil

Nadu. He studied the soils in the region and grouped into land capability classification and land irrigability classification.

Um and Noh (1992) did Land Capability Classification of wet soils of Korea. They considered the soil and land characteristics such as slope, natural drainage, texture, erosion, soil depth, stone content, EC and presence of a sulfate layer for the classification. Each soil has been rated in one of 4 classes based on degree of limitations.

2.2.2 Land Irrigability Classification

Soils with properties suited to sustained use under irrigation are further classified in land irrigability classes according to physical factors and socio-economic considerations. Lands under class I to IV are generally irrigable, class V lands are not used for irrigation and class VI lands are not suited to sustained use under irrigation.

Soil and land irrigability classification provides basic information required in solving agronomic, economic and engineering problems for command area development. The irrigation suitability of soil and land appropriate for arid and semiarid climate was developed by Thorne and Peterson (1949). In India, the All India soil and Land Use Survey Organisation (1970) classified the soils into five classes for irrigation suitability under arid and semiarid conditions. The subdivision in a class was based on limitations such as soil properties, topography and drainage.

Mayalagu and Paramasivam (1992) conducted a detailed soil survey of Agricultural Research Farm, Paramkudi and characterisation of soil were made. They identified two series, namely Padugai and Subramaniapuram, and mapped. The rating of these soils for land capability, storie index and productivity was of grade 'Fair'. In irrigability classification they were in B and A classes respectively. The soil irrigability class 'B' of Pudugai series indicates the moderate soil limitations for sustained use under irrigation. The 'A' series indicates that it has slight limitations for sustained use under irrigation.

Nanda *et al.* (1997) classified the soil in the cultural command area of Kuanria irrigation project in Orissa into four series. Based on the fifteen characteristics pertaining to soil topography and conditions under subhumid climate, the soils were classified into four soil and land irrigability subclasses.

2.2.3 Crop Suitability Classification

Mayalagu and Paramasivam (1992) have carried out a detailed survey of cotton Research Station Farm, Srivilliputhur, to investigate the morphological characteristics of the soil series and finally to arrive at interpretative groupings and taxonomy for the different soil phases of each farm and to suggest management practices. It is revealed that the identified two series are placed under storie index rating of 58.48 and 48.48% respectively both falling under grade 3 and pointing out the near marginal suitability for sustained use under agriculture.

Premachandran (1998) conducted a systematic survey and land evaluation of the soils of Onattukara region was taken upto study, interpret, classify and to show their location and extend on base maps. On this study, investigations were done on land evaluation, crop suitability and other management aspects for sustained use of soil resource data to the best advantage.

Challa (1999) did the land evaluation in Buldhana district of Maharashtra. Physiographically he divided the land into different region. By studying the soil resource information and land use at that time he tried to delineate growing zones and land use optimum for optimal land use.

2.2.4 Fertility Capability Classification

Soil Fertility Capability Classification was originally published in 1975 (Boul *et al.,* 1975) to bridge the gap between soil classification and soil management. As a technical soil classification system, it focuses on specific uses of natural soil classification systems, such as Soil Taxonomy (Soil Survey Staff, 1975) or of the FAO system (FAO, 1971; 1974), which is essentially a record of soil properties.

The fertility capability classification intends to group soils that have the same kind of limitations from the point of view of fertility management. It helps grouping of experimental sites that are expected to respond similarly to soil management practices based on measurements of the top soil and subsoil characteristics directly relevant to plant growth.

It is the intend of the FCC system to generate soil groups within which similar responses to soil management practices can be expected (Sanchez *et al.*, 1982). The process of defining FCC unit will comprise examination of the surface soil (top 20 cm) and subsoil (20-40 cm) for several parameters (modifiers) which include: mottling, moisture regimes, CEC, Aluminium saturation, acidity, P-fixing capacity, slope, graveliness etc. which have direct relevance to plant growth.

Mathan (1990) applied soil fertility capability classification to acid soil of districts of Nilgiri for the assessment of fertility level. Among the several approaches in providing information on the potential of the soil for crop production, soil fertility capability classification is one which lays emphasis on soil fertility within the 50cm layers from the surface.

Investigations on Kerala soils have revealed that the FCC parameters are predominantly limiting crop yields in our soils. FCC grouping of the wetland soils of Thrissur district was attempted by Ambili (1995). Soils of Banana Research Station, Kannara (Sreerekha, 1995) and soils of RARS Campus, Pattambi (Deepa, 1995) have also been grouped under fertility classes.

Mahendran *et al.* (1997) did soil fertility capability classification of problem soils of Tirunelveli, Tuticorin and Kanyakumari districts of Tamil Nadu for studying the fertility level and limitations of fertility management.

Miura and Badayos (1999) evaluated soil fertility status of low land areas of Philippines. Eight soil characters namely organic C, total N, available P_2O_5, exchangeable K, available SiO_2, clay contents and CEC for surface soil samples were considered for characterisation. This characterisation helped to identify the factors determining the productivity of low land for rice cultivation.

2.3 Physical Properties of Soils

Physical properties of soil are generally considered more important in assessing merits of the soil for crop production. Texture and structure determine plant growth, root volume, anchorage and extent of nutrient uptake. Moreover suitability of soil for specific crops is largely determined by this permanent properties, where as fertility aspect can be managed with suitable amendments.

According to Sathyanarayana and Thomas (1961) the colour of laterite soils dependent on the content and form of iron hydroxides and oxides which impart yellow, pink, brown and red colours to the ground matrix earth clay.

In the studies on cultivated soils of Kerala, Janardhanan *et al.* (1966) found that the absolute specific gravity and apparent specific gravity are a function of the coarser particles of the soil while water holding capacity, pore space and organic carbon are related to the finer particles of the soil.

Ghatol (1972) studied the physico-chemical properties of soils of farms under Marathwada Krishi Vidhyapeeth campus, Parbhani. The clay content showed an increasing trend in down to profile in the study area.

According to Yadev *et al.* (1977) the topography and drainage are responsible for the colour development in red soils of U.P.

Venugopal (1980) reported that bulk density ranges 0.58 – 2.0 g/cc for the red soil profile in a study of lateritic catena in Varkala area of Kerala.

Singh and Kolarkar (1983) studied some physico-chemical properties of *khadins* in western Rajasthan and found that clay content of soil ranges from 9.8 to 66.8, silt content 9.5-47.5, fine sand 15.3-69.6 and coarse sand 0.34-20.4

Laterite soils in different locations in Kerala have striking similarity in colour with red hue predominantly increasing with depth in the profile (Jacob, 1987).

Patil *et al.* (1987) studied some physical and chemical properties and micronutrient status of the bench terraced soils of Konkan and colour ranged from yellowish red, reddish brown to dark red.

It was observed that the red and laterite soil groups of Kerala have an excellent state of aggregation. The soils contain more than 70% of the aggregates in the size range of diameter more than 0.25mm (Antony and Koshy, 1988).

Antony (1988) studied on some physical properties of the major soil groups in humid tropical region of Kerala namely red loam, laterite, coastal alluvium, riverine alluvium, brown hydromorphic and forest loam. He found that particle was generally high for laterite soil. Correlation between clay content and water holding capacity was positive in all soils except forest loam.

Based on the study conducted on the Edamalayar project area, Krishnakumar (1991) reported that coarse fragments formed a predominant part in the soils from upland which increase in content with depth.

2.4 Electrochemical Properties of Soils

A knowledge of soil pH can give a clear picture of the distribution pattern of certain important soil properties and that the understanding of the property of a given soil will be rendered considerably simple in the event of these properties being related to the soil pH. No information is available on these correlation relating to the soils of Kerala except for the observation of Koshy and Brito- Muthunayagam (1961) that the high acidic nature and high sesquioxide content are prevalent in the soils of Kerala and acid soils of Kerala contain only meagre quantity of potassium, calcium and magnesium.

Kanwar and Grewal (1960) reported about 72.2% of phosphorus retention in acid soils and 29.6% in calcareous soils from the analysis of soil samples from different types of soils of Punjab. It was found to be due to free sesquioxide and exchangeable calcium and magnesium.

A study on fixation and penetration of soluble phosphate in some soils of Kerala, showed that soils studied differ widely in their capacities to fix phosphorus. Acid soils with high sesquioxide content have high capacity for fixation. The results revealed that the soils of Kerala possesses very high capacities for phosphorus fixation and it may be attributed to the acidic nature and high sesquioxide content of these soils (Koshy and Brito-Muthunayagam, 1961).

According to Sathyanarayana and Thomas (1962) the cation exchange capacity of laterite soils of Angadipuram vary from 4.5-5.8 cmol(+) kg^{-1} in the profile. For Kasargode area, it varies from 2.5 – 7.0 cmol(+) kg^{-1}.

Alexander and Durairaj (1968) studied the influence of soil reaction on certain soil properties and availability of major nutrients in Kerala soils. They found that the organic carbon, cation exchange capacity and lime requirement are negatively and available phosphorus is positively correlated with pH.

Nad *et al.* (1975) determined phosphorus-fixing capacity of the different major soil groups of India. Clay and free iron oxide content of the soils were the two dominant factors determining the phosphorus fixing capacity. The range of phosphorus fixation for laterite soil was 21-55% and red soil was 38- 85.2%.

It is a well established fact that the content and nature of exchangeable bases have a profound bearing on crop growth. In view of the dominant role played by cation exchange reaction and exchangeable bases in soil productivity and plant nutrition, it is desirable to take up such studies, which will be of considerable help in evolving suitable management practices.

Venugopal and Koshy (1976a) reported that the red soils of Kerala State were poor in exchangeable bases. The occurrence of bases decrease in the order of Ca>Mg>K>Na. In the laterite profiles calcium formed the predominant exchangeable base followed by magnesium.

The relationship between cation exchange capacity and different size fraction vary considerably, increasing from coarse sand to clay. The sandy soils recording the lowest and the black soils the highest value. With the exception of black, kari and some alluvial soils, all other soil groups gave very low value. Correlation between cation exchange capacity and clay for all the soil samples together was positive and highly significant. The relationship between organic matter and cation exchange capacity for all samples was positive but not significant (Venugopal and Koshy, 1976b).

Red, black, alluvial and laterite soils of Tamil Nadu were found to differ widely in their phosphorus fixing capacity, the highest values being for laterite and the lowest for alluvial soils .The phosphorus fixing capacity was found to be positively correlated with clay, total sesquioxide and total alumina.(Kothandaraman and Krishnamoorthty,1978)

An investigation was done in the lateritic soils in the ribbon valleys and corresponding uplands of Kerala and found that CEC of the soil ranges from 4.05-8.44 cmol(+) kg^{-1} (Hassan, 1980).

Venugopal (1980) found that iron content of soil profiles of Varkala toposequence range between 1.16 and 10.93% and aluminium content varied from 3.13-25.28%.

Singh and Kolarkar (1983) studied some physico-chemical properties of khadins in western Rajasthan and found that electrical conductivity (1:2) is below 1mmho cm^{-1} and cation exchange capacity ranges from 5.81-12.5 cmol(+) kg^{-1} in most of the soils.

Patil *et al.* (1987) studied some physical and chemical properties and micronutrient status of the bench terraced soils of Konkan and found pH ranges from 3.4-6.5 and electrical conductivity values were in the range of 0.011-0.38mmhos/cm.

Balasubramanian (1987) revealed that Ca and Mg are dominant exchangeable cations in Periyakulam farm soils while calcium and sodium are dominant in vertisols of Paramkudi and Srivilliputhur farm soils. Anionic concentration exceeded cationic concentration in all the three farms.

According to Brady (1996) phosphorus will be fixed in high quantity if the soil is rich in clay content and also if it contains high amount of iron and aluminium oxides.

Sreerekha (1995) reported high P-fixation capacity in the soils of BRS and maximum value recorded in the area was 96.9%.The range of pH of the soil was 5.13-6.69 and EC was 0.01-0.18 dS m^{-1}.

2.5 Soil Fertility Investigations

Soil fertility map is entirely different from soil map, which accounts only surface features. It is the important aspect with respect to plant nutrition. Fertility investigations undertaken under different scales and methods are reported extensively. The analytical technique used for individual parameters and soil fertility ratings for different crops would vary with laboratories and locations. Available literature on this aspect was scanned and relevant references are cited. Soil testing and fertilizer recommendations based on this are key factors in the balanced nutrition and increasing agricultural production.

Balasubramanian (1987) analysed the soils of Periyakulam, Paramkudi and Srivilliputhur Research Farms under Tamil Nadu Agricultural University for their pedological characterisation. The morphological, physical and chemical properties of red, alluvial and black cotton soils of the farms were determined for taxonomic and interpretative classification.

2.5.1 Major Nutrients

Insufficiency of an available nutrient in the soil lowers crop yields because plant needs are not met with. Deficiency or excess of a plant food nutrient is more serious, since it may also prevent other nutrients from being absorbed by plants. The quantity of available nutrients present in the soil is a major factor determining the use of fertilizers for harvesting the bumper crops and maintenance of soil fertility. The information generated from the investigation could be used as a guide for judicious application of fertilizers and soil amendments so that the lands are benefited and production gets an impetus.

Ramaswamy (1965) observed positive correlation between organic carbon and nitrogen, organic carbon and phosphorus and nitrogen and phosphorus in his study on fertility status of the soils of Fairy Falls in Kodaikanal Hills. The soils contain appreciable organic matter, which helps to retain moisture and improve the physical property of soils.

Hassan (1980) investigated the chemical characteristics of lateritic soils in the ribbon valleys and corresponding uplands of Kerala and found that both the soils were poor in organic carbon (0.79-2.33%) Also reported that both the soils were low in total and available P.

Potassium is one of the major limiting elements which are usually in short supply in major groups of soils. Soils of east Vidharba are assessed for their content of different forms of potassium. Effort was made to collect this information on major soil types of this region (Kene *et al.,* 1987).

Patil *et al.* (1987) studied some physical and chemical properties and micronutrient status of the bench terraced soils of Konkan and found that organic carbon varied from 0.81-2.79%. Available phosphorus ranges from 5.2-16.5 kg ha^{-1}. Available potash is 162.8-854.9 kg ha^{-1}.

Balasubramanian (1987) observed in his study that soils of Periyakulam Farm is acidic and that of Paramkudi and Srivilliputhur is tending alkaline region especially in subsurface level. Regarding major nutrients N and P were low to medium and K was high.

It was observed by Jacob (1987) that organic carbon and C:N ratio of laterite soils, from different parent materials, in Kerala are low. Highly significant positive correlation was observed between organic carbon and nitrogen.

Surface soils contained relatively more organic matter than subsurface layers. Wide differences in organic matter content in surface and subsurface soils of Bhandwa and Chandrapur districts were observed (Danke *et al.,* 1988).

Krishnakumar (1991) reported that organic carbon content of both upland and wetland soils of Edamalayar command area recorded low values. A steady decrease in organic carbon with depth was observed except for Konchira.

Deepa (1995) reported in the soils of RARS Pattambi, that the organic carbon content of all soils from both upland and lowland were low in the study area.

Sreerekha (1995) reported that the organic carbon content of the soils of BRS was very low (0.01-0.91%).

Bridgit (1999) found out that the phosphorus content in laterite soils was low (3.7 - 18.6 kg ha^{-1}).

2.5.2 Secondary Nutrients

Mathan *et al.* (1973) investigated the necessity of magnesium fertilization of Nilgiri Soils. During the field inspection for the preparation of soil fertility map of the district, magnesium was found to be deficient in soils of Thummanatty village Thettukkal areas in Oottakamand Block.

Patil *et al.* (1987) studied some physical and chemical properties and micronutrient status of the bench terraced soils of Konkan and found that the range for exchangeable calcium was 1.9-7.2 cmol(+) kg^{-1} and that of exchangeable magnesium was 2.0-7.75 cmol(+) kg^{-1} of soil.

The total reserves of CaO, MgO, K_2O and P_2O_5 are very low in laterite soils of Kerala and is mainly indicating the mineralogy of sand fraction dominated by quartz. (Jacob, 1987 and Krishnakumar, 1991).

It is reported that among the exchangeable bases, calcium was found to be the predominant cation. The exchangeable bases of the soils were in the order Ca>Mg>K>Na in uplands (Deepa, 1995).

2.5.3 Micronutrients

Micronutrient research has gained considerable importance recently as a consequence of multiple cropping with high yielding and fertilizer responsive crops. Heavy fertilization and intensive cropping have laid to nutritional imbalance particularly for the micronutrients, whose range of deficiency normally is very narrow. Obviously, a knowledge of soil types, its fertility status and soil conditions promoting deficiencies or sufficiencies may be proved to be a best approach for achieving reliable information about the need of the micronutrients.

Praseedom (1970) reported that the total copper content of the laterite soils of Kerala ranged from 9-78ppm with a mean value of 34.4ppm.

According to Fatehlal and Biswas (1973) the total micronutrient content of soil is directly related to the nature of parent material and degree of weathering. The pH, organic carbon, textures and type of clay minerals was reported to be markedly controlling the availability of micronutrients in the major soil groups of Rajasthan.

Rajagopal *et al.* (1973) studied the micronutrient status of hilly tracts of Tamil nadu. They reported that the organic carbon, being a very important factor influencing micronutrient availability, plays a role in the hilly area. In their study copper was practically deficient in almost all the soils.

Zinc has received considerable attention in India in recent years and showed that the khaira disease of paddy is due to deficiency of zinc. It is proved that in Kerala soils, it is possible that under the influence of intensive fertilizer use for higher crop production an imbalance or deficiency of some of the micronutrients, especially zinc, might eventually occur.

Total zinc in 14 typical soil profiles of Kerala varied from 3.5-72ppm, in the surface horizons 3.5-56 and in second horizon from 3.5-20.9ppm. Variation in available zinc is 0.3-7.7., 0.8-7.7 and 1.3-8ppm in 0-30cm, 30-60cm and 60-90cm depths respectively. Total zinc is not having any regular order in profile. Available zinc increases in the 10 out of 14 profiles downwards. Threshold value is 0.55ppm. Kerala soils may be generally considered to be with satisfactory level (Praseedom and Koshy, 1975).

The deficiencies of micronutrients are increasingly being felt in almost all parts of the Punjab state in the wake of intensive agricultural practices. Soil is the main reservoir for the supply of micronutrients to plants and it may vary from place to place due to soil inherent characteristics or due to other factors which may affect their availability. The available micronutrient status of some of the districts of the state has been reported (Mann *et al.,* 1977).

Malewar and Randhawa (1978) studied the distribution of Zn, Fe, Mn and Cu in Marathwada soils. From five well established soil types of the region it is found that total Zn, Mn, Cu and Fe in surface soils varied from 72 to 284 ppm, 642 to 1698 ppm, 64 to 264 ppm and 2.36 to 8.32 % respectively. Available Zn, Fe, Mn and Cu were in the range of 0.28- 4.4 ppm, 6.62-28.6 ppm, 13.2-65.2 ppm and 1.2-7.4 ppm respectively. Available Zn, Cu and Fe were positively correlated with organic carbon and Mn with soil pH.

Nayyar *et al.* (1982) studied the available Zn, Cu, Fe and Mn status of the soils of twelve blocks of Gurdaspur district in Punjab. Significant correlation was found with organic carbon with micronutrients

Patil *et al.* (1987) studied some physical and chemical properties and micronutrient status of the bench terraced soils of Konkan and found that available Fe content ranged from 10.2-19.2ppm, Mn from 4.8-200ppm and Cu from 0.1-1.2ppm.

Balasubramanian (1987) found that among the micronutrients, the predominance followed the order Fe>Mn>Zn>Cu in all the three farm soils under study. Fe and Mn were sufficient in Periyakulam farm and deficient in Paramkudi and Srivilliputhur farm soils. All the soils are below critical level status of available Zn.

MATERIALS AND METHODS

MATERIALS AND METHODS

3.1. General Description of Study Area

3. 1.1. Location and Extent

The main campus of the Kerala Agricultural University is situated in Madakkathara and Vellanikkara villages of Thrissur Taluk, Thrissur district, about 9 km from Thrissur on the Thrissur-Palakkad national highway (Fig.1). The total area of the campus is 384.56 ha. The inventory under report was carried out covering the eastern part of the campus comprising an area of 214ha which is divided into 25 blocks (Fig. 2). Laboratory experiments were conducted at Radiotracer Laboratory and at the Department of Soil Science and Agricultural Chemistry.

3.1.2. Physiography, Relief and Drainage

The physiography of the area is typical of a very old landscape, characterised by nearly level to gently sloping undulating plains with a few isolated hills formed due to the vertical movement of the tectonic process resulting in upheavals. The area has a dendritic pattern of drainage.

3.1.3. Climate

The climate of the area is humid tropical with an average annual rainfall of 3324 mm. and temperature ranging from 20.8 to 36'C. Weather data of Vellanikkara is presented in Appendix. I.

3.1.4. Geology

The major rock type observed in the area is granite gneiss. Most of the soils appear to have developed from the weathered material derived from these rock forms.

3.1.5 Natural Vegetation

Natural vegetation is of minor importance in the campus area. Very little land is kept out of the cultivation for long periods. Weeds comprising of both monocots and dicots are common in the area.

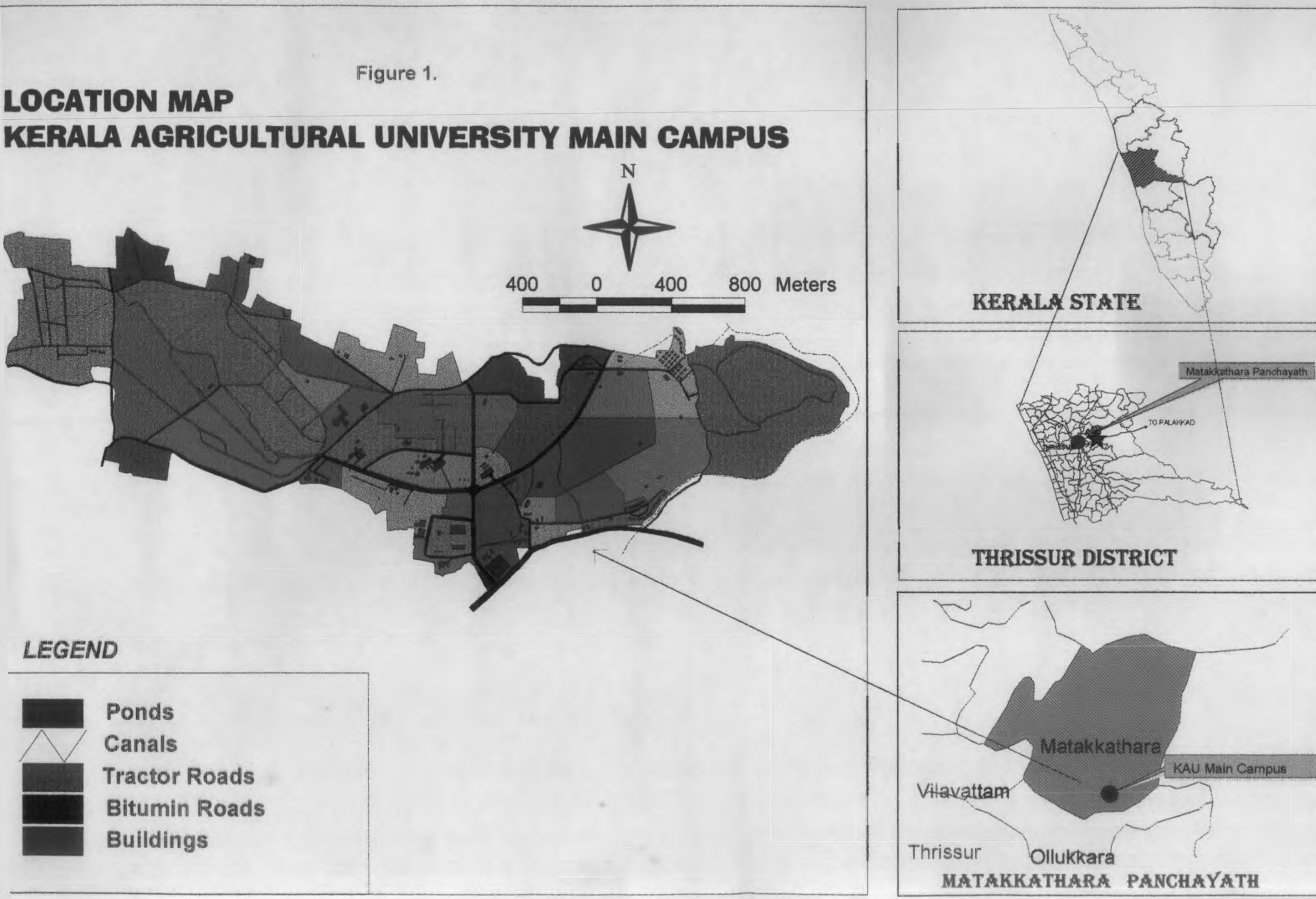
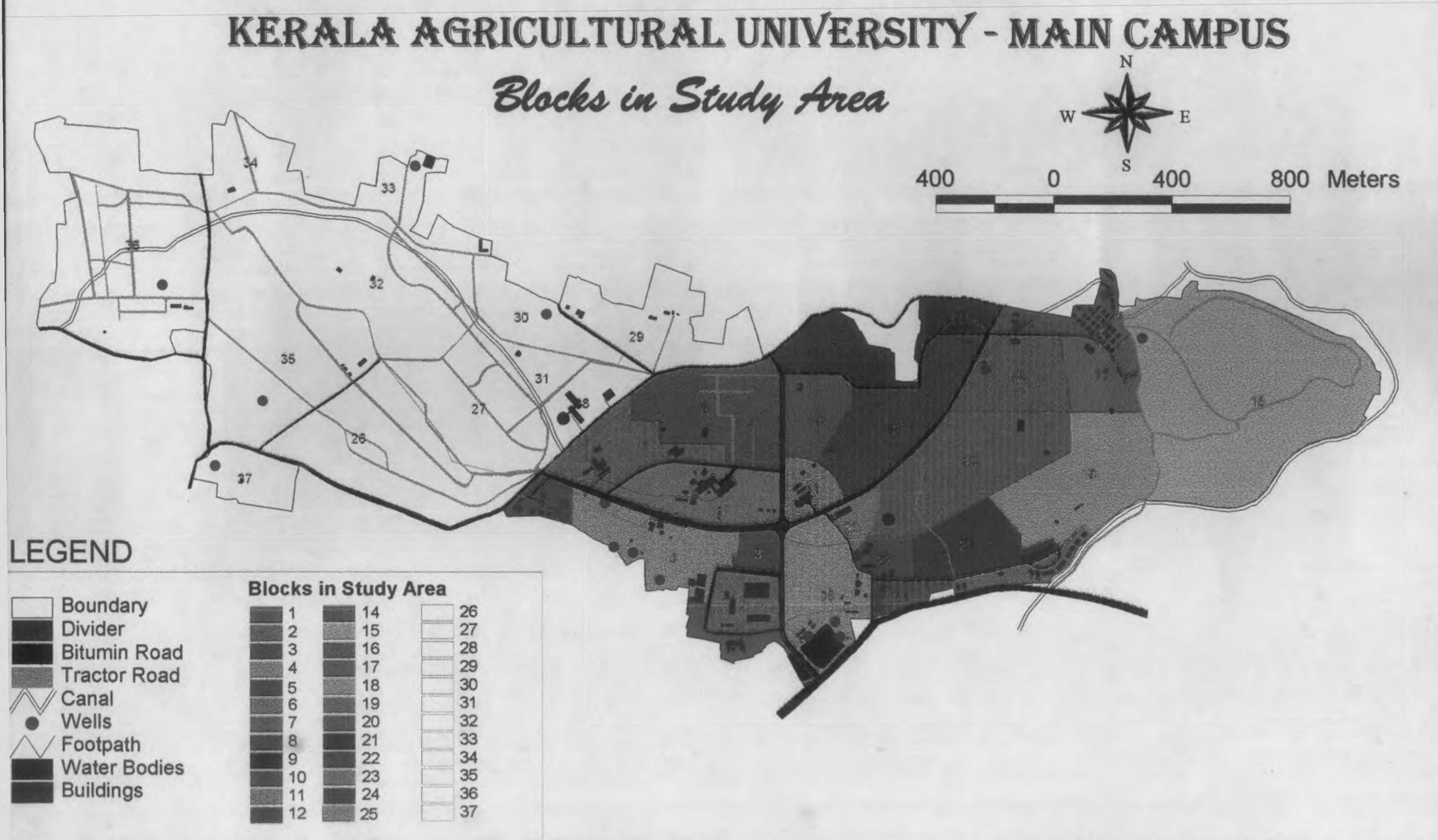


Figure 1.
LOCATION MAP
KERALA AGRICULTURAL UNIVERSITY MAIN CAMPUS
N
400 0 400 800 Meters
LEGEND
Ponds
Canals
Tractor Roads
Bitumin Roads
Buildings
KERALA STATE
Matakkathara Panchayath
TO PALAKKAD
THRISSUR DISTRICT
Matakkathara
KAU Main Campus
Vilavattam
Thrissur
Ollukkara
MATAKKATHARA PANCHAYATH

Figure 2.



KERALA AGRICULTURAL UNIVERSITY - MAIN CAMPUS
Blocks in Study Area
N
W
E
S
400 0 400 800 Meters
LEGEND
Boundary
Divider
Bitumin Road
Tractor Road
Canal
Wells
Footpath
Water Bodies
Buildings
Blocks in Study Area
1 2 3 4 5 6 7 8 9 10 11 12
14 15 16 17 18 19 20 21 22 23 24 25
26 27 28 29 30 31 32 33 34 35 36 37

3.1.6 Water Supply

Water received from the Peechi dam through the Peechi canal forms good sources of irrigation for the area. Dug wells at different points and natural ponds in a few locations form supplementary sources of water.

3.1.7 Land Use

The area comprises Kerala Agricultural University Head Quarters, College of Horticulture, College of Forestry, College of Co-operation, Banking and Management, Radiotracer Laboratory, Kitchen Garden, Herbal Garden,Vegetable seed production unit, Orchards, STCR Research Schemes and Nursery, Central Nursery, Forestry Experimental Plots, Rubber Estate, Botanical Garden and Water Management Project. A variety of crops are cultivated in this part of the campus (Table 2).

Table 2. Major crops grown in the study area

Sl. No.	**Block No.**	**Major crops of the study area**
1	1	Forest trees
2	2	Mango, Cashew, Guava, Jack, Minor fruits, Vegetables, Banana
3	4	Vegetables
4	5	Rubber, Forest trees
5	6	Coconut, Ornamental plants
6	7	Rubber
7	8	Mango, Guava, Jack, Sapota, Minor fruits
8	9	Coconut, Arecanut
9	10-13	Rubber, Cashew, Vegetables, Pine apple, Banana, Trees
10	15	Rubber, Teak, Mangium, Bamboo
11	16-18 & 20-23	Coconut, Rubber, Mango
12	19	Cashew
13	24	Vegetables
14	25	Banana, Vegetables, Ornamental plants

3.2. Base Resource Material

A soil map at a scale of 1:4000, which was prepared in 1976 by the Soil Survey Wing of the Dept. of Agriculture (Soil Survey Wing, 1976) was used as the base resource material. Three soil series namely Vellanikkara I, Vellanikkara II and Vellanikkara III were delineated in the said soil map. Series descriptions as provided in the original report are given in AppendixII. The soil series were tentatively distributed into 12, 14 and 12 phases respectively for the current investigation on soil fertility. The various phases and their tentative description are provided in Table 3.

Table 3. Phase distribution in the campus and the number of occurrences of the map units

Vellanikkara I			Vellanikkara II			Vellanikkara III		
Phase No	Soil phase	Occurrence	Phase No	Soil phase	Occurrence	Phase No	Soil phase	Occurrence
1	Vka I - cl - d5 B - el	11	**13**	Vka II - cl - d4 B - el	20	**27**	Vka III - cl - d5 B – el	8
2	Vka I - Sicl - d5 B - el	6	**14**	Vka II - Scl - d4 B - el	2	**28**	Vka III – Sicl - d5 B – el	2
3	Vka I - Scl - d5 B - el	1	**15**	Vka II - Sicl - d4 B - el	3	**29**	Vka III - cl - d4 B – el	1
4	Vka I - Sicl - d5 C - el	4	**16**	Vka II - cl - d4 C - el	14	**30**	Vka III - cl - d5 C – el	6
5	Vka I - Scl - d5 B - el	0	**17**	Vka II - Scl - d4 C - el	3	**31**	Vka III – Sicl - d5 C – el	3
6	Vka I - cl - d5 C - el	15	**18**	Vka II - Sicl - d4 C - el	3	**32**	Vka III - cl - d5 C – el	8
7	Vka I - cl - d5 D - el	4	**19**	Vka II - cl - d4 D - el	14	**33**	Vka III - cl - d5 D – el	7
8	Vka I - Sicl - d5 D - el	3	**20**	Vka II - Scl - d4 D - el	2	**34**	Vka III - cl - d5 D – e2	0
9	Vka I - cl - d5 E - e2	3	**21**	Vka II - Sicl - d4 D - el	3	**35**	Vka III – Sicl - d4 D – el	2
10	Vka I - Sicl - d5 E - e2	1	**22**	Vka II - cl - d4 E - e2	8	**36**	Vka III – Sicl - d5 E – e2	2
11	Vka I - cl - d5 F - e2	3	**23**	Vka II - Sicl - d4 E - e2	1	**37**	Vka III - cl - d4 E – e2	3
12	Vka I - cl - d5 G - e2	2	**24**	Vka II - cl - d4 F - e2	4	**38**	Vka III - cl - d5 F – e2	1
			25	Vka II - Sicl - d4 F - e2	1			
			26	Vka II - cl - d4 G - e2	1			

3.3. Preparation of Base Map

A chain survey document of the main campus was referred for preparation of individual block maps of the campus. The block maps were then mosaiced to prepare the whole campus map at 1:2000 scale. Eighty meter grids were then laid on the base map measuring 1cm = 20 metres i.e. 4cm grids. Ammonia prints of the base map were used for field traversing and collection of samples. Sampling sites were located at 80m x 80m spacing using measuring tapes and rods.

3.4. Soil Sample Collection

Soil samples were collected from selected sites identified from the base map. Area occupied by buildings and roads were avoided. A 40cm deep pit was dug out at each sample site. Surface samples from 0-20cm depth and subsurface samples from 20-40cm depth were collected. About 1.5kg soil sample each, after uniform mixing, was taken in a polythene bag and labeled for transportation to the laboratory. Details of the soil samples collected from different blocks are given in Table 4.

Table 4. Details of blocks and soil samples

Sl. No.	*Block No.*	*Block area (ha)*	*No. of sample sites*	*No. of soil samples*
1.	1	25.68	6	12
2.	2		4	8
3.	3		-	-
4.	4		11	22
5.	5		4	8
6.	6	10.3	13	26
7.	7	23.45	9	18
8.	8		15	30
9.	9	9.38	11	22
10.	10-13	23.17	22	44
11.	14	4.21	-	-
12.	15	44.35	40	80
13.	16-18 & 20-23	58.68	46	92
14.	19	4.85	5	10
15.	24		3	6
16.	25	12.38	9	18
17.				
Total		214	198	396

3.5. Sample Processing

The soil samples were transported in jeep loads to the Centre for Land Resources Research and Management, located in the Radiotracer Laboratory of College of Horticulture. Samples were then air dried, powdered gently. Weighed samples were sieved through a 2mm sieve. Coarse fractions above 2mm were discarded after careful weighing in an analytical balance. Fine earth fractions were packed in plastic jars and arranged serially in sample racks for laboratory investigations.

3.6. Laboratory Investigations

3.6.1. Mechanical Analysis

Fine-earth to gravel ratio was determined on weight basis for each sample using an analytical balance. Sand, silt and clay fractions of the samples (surface and subsurface) were estimated by the International Pipette Method. Textural triangle of USDA was referred to determine textural class of each sample (Piper, 1966; Gee and Bauder as described by Page, 1986)

3.6.2. Chemical properties

Soil fertility parameters covering various electro-chemical and chemical constituents of the soil were analysed as per published procedures.

3.6.2.1. Soil pH

The pH of the soil was determined by 1:2.5 soil water suspension using combined electrode in a μ pH System 362 of Systronics (Jackson ,1973.)

3.6.2.2. Electrical conductivity

Electrical conductivity was determined in the supernatant liquid of the soil water suspension (1:2.5) with the help of Systronics conductivity meter 304 (Jackson, 1973).

3.6.2.3. Organic carbon

Organic carbon of the soil was determined by wet digestion method of Walkley and Black (Walkley and Black, 1934).

3.6.2.4. Available Phosphorus

Available phosphorus in the soil samples was determined by extracting with Bray No.1 reagent and estimating colourimetrically by vanadomolybdic-ascorbic acid blue colour method using Spectronic 20 spectrophotometer (Bray and Kurtz, 1945).

3.6.2.5. Available Potassium and Sodium

Available potassium and sodium were extracted with neutral-1normal ammonium acetate solution. Contents of respective elements in the extract were determined by flame photometry using ELICO flame photometer (Jackson,1973).

3.6.2.6. Available Calcium and Magnesium

Available calcium and magnesium were determined from the above said ammonium acetate extract using Perkin Elmer atomic absorption spectro-photometer.

3.6.2.7. Cation Exchange Capacity

The cation exchange capacity was estimated by the method proposed by Hendershot and Duquette (1986). The exchangeable cations (Ca, Mg, Na, K, Al, Fe, and Mn) present in the exchange sites in soil were replaced by 0.1M $BaCl_2$ solution and the thus extracted cations were estimated.

Four grams of the soil sample was taken in a conical flask and 40ml of 0.1M $BaCl_2$ solution was added. The sample was then shaken for 2hrs and filtered through Whatman No. 42 filter paper. Filtrate was used for aspiration to a Perkin Elmer Atomic Absorption Spectrophotometer for determination of Ca, Mg, Fe and Mn. Sodium and potassium were determined with the help of Elico flame photometer. Aluminium was estimated colorimetrically using aluminon (Hsu, 1963; Jayman & Sivasubramaniam, 1974 as described by Page, 1982). The sum of the exchangeable cations expressed in cmol(p+) kg^{-1} soil was recorded as CEC of the soil

3.6.2.8. Lime Requirement

Five grams of dried soil was weighed into a beaker. 5 ml of distilled water was added and the same was mixed thoroughly. Then 20 ml of SMP (Shoemaker, McClean and Pratt) buffer solution was added to the soil water suspension. The suspension was stirred well and the pH was recorded in μ pH system 362 (Shoemaker et al. 1962). After getting the buffered pH of soils, quantity of lime in terms of pure calcium carbonate required to bring the soil pH to neutral level was calculated.

3.6.2.9. P- Fixing Capacity

P- fixing capacity of the soil was determined by incubating 2 grams each of soil samples for 96hrs with various concentrations of phosphorus solutions prepared out of potassium di-hydrogen ortho phosphate. Various P concentrations used were 0ppm, 25ppm, 50ppm, 75ppm, 100ppm, 125ppm, 250ppm, 375ppm and 500ppm. One milli litre of the P solution was added to 2g of the soil and then it was kept for incubation. After incubation the labile phosphorus was extracted using Bray No.1 and was estimated by vanadomolybdic-ascorbic acid blue colour method.

3.6.2.10. Available Micronutrients (Fe, Mn, Cu and Zn) in soil

Available micronutrients in both surface and subsurface samples were extracted using 0.1M HCl (Sims and Johnson, 1991). Four grams of soil with 40 ml of 0.1M HCl was shaken for 5 minutes. It was filtered through Whatman No. 1 filter paper and the filtrate was collected and analysed for Fe, Mn, Cu and Zn using Perkin Elmer Atomic Absorption Spectrophotometer.

3.6.2.11. Extractable Al / Exchangeable Al

Exchangeable/extractable aluminium was determined from the 0.1M $BaCl_2$ extract prepared as described above. Exactly 2ml of the extract was taken in a 25ml volumetric flask and the pH was corrected between 2and 3 using HCl. The volume was then made up to 5ml. Then 1ml ascorbic acid was added to it and was heated for half an hour at temperature 80-85°C. The solution was then cooled, approximately 12ml of distilled water was added and 5ml aluminon acetate buffer was added for colour development. After 2 hours reading was taken in spectronic 20 spectrophotometer at 530nm (Barnhisel and Bertch as described by Page 1982).

3.7 Data Processing and Statistical Analysis

Data generated through physical and chemical analysis of the samples were tablulated and organised for information generation. Out of the 38 soil phases identified in the base map, 23 are covered in the present study. Phase level mean tables of various soil physical and chemical parameters are provided in the ensuing text. Original data generated are provided in AppendixIII.

Multiple regression analyses were carried out to study interaction of plant nutrients in the soil, using MSTAT software in a personal computer(Panse and Sukhatme,1978).

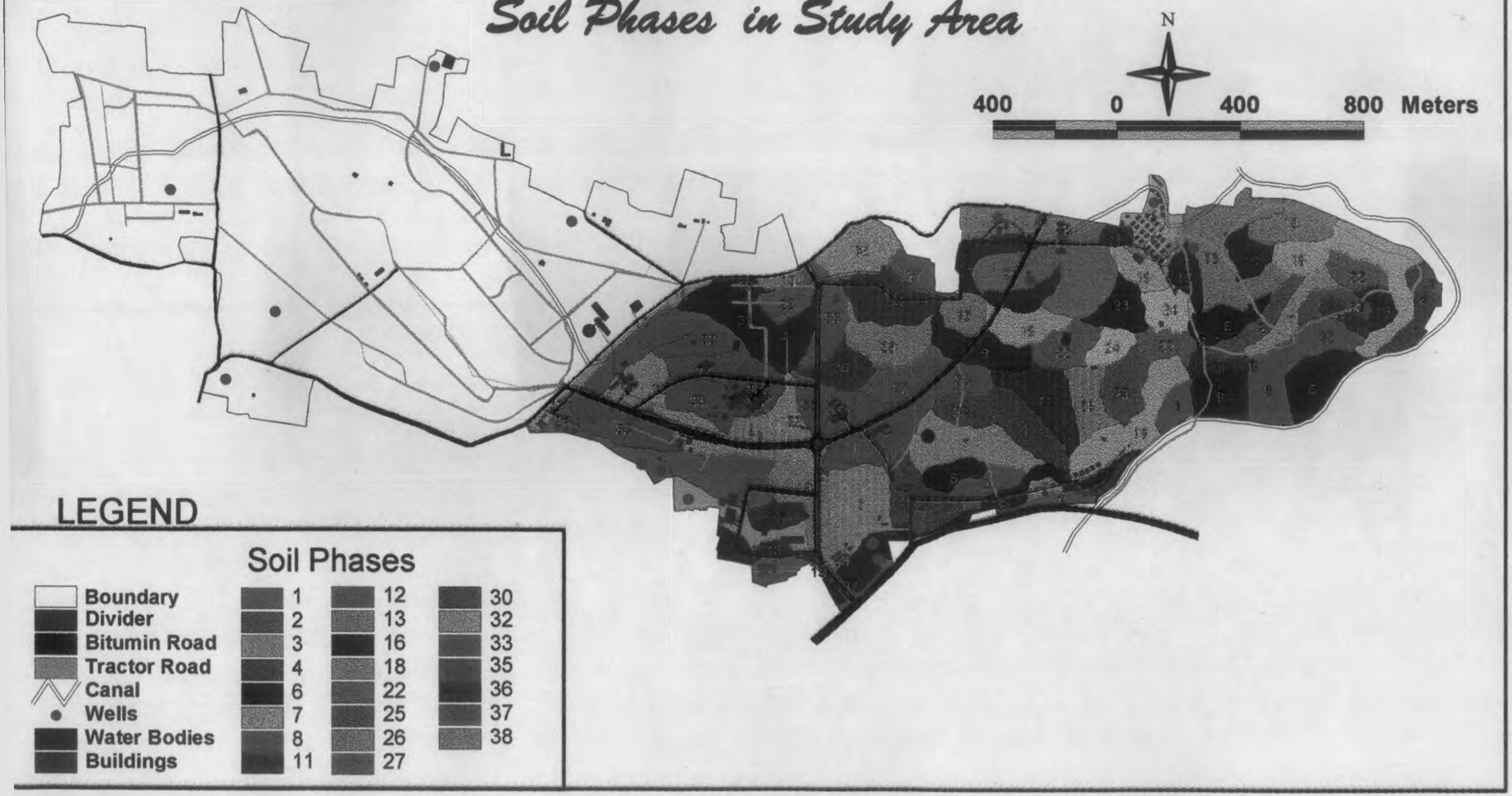
3.8 Soil Fertility Mapping

The base map of the campus, prepared out of chain survey at 1: 2000 scale was scanned through an A_0 scanner and the raster image was digitised on-screen using Auto CAD Release 14. The original soil map of the campus was also computerised in the same way. Altogether 175 polygons covering 38 phases of the three soil series were digitised. Out of them, 86 polygons covering 23 phases occur in the Eastern part of the campus (Fig. 3). The digitised maps were converted to DXF format and exported to PC ARC INFO software, which is a popular software used for developing Geographic Information Systems (GIS). The files were then subjected to topology building and the same were converted to PC ARC INFO coverages.

Figure 3.

KERALA AGRICULTURAL UNIVERSITY - MAIN CAMPUS

Soil Phases in Study Area



Phase level mode data on various soil characteristics generated during the study were attached to respective polygons in the PC ARC INFO coverages. Thematic maps were generated using GIS techniques.

3.9 Fertility Capability Classification

Among the various approaches in providing information on the potential of the soil for crop production, soil fertility capability classification is one which lays emphasis on the components of soil fertility within 50 cm layers from the surface. An attempt has been made to use this concept for the soils of the main campus.

The modified Fertility Capability Classification (FCC) system proposed by Sanchez et. al. (1982) focuses on some of the essential fertility parameters with respect to soil and crop management. Properties such as surface soil texture or pH determine crop choices as well as fertilizer management. However these are not specifically expressed in taxonomic classification of the soils.

The FCC system consists of three categorical levels: Type (soil texture), Substrata Type (subsoil texture) and several "modifiers" that are generally relevant to crop management alternatives. The modifiers proposed in the original system and the criteria used for identifying limitations in the current study are provided in Table 5.

Some of the modifiers are not pertinent to the current study. For example, gleyness is not applicable since the soils under investigation are never submerged for long periods. The data generated thorough field traversing and chemical analysis of soil samples were compiled to prepare a working table for the FCC classification. Type, Substrata Type and Modifiers of the FCC system were identified for different soil phases in the Eastern part of the campus and the final FCC unit for each phase was derived as per notations provided in Table 5.

Table 5. Modifiers and the criteria used in Fertility Capability Classification

No	Category	Unit	Criteria
I	TYPE	S, L, C, O	Texture of plow-layer or surface 20 cm whichever is shallower
II	SUBSTRATA TYPE	S, L, C, R	Texture of subsoil*
III	MODIFIERS		
1	Gravel	"	> 35% gravel or coarser particles (>2mm)
2	Moisture regime	d	Ustic, aridic or xeric (Ustic in this case)
3	Low CEC ▸	e	CEC <4 me/100g by Σ of cations + KCl-extractable Al (effective CEC)
4	Al toxicity	a	> 60% Al saturation of the effective CEC within 50cm of the soil surface
5	Acidity	h	10-60% Al saturation of effective CEC within 50 cm of soil surface
6	High P fixation by iron	i	> 50% P fixing capacity as estimated in the present study
7	Low K reserves	k	Exchangeable K < 0.2me/100g
8	Natric	n	/15% Na saturation of CEC within 50 cm
9	Salinity	s	/ 4 mmhos/cm of electrical conductivity
10	Basic Reaction	b	Free CaCO3 within 50 cm of soil surface
11	X-ray amorphous	x	Not studied in the current work
12	Gley	g	Soil saturated with water for >60 days in most years
13	Cat clay	c	Not applicable in the area under study
14	Vertisol	v	Not applicable in the soils under study
15	Slope	%	> 3% slope

S-Sandy, L-Loamy, C-Clayey, O-Organic, R-Rock or other root restricting layer

*- Used only if there is a marked textural change or if a hard root-restricting layer is found

▸ - Applies only to plow layer or surface 20 cm, whichever is shallower

RESULTS

RESULTS

The study area, *namely*, eastern part of the main campus comprised of 23 phases as per the base map used (Soil survey staff, 1976). One hundred and ninety eight samples each of surface (0-20 cm) and subsurface (20-40 cm) layers collected from the grid points ($80m^2$ grid size) of the study area, were analysed for different physical, chemical and electrochemical properties as detailed in Materials and methods. The data thus generated were grouped according to the different phases (23 phases) from which the samples were collected. These results are presented here under different headings. The data on individual samples are given in Appendix III, where as the phase wise mean, range and mode values are presented in tables.

4.1. Gravelliness of the soil samples

Phase wise comparison of gravel percentage and fine earth percentage was done and presented in table 6. In the surface samples maximum gravel was found in phase12, the values ranging from 70-90% (mean 81.5%). Average minimum gravel percentage was recorded in phase18 (42.5%) with a range of 40 to 50 per cent. However the minimum value for percentage gravel was recorded as 22 in a sample from phase 35. In 13 phases out of the total 23 phases the mean as well as the mode values were above 60 per cent.

In comparison to the surface samples, the gravelliness of sub surface samples was generally low. The average maximum percentage of gravel was in phase 26 (54.05%). Gravel percentage in the sub surface soil ranged from a minimum of 18% in phase 4 to a maximum of 69.6% in phase 7.

. Fine earth percentage also varied accordingly. In the surface layer the maximum mean value for fine earth percentage was recorded in phase18 (57.5%). Fine earth percentage was comparatively higher in sub surface layer than surface layer, the highest being in a sample from phase 4(82%).

Table 6. Gravelliness of soil samples

No.	Soil Phase		Surface		Sub - surface	
			Gravel (%)	Fine earth (%)	Gravel (%)	Fine earth (%)
1	1	Mean	65.89	34.11	44.57	55.43
		Range	49.00 – 70.00	30.00 – 51.00	28.00 – 60.86	39.14 – 72.00
		Mode	70.00	30.00	44.57	55.43
2	2	mean	52.75	47.25	32.16	41.72
		Range	45.00 – 64.00	36.00 – 55.00	19.33 – 48.66	51.34 - 80.67
		Mode	52.75	47.25	32.16	41.72
3	3	Mean	57.00	43.00	43.97	56.03
		Range	45.00 – 68.00	32.00 – 55.00	27.86 – 62.00	38.00 - 72.14
		Mode	57.00	43.00	43.97	56.03
4	4	Mean	63.38	36.62	44.11	55.89
		Range	41.00 – 84.00	16.00 – 59.00	18.00 - 65.73	34.27 – 82.00
		Mode	60.00	40.00	44.11	55.89
5	6	Mean	50.00	50.00	25.65	74.35
		Range	40.00 – 60.00	40.00 – 60.00	25.30 – 26.00	74.00 –74.70
		Mode	50.00	50.00	25.65	74.35
6	7	Mean	70.91	29.09	46.03	53.97
		Range	50.00 – 90.00	10.00 –50.00	30.00 –69.60	30.40 –70.00
		Mode	70.91	29.09	46.03	53.97
7	8	Mean	68.70	31.30	40.07	59.93
		Range	59.00 – 80.00	20.00 – 41.00	28.00 - 66.63	33.37 – 72.00
		Mode	60.00	40.00	32.66	67.34
8	11	Mean	66.33	33.67	47.20	52.80
		Range	61.00 – 74.00	26.00 – 39.00	33.06 - 63.26	36.74 - 66.94
		Mode	61.00	39.00	47.20	52.80
9	12	Mean	81.50	18.50	45.43	54.57
		Range	70.00 – 90.00	10.00 –30.00	34.40 –58.4	41.60 –65.6
		Mode	81.50	18.50	45.43	54.57
10	13	Mean	62.40	37.60	32.77	67.23
		Range	47.00– 86.00	14.00– 53.00	21.30 –48.66	51.34 –78.70
		Mode	54.00	46.00	32.00	68.00
11	16	Mean	60.67	39.33	48.42	51.58
		Range	29.00– 84.00	16.00 – 71.00	21.33 –66.20	33.80 –78.67
		Mode	64.00	36.00	48.42	51.58
12	18	Mean	42.50	57.50	43.39	56.61
		Range	40.00 – 50.00	50.00– 60.00	34.33 –53.3	46.7 –65.67
		Mode	40.00	60.00	43.39	56.61
13	22	Mean	59.83	40.17	46.78	53.23
		Range	48.00 – 87.00	13.00 – 52.00	24.66 –63.40	36.60 –75.34
		Mode	50.00	50.00	46.78	53.23
14	25	Mean	49.20	50.80	48.54	51.46
		Range	48.00 – 50.00	50.00 – 52.00	22.20 –63.86	36.14 - 77.80
		Mode	50.00	50.00	48.54	51.46
15	26	Mean	68.20	31.80	54.05	45.95
		Range	49.00– 85.00	15.00 – 51.00	44.00- 66.00	34.00 – 56.00
		Mode	68.20	31.80	54.05	45.95

(Continued............)

Table 6. Gravelliness of soil samples (............Continued)

No.	Soil Phase		Surface		Subsurface	
			Gravel (%)	Fine earth (%)	Gravel (%)	Fine earth (%)
16	27	Mean	61.27	38.73	40.88	59.12
		Range	48.00– 79.00	21.00 – 52.00	26.66 - 52.66	47.34 - 73.34
		Mode	58.00	42.00	42.66	57.34
17	30	Mean	56.60	43.40	38.00	62.00
		Range	46.00 – 67.00	33.00 – 54.00	32.26 - 45.93	54.07 - 67.74
		Mode	59.00	41.00	38.00	62.00
18	32	Mean	58.50	41.50	42.56	57.44
		Range	45.00 – 82.00	18.00 –55.00	28.00 –55.30	44.70 –72.00
		Mode	61.00	39.00	55.30	44.70
19	33	Mean	61.75	38.25	39.18	60.82
		Range	40.00 – 79.00	21.00 – 60.00	20.00 –50.00	50.00 –80.00
		Mode	70.00	30.00	46.00	54.00
20	35	Mean	53.00	47.00	32.79	67.21
		Range	22.00 – 71.00	29.00 –78.00	27.30 –42.66	57.34 - 72.70
		Mode	53.00	47.00	32.00	68.00
21	36	Mean	62.25	37.75	39.67	60.33
		Range	44.00 – 84.00	16.00 –56.00	20.00 –54.4	45.60 –80.00
		Mode	61.00	39.00	39.67	60.33
22	37	Mean	62.00	38.00	34.27	65.73
		Range	56.00 – 74.00	26.00 –44.00	20.00 –46.00	54.00 –80.00
		Mode	63.00	37.00	34.27	65.73
23	38	Mean	58.56	41.44	41.34	58.66
		Range	49.00 – 64.00	36.00 –51.00	29.33 - 50.66	49.34 - 70.67
		Mode	64.00	36.00	44.00	56.00

4.2.Textural class

Textural classes were identified using the sand, silt, and clay percentage obtained from mechanical analysis. The data are given in Table 7. Twelve phases out of the 23 were clay loam in texture with respect to surface samples while 12 were clay loam in subsurface samples indicating little variations in the textural classes of surface and subsurface soils. There was one sandy loam class in surface soil, and the corresponding subsurface soil texture was sandy clay loam. Sandy loam texture was absent in subsurface samples. The remaining phases were clay loam or sandy clay loam in texture. In the surface samples, highest sand percentage was observed in the phase 1 (57.75%) where as the minimum was noted in phase 3(25.63%). Silt percentage was ranging across the phases from 13.18-30.56%, the minimum in phase 6 and the maximum recorded in phase 1. The highest clay content was recorded in the phase 3 (44.27%) and the lowest clay percentage was in phase 1(11.69%).

Table 7. Textural variations in the study area

No	Soil Phase		Surface				Sub-surface			
			sand (%)	Silt (%)	clay (%)	Textural class	sand (%)	silt (%)	clay (%)	Textural class
1	1	Mean	57.75	30.56	11.69	Sandy Loam	50.40	28.72	20.88	Sandy Clay Loam
		Range	N.A	N.A	N.A		N.A	N.A	N.A	
		Mode	N.A	N.A	N.A		N.A	N.A	N.A	
2	2	mean	43.22	29.99	26.79	Loam	41.72	31.40	26.88	Loam
		Range	N.A	N.A	N.A		N.A	N.A	N.A	
		Mode	N.A	N.A	N.A		N.A	N.A	N.A	
3	3	Mean	25.63	30.10	44.27	Loam	26.46	29.64	43.90	Loam
		Range	N.A	N.A	N.A		N.A	N.A	N.A	
		Mode	N.A	N.A	N.A		N.A	N.A	N.A	
4	4	Mean	41.10	25.71	33.19	Clay Loam	39.91	24.98	35.11	Clay Loam
		Range	N.A	N.A	N.A		N.A	N.A	N.A	
		Mode	N.A	N.A	N.A		N.A	N.A	N.A	
5	6	Mean	54.92	16.32	28.75		50.05	20.14	29.81	
		Range	N.A	N.A	N.A	Sandy clay Loam	N.A	N.A	N.A	Sandy clay Loam
		Mode	N.A	N.A	N.A		N.A	N.A	N.A	
6	7	Mean	45.20	22.65	32.15	Clay Loam	41.20	24.26	34.54	Clay Loam
		Range	N.A	N.A	N.A		N.A	N.A	N.A	
		Mode	N.A	N.A	N.A		N.A	N.A	N.A	
7	8	Mean	43.61	22.70	33.69	Clay Loam	41.28	24.10	34.62	Clay Loam
		Range	N.A	N.A	N.A		N.A	N.A	N.A	
		Mode	N.A	N.A	N.A		N.A	N.A	N.A	
8	11	Mean	40.10	23.70	36.20	Clay Loam	39.90	24.42	35.68	Clay Loam
		Range	N.A	N.A	N.A		N.A	N.A	N.A	
		Mode	N.A	N.A	N.A		N.A	N.A	N.A	
9	12	Mean	41.34	21.84	36.82	Clay Loam	40.64	22.60	36.76	Clay Loam
		Range	N.A	N.A	N.A		N.A	N.A	N.A	
		Mode	N.A	N.A	N.A		N.A	N.A	N.A	
10	13	Mean	45.13	19.40	35.47	Clay Loam	46.39	20.61	33.00	Clay Loam
		Range	N.A	N.A	N.A		N.A	N.A	N.A	
		Mode	N.A	N.A	N.A		N.A	N.A	N.A	
11	16	Mean	39.84	27.49	32.67	Clay Loam	37.65	26.20	36.15	Clay Loam
		Range	N.A	N.A	N.A		N.A	N.A	N.A	
		Mode	N.A	N.A	N.A		N.A	N.A	N.A	

N.A- Not Applicable

Table 7. Textural variations in the study area (.....Continued)

No	Soil Phase		Surface				Sub-surface			
			Sand (%)	Silt (%)	clay (%)	Textural class	sand (%)	silt (%)	clay (%)	Textural class
12	18	Mean	46.16	16.40	37.44	Sandy Clay	50.88	17.82	31.30	Sandy Clay Loam
		Range	N.A	N.A	N.A		N.A	N.A	N.A	
		Mode	N.A	N.A	N.A		N.A	N.A	N.A	
13	22	Mean	45.00	23.40	31.60	Clay Loam	43.80	24.80	31.40	
		Range	N.A	N.A	N.A		N.A	N.A	N.A	Clay Loam
		Mode	N.A	N.A	N.A		N.A	N.A	N.A	
14	25	Mean	30.51	30.40	39.09	Clay Loam	31.20	29.81	38.99	Clay Loam
		Range	N.A	N.A	N.A		N.A	N.A	N.A	
		Mode	N.A	N.A	N.A		N.A	N.A	N.A	
15	26	Mean	46.95	25.34	27.71	Sandy Clay Loam	44.32	25.70	29.98	Clay Loam
		Range	N.A	N.A	N.A		N.A	N.A	N.A	
		Mode	N.A	N.A	N.A		N.A	N.A	N.A	
16	27	Mean	30.65	26.60	42.76	Clay	29.10	26.36	44.55	Clay
		Range	N.A	N.A	N.A		N.A	N.A	N.A	
		Mode	N.A	N.A	N.A		N.A	N.A	N.A	
17	30	Mean	43.40	23.28	33.32	Clay Loam	41.97	22.84	35.19	Clay Loam
		Range	N.A	N.A	N.A		N.A	N.A	N.A	
		Mode	N.A	N.A	N.A		N.A	N.A	N.A	
18	32	Mean	39.80	22.40	37.80	Clay Loam	37.60	21.80	40.60	Clay
		Range	N.A	N.A	N.A		N.A	N.A	N.A	
		Mode	N.A	N.A	N.A		N.A	N.A	N.A	
19	33	Mean	45.40	20.70	33.90	Sandy Clay Loam	46.45	21.90	31.65	Sandy Clay Loam
		Range	N.A	N.A	N.A		N.A	N.A	N.A	
		Mode	N.A	N.A	N.A		N.A	N.A	N.A	
20	35	Mean	46.20	19.60	34.20	Sandy Clay Loam	48.55	19.70	31.75	Sandy Clay Loam
		Range	N.A	N.A	N.A		N.A	N.A	N.A	
		Mode	N.A	N.A	N.A		N.A	N.A	N.A	
21	36	Mean	40.70	30.10	29.20	Clay Loam	42.10	29.80	28.10	Clay Loam
		Range	N.A	N.A	N.A		N.A	N.A	N.A	
		Mode	N.A	N.A	N.A		N.A	N.A	N.A	
22	37	Mean	46.90	19.10	34.00	Sandy Clay Loam	48.90	19.30	31.80	Sandy Clay Loam
		Range	N.A	N.A	N.A		N.A	N.A	N.A	
		Mode	N.A	N.A	N.A		N.A	N.A	N.A	
23	38	Mean	41.80	25.10	33.10	Loam	43.50	23.90	32.60	Loam
		Range	N.A	N.A	N.A		N.A	N.A	N.A	
		Mode	N.A	N.A	N.A		N.A	N.A	N.A	

The data on particle size distribution of subsurface soil showed that the highest content of sand was in phase 6 (57.7%) and the same was lowest in phase 3(26.46). The silt content of phase 2 recorded the highest value (31.4%) while the phase 6 recorded the minimum value (13.45%). The clay content was maximum in phase 32(40.6%) and the same was minimum in phase 1(20.8%). Percentage of sand was lower in sub surface layer than surface.

4.3. Electro Chemical Properties

The data on soil reaction, electrical conductivity, buffer pH and lime requirement of the soil is given in Table 8. Here the lime requirement is the actual $CaCO_3$ equivalent in tonnes per hectare required to bring the soil pH to 7.

All the soils were acidic in nature in 1:2.5 soil water suspension. The pH of the surface soil ranged from 4.5-6.5 and that of the sub surface soil ranged from 4.2-6.9. Any relation or trend was hardly observed between surface and sub surface soils in pH. In surface soil, the lowest pH was noticed in phases 22 and 36(4.5). In the case of sub surface soil lowest pH was noticed in phase 26(4.2).

The electrical conductivity (EC) values were low in most of the soil samples. Among the surface soil samples, the lowest EC was recorded in phase 11(0.008 dS m^{-1}). The EC of the sub surface soils were generally lower than surface soils and the lowest value was recorded in phase 1(0.005 dS m^{-1}). The electrical conductivity was highest in phases 13 and 16 (0.990 dS m^{-1}) in surface soil and it was highest in phases 13, 16 and 18 (0.880 dS m^{-1}) in subsurface soils.

Table 8. Electro chemical Properties

No.	Soil Phase		Surface				Sub - surface			
			pH	EC dS/m	Buffer pH	Lime R. (t ha^{-1})	pH	EC dS/m	Buffer pH	Lime R. (t ha^{-1})
1	1	Mean	5.1	0.040	6.3	10.1	5.1	0.030	6.3	10.1
		Range	4.5 – 6.4	0.009 – 0.110	5.8 – 6.5	7.0 – 18.6	4.6 – 5.6	0.005 – 0.088	6.1 – 6.5	7.0 – 13.4
		Mode	4.8	0.020	6.3	10.5	5.1	0.010	6.4	9.0
2	2	mean	4.9	0.080	6.0	14.8	4.9	0.070	6.2	12.7
		Range	4.6 – 5.3	0.011 – 0.110	5.6 – 6.2	12.1 – 21.8	4.5 – 5.3	0.033 – 0.110	6.1 – 6.2	12.1 – 13.4
		Mode	4.9	0.110	6.2	12.1	4.9	0.070	6.2	12.1
3	3	Mean	5.1	0.040	5.9	17.2	5.2	0.020	5.7	19.2
		Range	4.8 – 5.2	0.011 – 0.077	5.7 – 6.2	12.1 – 20.1	4.8 – 5.8	0.011 – 0.033	5.5 – 6.1	13.4 – 23.3
		Mode	5.1	0.040	5.7	20.1	5.2	0.010	5.8	5.7
4	4	Mean	5.2	0.060	6.1	14.5	5.2	0.040	6.0	14.8
		Range	4.9 – 5.6	0.011 – 0.110	5.5 – 6.4	9.0 – 23.3	4.9 – 5.9	0.011 – 0.110	5.7 – 6.4	9.0 – 20.1
		Mode	5.6	0.010	6.4	9.0	5.2	0.030	6.4	9.0
5	6	Mean	5.1	0.020	5.9	16.9	4.8	0.020	5.7	19.3
		Range	4.8 – 5.4	0.022 – 0.022	5.8 – 6.0	15.2 – 18.6	4.7 – 4.9	0.011 – 0.022	5.7 – 5.8	18.6 – 20.1
		Mode	5.1	0.020	5.9	6.9	4.8	0.020	5.7	5.7
6	7	Mean	4.9	0.060	6.1	13.5	5.0	0.040	6.0	14.6
		Range	4.6 – 5.4	0.011 – 0.110	5.8 – 6.5	7.0 – 18.6	4.6 – 5.5	0.011 – 0.110	5.6 – 6.4	9.0 – 21.8
		Mode	4.6	0.030	6.1	13.4	5.0	0.010	6.3	10.5
7	8	Mean	5.1	0.050	6.1	13.8	4.9	0.040	6.1	13.5
		Range	4.8 – 5.7	0.011 – 0.110	5.6 – 6.5	2.4 – 21.8	4.6 – 5.3	0.011 – 0.110	5.8 – 6.4	9.0 – 18.6
		Mode	5.1	0.060	6.2	12.1	5.2	0.010	6.1	13.4
8	11	Mean	5.1	0.050	6.0	15.1	5.1	0.050	6.1	14.3
		Range	4.7 – 5.3	0.008 – 0.110	5.9 – 6.3	10.5 – 17.2	4.9 – 5.4	0.011 – 0.110	5.8 – 6.5	7.0 – 18.6
		Mode	5.1	0.050	5.9	17.2	5.1	0.020	5.9	17.2
9	12	Mean	5.1	0.030	6.2	11.1	5.2	0.020	6.2	11.7
		Range	4.6 – 5.4	0.011 – 0.044	6.1 – 6.5	7 – 13.4	5.1 – 5.4	0.011 – 0.033	6.2 – 6.3	10.5 – 12.1
		Mode	5.2	0.030	6.1	13.4	5.2	0.020	6.2	12.1
10	13	Mean	4.9	0.250	5.9	15.4	4.9	0.180	5.9	15.8
		Range	4.5 – 5.3	0.009 – 0.990	5.4 – 6.3	10.5 – 25.3	4.5 – 5.4	0.011 – 0.880	5.6 – 6.4	9.0 – 21.8
		Mode	4.9	0.010	5.8	18.6	4.9	0.020	5.9	17.2
11	16	Mean	5.0	0.220	6.1	13.4	4.9	0.120	6.0	14.8
		Range	4.6 – 5.6	0.022 – 0.990	5.6 – 6.5	7.0 – 21.8	4.6 – 5.5	0.011 – 0.880	5.5 – 6.4	9.0 – 23.3
		Mode	4.7	0.070	6.2	12.1	4.9	0.060	6.3	10.5

(continued.....)

Table 8. Electro chemical Properties (.....continued)

No.	Soil Phase		Surface pH	Surface EC dS m⁻¹	Surface Buffer pH	Surface Lime R. (t ha⁻¹)	Sub – surface pH	Sub – surface EC dS m⁻¹	Sub – surface Buffer pH	Sub – surface Lime R. (t ha⁻¹)
12	18	Mean	5.1	0.370	5.9	16.1	4.9	0.390	6.0	15.6
		Range	4.8 – 5.7	0.011 – 0.770	5.5 – 6.3	10.5 – 23.3	4.4 – 5.5	0.011 – 0.880	5.7 – 6.3	10.5 – 20.1
		Mode	5.1	0.370	5.9	6.9	4.9	0.390	6.0	5.9
13	22	Mean	5.0	0.040	6.2	11.8	5.1	0.030	6.3	11.1
		Range	4.5 – 5.3	0.009 – 0.110	6.0 – 6.4	9.0 – 15.2	4.8 – 5.3	0.011 – 0.044	5.9 – 6.4	9.0 – 17.2
		Mode	5.0	0.030	6.2	12.1	5.1	0.030	6.3	10.5
14	25	Mean	5.0	0.030	6.2	11.9	5.0	0.060	6.0	15.3
		Range	4.6 – 5.5	0.011 – 0.066	5.9 – 6.4	9.0 – 17.2	4.7 – 5.2	0.011 – 0.110	5.6 – 6.3	10.5 – 21.8
		Mode	5.0	0.020	6.2	12.1	5.2	0.060	6.0	14.1
15	26	Mean	5.4	0.030	6.2	11.7	4.9	0.030	6.1	13.1
		Range	5.2 – 5.6	0.011 – 0.088	6.0 – 6.4	9.0 – 15.2	4.2 – 5.4	0.009 – 0.044	5.9 – 6.3	10.5 – 17.2
		Mode	5.4	0.010	6.4	9.0	4.9	0.040	6.2	12.1
16	27	Mean	5.0	0.050	5.8	18.3	5.2	0.040	5.8	17.4
		Range	4.2 – 6.5	0.011 – 0.110	5.2 – 6.4	9.0 – 28.5	4.6 – 6.7	0.011 – 0.110	5.1 – 6.5	7.0 – 30.2
		Mode	4.5	0.020	6.1	13.4	4.8	0.020	5.9	17.2
17	30	Mean	5.3	0.040	6.1	14.4	5.3	0.030	6.3	11.1
		Range	4.7 – 5.5	0.011 – 0.110	5.8 – 6.4	9.0 – 18.6	5.0 – 5.7	0.011 – 0.055	6.0 – 6.5	7.0 – 15.2
		Mode	5.3	0.010	6.1	7.0	5.3	0.020	6.2	12.1
18	32	Mean	5.4	0.130	5.8	17.9	5.2	0.090	6.1	14.1
		Range	4.5 – 6.5	0.022 – 0.407	5.4 – 6.5	7.0 – 25.3	4.5 – 6.9	0.022 – 0.264	5.4 – 6.6	5.3 – 25.3
		Mode	5.4	0.100	5.7	20.1	5.2	0.090	6.6	5.3
19	33	Mean	4.9	0.080	5.9	15.8	5.2	0.050	5.8	17.6
		Range	4.6 – 6.1	0.011 – 0.374	5.4 – 6.6	5.3 – 25.3	4.5 – 6.3	0.011 – 0.110	5.4 – 6.4	9.0 – 25.3
		Mode	4.7	0.070	5.7	20.1	5.2	0.020	5.9	17.2
20	35	Mean	4.9	0.090	5.9	15.6	5.1	0.100	5.8	17.3
		Range	4.7 – 5.1	0.022 – 0.242	5.9 – 6.0	15.2 – 17.2	4.7 – 5.5	0.022 – 0.242	5.4 – 6.1	13.4 – 25.3
		Mode	4.7	0.090	6.0	15.2	5.1	0.100	6.0	15.2
21	36	Mean	5.1	0.050	5.9	15.3	5.2	0.040	5.9	16.7
		Range	4.5 – 6.5	0.011 – 0.110	5.5 – 6.4	9.0 – 23.3	4.8 – 6.4	0.011 – 0.099	5.4 – 6.4	9.0 – 25.3
		Mode	4.9	0.010	5.8	18.6	5.3	0.010	5.9	17.2
22	37	Mean	5.2	0.040	6.1	13.2	5.2	0.040	5.9	16.3
		Range	4.6 – 5.7	0.011 – 0.110	5.6 – 6.4	9.0 – 21.8	4.6 – 5.9	0.011 – 0.088	5.5 – 6.4	9.0 – 23.3
		Mode	5.7	0.010	6.2	12.1	5.2	0.020	5.7	20.1
23	38	Mean	5.1	0.030	5.9	16.1	5.1	0.030	5.9	15.6
		Range	4.5 – 5.6	0.011 – 0.099	5.7 – 6.3	10.5 – 20.1	4.6 – 5.4	0.011 – 0.077	5.4 – 6.3	10.5 – 25.3
		Mode	5.1	0.010	6.0	15.2	5.1	0.020	6.1	13.4

In order to find out the lime requirement of the soil, buffer pH of the soils were found out after shaking the soil with Shoemaker, Mcclean and Pratt (SMP) buffer solution. After getting the buffered pH of the soils, quantity of lime in terms of pure $CaCO_3$ required to bring the soil pH to neutral level were obtained. Buffer pH of both surface and sub surface soils were found out and the respective lime requirements were also recorded. In surface samples the highest buffer pH was recorded in phase 33 (6.6) and the lowest was in phase 27 (5.2). Buffer pH values of the subsurface samples were also recorded and the highest value was noted in phase 32(6.6) while the lowest was in phase 27(5.1). Lime required to bring these buffer pH to 7 was worked out accordingly and given in the table. The lime requirement will be more as the buffer pH decreases. Accordingly, the lime required to raise pH of the surface soil to neutrality was highest in phase 27(28.5 t ha^{-1}) and was lowest in phase 33(5.3 t ha^{-1}). The lime requirement of the subsurface soil varied from 5.3 t ha^{-1} in phase 32 to 30.2 t ha^{-1} in phase27 which has recorded the highest value in surface soil also.

4.4. Major nutrients

The data on organic carbon, available phosphorus and available potassium content in surface and subsurface soils are given in Table 9.

4.4.1. Organic carbon

Organic carbon contents in sub surface samples were lower than surface samples except in four phases (Phases25, 26,30 and 35). Organic carbon in the surface soil ranged from 0.1.5 -2.035% with a highest average of 1.78% in phase 2 and the lowest of the phase mean values was 0.73% in phase 30. In the sub surface layer organic carbon ranged from 0.424-2.095%. Highest organic carbon content was recorded in phase 2 both in the case of surface and sub surface soil (2.035 and 2.095 respectively). Similarly the lowest content of organic carbon was recorded in phase 1 with respect to both surface and subsurface soils (0.417 and 0.424% respectively).

One hundred and ninety eight surface samples analysed were grouped into the ten fertility classes of zero to nine as per the soil test based fertilizer recommendation of Department of Agriculture, Kerala. Of these classes class 0 to class2 comes under low fertility group, class3 to 6 in medium fertility and 7 to 9 in high fertility. The details are given in table 11. Accordingly, only one sample comes under the class 0, no samples in class 1, 2 in class 2, 31 in class 3, 56 in class 4, 59 in class 5, 35 in class 6, 11 in class 7, 3 in class 8 and no samples in class 9. Similarly subsurface samples were also grouped. Here no samples came under class 0 and class 1, but 6 samples were in class 2, 42 in class 3, 62 in class 4, 47 in class 5, 26 in class 6, 14 in class 7, and only one sample in class 8 while no samples were in class 9.

Thus, among the one hundred and ninety eight surface samples analysed 181 samples (91.4%) were under medium nutrient class in the fertility rating. Fourteen samples (7%) were under high and only 3(1.5%) were under low fertility classes. In the subsurface samples 177 samples (89.4%) were included in the medium class 15 samples (7.5%) were under high and 6 samples (3%) were in low fertility classes respectively.

On phase based evaluation, the mean values of organic carbon for the surface soils in table 9 showed that no phase was coming under low category; only one phase was there in high level and the remaining 22 phases were categorised as medium with respect to organic carbon. The data on subsurface samples also showed the same trend as that of surface samples.

4.4.2. Available Phosphorus

Available phosphorus content ranged from 1.25 to 19.16 $\mu g\ g^{-1}$ in the surface layer with a highest average of 7.51$\mu g\ g^{-1}$ in phase3 (Table 9). Lowest average was recorded in phase 25(1.83 $\mu g\ g^{-1}$). There was no relation observed between the phosphorus content of surface and subsurface soils. In the sub surface layer the available phosphorus content ranged from 1.04-17.08 $\mu g\ g^{-1}$. The lowest and highest mean values for available phosphorus were 1.95$\mu g\ g^{-1}$ in phase 25 and 5.57$\mu g\ g^{-1}$ in phase1.

In the case of available phosphorus also, soils were grouped into 0-9 classes based on the phosphorus level (Table 11). Here in surface samples, the pattern of distribution was, 5 samples were coming under class 0, 109 samples in class 1, 41 samples in class 2, 16 samples in class 3, 10 samples in class 4, 5 samples in class 5, 3 samples in class 6, only one sample in class 7, 4 samples each in class 8 and 9. In the subsurface samples 5 samples included in class 0, 125samples in class 1, 36samples in class 2, 16 samples in class 3, 3 samples in class 4, 5 samples in class 5, 2 samples in class 6, 4 samples in class 7, 1 sample each in class 8 and 9.

With regard to the fertility rating, most of the surface and subsurface soils were coming under low class. In the surface soils, 155 samples (78%) were under low class and in subsurface soils, 166 samples (84%) were under low category. Thirty four surface samples and 26 subsurface samples (17% and 13%, respectively) were medium in fertility while 9 surface samples and 6 subsurface samples (5% and 3%, respectively) were coming under high fertility class.

The mean values of available phosphorus content of different phases given in table 9 showed that of the 23 phases 20 were rated as low and only 3 came under medium, both in surface and subsurface soils. There were no phases in high fertility category with respect to phosphorus.

4.4.3. Available Potassium

Available potassium content in the surface layer ranged from a minimum value of 20 $\mu g\ g^{-1}$ in phase 36 to a maximum of 192 $\mu g\ g^{-1}$ in the same phase. The contents of available potassium in the subsurface soil varied from 16 $\mu g\ g^{-1}$ in phases 27 and 36 to 192$\mu g\ g^{-1}$ in phase 1. (Table 9).

Surface and subsurface samples were also grouped in the 0-9 fertility classes and the number of samples under different fertility classes is listed in Table 11. None of the samples were coming under class 0. Thirteen surface samples and 14 subsurface samples were included in class 1 and 48 surface samples and 52 subsurface samples were included in class 2. Fifty of surface samples and 58 of subsurface samples were coming under class 3, 40 of surface samples and 37 of subsurface samples were in class 4, 27 of surface samples and 24 of subsurface samples were in class 5, 11 of surface samples and 5 of subsurface samples in class 6, 5 of surface samples and 3 of subsurface samples were in class 7, 3 of surface samples and 2 of subsurface samples were in class 8 and one surface samples and 3 subsurface samples were in class 9.

Among the soil samples analysed 128 surface samples (64.64%) and 124 subsurface samples (62.62%) were under medium fertility. Also 60 surface samples (30.3%) and 66 subsurface sample (33.33%) were coming under low fertility class and 10 surface samples (5.05%) and 8 (4.04%) subsurface samples were in high fertility class.

The mean values for available potassium for phases given in table 5 showed that all the 23 phases irrespective of the depth of sampling fall under medium fertility group.

4.5.Secondary nutrients

The data on calcium and magnesium content of the soil extracted by neutral normal ammonium acetate are given in Table 12.

4.5.1. Available calcium

In both surface and subsurface soils calcium was dominating magnesium with respect to the content. Highest calcium content in the surface soil was recorded in phase 32 (367.5μg g^{-1}) and the lowest was recorded in phase 27(11μg g^{-1}). With respect to subsurface layer calcium content was highest in phase 36 (339.50 μg g^{-1}) and that of lowest in phase 27 (15μg g^{-1}). The mean value among the phases ranged from 81.13 μg g^{-1} to 205.80 μg g^{-1} in surface soil and that for subsurface were from 56.38 μg g^{-1} to 214.42 μg g^{-1} soil.

4.5.2. Available Magnesium

Magnesium content of the surface soil was recorded with the highest value in phase 8 (46.62 μg g^{-1}) and the lowest value in phase 33 (16.40μg g^{-1}). In the subsurface soil samples the highest content was noted in phase 2 with a value of 46.10 μg g^{-1} and the lowest one was noted in phase 37 with a value of 16.75 μg g^{-1}. The mean content of magnesium for surface soil ranged from 28.04 μg g^{-1} to 36.85 μg g^{-1} and that for subsurface varied from 25.42 μg g^{-1} to 34.77 μg g^{-1} soil.

Table 9. Major Nutrients

No.	Soil Phase		Surface			Sub - surface		
			Org.C (%)	Av.P(μg g^{-1})	Av.K(μg g^{-1})	Org.C (%)	Av.P(μg g^{-1})	Av.K(μg g^{-1})
1	1	Mean	0.77	6.79	72.00	0.64	5.57	72.89
		Range	0.417 – 1.149	1.70 – 15.83	41.00 – 124.00	0.432 – 0.955	1.54 – 11.66	36.00– 192.00
		Mode	0.54	3.00	72.00	0.64	5.57	52.00
2	2	mean	1.78	3.50	63.00	1.59	2.62	77.00
		Range	1.477 – 2.035	2.21 – 5.46	39.00 –88.00	1.149 – 2.095	1.54 – 3.42	63.00 – 93.00
		Mode	1.78	3.50	63.00	1.59	3.42	77.00
3	3	Mean	1.09	7.51	92.00	0.98	4.54	70.60
		Range	0.746 – 1.328	2.33 – 13.33	60.00 –122.00	0.716 – 1.119	1.67 – 7.75	40.00 – 98.00
		Mode	1.09	7.51	86.00	1.12	4.54	70.60
4	4	Mean	0.89	4.18	72.69	0.88	3.31	75.92
		Range	0.611 – 1.223	1.29 – 12.49	32.00 – 129.00	0.575 – 1.507	1.54 – 7.49	45.00– 103.00
		Mode	1.06	1.71	72.69	0.75	3.31	62.00
5	6	Mean	0.87	2.02	102.00	0.82	3.21	55.00
		Range	0.572 – 1.160	1.71 – 2.33	70.00 – 134.00	0.738 – 0.910	1.79 – 4.62	36.00 – 74.00
		Mode	0.87	2.02	102.00	0.82	3.21	55.00
6	7	Mean	1.10	2.60	74.18	1.02	2.19	61.73
		Range	0.597 – 1.471	1.33 – 6.54	31.00 – 112.00	0.716 – 1.567	1.54 – 4.12	34.00 – 89.00
		Mode	1.10	1.96	62.00	0.84	2.13	75.00
7	8	Mean	1.00	2.91	65.90	0.97	2.31	65.60
		Range	0.482 – 1.641	1.67 – 5.87	41.00 – 90.00	0.518 – 1.492	1.41 – 5.42	38.00 –154.00
		Mode	1.00	2.91	65.90	0.97	2.31	65.60
8	11	Mean	1.16	3.88	73.00	0.96	2.77	76.50
		Range	0.611 – 1.656	1.46 – 8.75	54.00 – 82.00	0.805 – 1.238	1.25 – 3.71	52.00 – 92.00
		Mode	1.16	2.04	82.00	0.91	2.77	76.50
9	12	Mean	1.31	2.29	57.50	1.30	2.99	64.25
		Range	0.985 – 1.805	1.42 – 3.79	41.00 – 78.00	0.940 – 1.716	1.37 – 4.42	52.00 – 79.00
		Mode	0.99	2.29	57.50	1.30	2.99	52.00
10	13	Mean	1.00	3.57	73.00	1.06	2.55	61.47
		Range	0.105 – 1.643	1.25 – 7.38	27.00 – 110.00	0.750 – 1.673	1.04 – 5.00	18.00 –100.00
		Mode	1.00	3.57	98.00	0.99	2.04	61.47
11	16	Mean	1.14	3.38	64.53	1.00	3.70	57.93
		Range	0.645 – 1.835	1.50 – 8.54	31.00 – 141.00	0.575 – 1.597	1.5 – 8.75	26.00 –114.00
		Mode	1.04	1.71	66.00	1.00	2.04	68.00
12	18	Mean	0.80	4.41	77.25	0.92	3.17	56.00
		Range	0.738 – 0.930	1.63 – 6.46	31.00 – 149.00	0.600 – 1.190	2.04 – 4.54	39.00 – 84.00
		Mode	0.80	4.41	77.25	0.92	3.17	56.00
13	22	Mean	1.10	2.07	60.50	1.00	3.47	47.50
		Range	0.597 – 1.611	1.50 – 3.21	31.00 – 92.00	0.618 – 1.582	1.93 – 8.04	27.00 – 78.00
		Mode	1.10	2.07	60.50	1.00	3.47	47.50
14	25	Mean	1.18	1.83	56.20	1.21	1.95	69.80
		Range	0.507 – 1.805	1.54 – 2.21	36.00 – 79.00	0.865 – 1.477	1.63 – 2.21	37.00 –105.00
		Mode	1.18	1.83	56.20	1.21	1.95	84.00
15	26	Mean	1.21	2.25	83.60	1.28	2.61	75.60
		Range	0.805 – 1.731	1.92 –3.25	63.00 – 100.00	1.014 – 1.582	1.71 – 3.71	50.00 –104.00
		Mode	1.21	2.25	89.00	1.28	2.61	75.60
16	27	Mean	0.95	6.15	62.27	0.77	4.67	64.36
		Range	0.621 – 1.302	1.29 – 19.16	25.00 – 136.00	0.424 – 1.346	1.30 – 17.08	16.00 –125.00
		Mode	0.98	6.15	42.00	0.91	4.67	64.36

(Continued.....)

Table 9. Major Nutrients (.....Continued)

No.	Soil Phase		Surface			Sub – surface		
			Org.C(%)	Av.P(μg g^{-1})	Av.K(μg g^{-1})	Org.C(%)	Av.P(μg g^{-1})	Av.K(μg g^{-1})
17	30	Mean	0.73	2.09	64.40	0.96	2.19	48.40
		Range	0.522 – 1.164	1.63 – 2.63	47.00 – 86.00	0.701 – 1.164	1.71 – 2.75	36.00 – 63.00
		Mode	0.52	2.09	47.00	0.96	2.19	48.40
18	32	Mean	1.28	2.35	78.50	1.18	3.17	88.50
		Range	0.895 – 1.580	1.63 – 3.38	41.00 –154.00	0.791 – 1.375	1.46 – 9.88	36.00–155.00
		Mode	1.28	2.46	44.00	1.32	1.63	88.50
19	33	Mean	1.09	2.55	57.69	0.99	2.56	63.88
		Range	0.803 – 1.432	1.29 – 5.54	21.00 –112.00	0.651 – 1.390	1.46 – 11.95	25.00–163.00
		Mode	0.88	2.42	34.00	0.80	2.13	41.00
20	35	Mean	1.23	2.43	55.60	1.28	2.47	64.00
		Range	1.150 – 1.302	1.71 – 4.21	34.00 – 67.00	0.878 – 1.682	1.58 – 3.75	34.00 – 86.00
		Mode	1.23	1.71	55.60	1.26	2.47	86.00
21	36	Mean	1.03	2.99	71.08	1.03	2.46	73.08
		Range	0.738 – 1.656	1.63 – 7.75	20.00– 192.00	0.611 – 1.311	1.38 – 5.71	16.00–164.00
		Mode	1.03	2.58	44.00	1.10	2.04	73.08
22	37	Mean	1.04	2.79	76.57	0.96	3.10	58.71
		Range	0.590 – 1.400	1.46 – 5.95	35.00– 111.00	0.629 – 1.300	1.67 – 5.79	23.00–101.00
		Mode	1.04	2.79	76.57	0.96	3.10	58.71
23	38	Mean	1.16	4.35	62.22	0.96	2.54	54.78
		Range	0.865 – 1.462	1.46 – 12.67	34.00– 100.00	0.694 – 1.579	1.29 – 4.96	26.00 – 99.00
		Mode	1.16	4.35	62.22	0.96	2.54	54.78

Table 10. Fertility status of Soil Samples and Phases

Sl.No.	Nutrients	Nutrient status	No. of Soil Samples		No.of phases	
			Surface	Subsurface	Surface	subsurface
1	Org. C	Low	3	6	0	0
		Medium	181	177	22	22
		High	14	15	1	1
2	Available P.	Low	155	166	20	20
		Medium	34	26	3	3
		High	9	6	0	0
3	Available K.	Low	60	66	0	2
		Medium	128	124	23	21
		High	10	8	0	0

Table 11. Fertility Rating of Soil Samples

Sl.No.	Class	No. of Samples								
		Org. C			Available P.			Available K.		
		Range	Surface	Subsurface	Range	Surface	Subsurface	Range	Surface	Subsurface
1	0	0.00 - 0.16	1	0	0.00 - 1.34	5	5	0.00 - 15.63	0	0
2	1	0.17 - 0.33	0	0	1.35 - 2.90	109	125	16.07 - 33.48	13	14
3	2	0.34 - 0.50	2	6	2.95 - 4.46	41	36	33.93 - 51.34	48	52
4	3	0.51 - 0.75	31	42	4.51 - 6.03	16	16	51.79 - 69.20	50	58
5	4	0.76 - 1.00	56	62	6.07 - 7.59	10	3	69.64 - 87.05	40	37
6	5	1.01 - 1.25	59	47	7.63 - 9.15	5	5	087.5 - 104.9	27	24
7	6	1.26 - 1.50	35	26	09.16 - 10.71	3	2	105.36 - 122.77	11	5
8	7	1.51 - 1.83	11	14	10.76 - 12.28	1	4	123.21 - 140.63	5	3
9	8	1.84 - 2.16	3	1	12.32 - 13.84	4	1	141.07 - 158.48	3	2
10	9	2.17 - 2.50	0	0	13.88 - 15.40	4	1	158.93 - 176.34	1	3

Table 12. Secondary Nutrients

No.	Soil Phase		Surface		Sub – surface	
			Ca(μg g^{-1})	Mg(μg g^{-1})	Ca(μg g^{-1})	Mg(μg g^{-1})
1	1	Mean	141.17	28.04	120.28	26.32
		Range	56.5 – 337.5	18.8 – 33.4	53.0 – 207.0	18.9 – 33.2
		Mode	141.17	28.04	165.00	26.32
2	2	mean	187.00	32.06	196.50	34.05
		Range	151.5–230.0	28.3 – 34.5	109.5 – 256.0	25.9 - 46.1
		Mode	187.00	32.06	196.50	34.05
3	3	Mean	136.40	30.48	112.70	25.42
		Range	99.0 – 196.0	27.5 – 34.1	57.0 – 185.0	17.8 – 33.3
		Mode	136.40	30.48	112.70	25.42
4	4	Mean	163.23	31.81	175.12	33.76
		Range	57.5 – 218.0	17.2 – 39.6	37.0 - 318.5	26.9 – 38.2
		Mode	163.23	31.81	175.12	33.76
5	6	Mean	199.75	32.58	108.50	30.28
		Range	151.5– 248.0	32.0 – 33.2	107.5 - 109.5	29.8 - 30.8
		Mode	199.75	32.58	108.50	30.28
6	7	Mean	165.05	33.00	158.18	31.81
		Range	37.0 – 284.5	27.3 – 38.7	47.0 – 255.0	25.5 – 34.7
		Mode	222.50	33.00	158.18	31.81
7	8	Mean	168.40	34.14	174.63	33.03
		Range	110.0–262.0	24.9 – 46.6	85.5 – 244.0	26.9 – 39.4
		Mode	168.40	34.14	174.63	33.03
8	11	Mean	140.17	31.93	124.42	30.02
		Range	51.5 – 202.0	27.5 – 35.0	50.0 – 240.0	25.5 – 33.6
		Mode	140.17	31.93	124.42	30.02
9	12	Mean	194.50	29.89	198.75	33.44
		Range	149.5– 244.0	19.8 – 34.6	159.0 – 232.0	31.7 – 36.1
		Mode	194.50	29.89	198.75	33.44
10	13	Mean	139.47	29.33	115.47	28.32
		Range	44.5 – 241.5	21.7 – 38.4	50.0 – 218.0	19.9 – 37.9
		Mode	139.47	29.33	111.00	28.32
11	16	Mean	96.55	33.46	85.13	32.68
		Range	15.0 – 186.0	28.7 – 40.3	18.0 - 180.5	26.5 - 40.3
		Mode	96.55	33.46	85.50	32.68
12	18	Mean	81.13	31.89	56.38	26.90
		Range	18.0 – 160.5	26.6 – 37.8	17.0 – 110.5	20.1 – 31.3
		Mode	81.13	31.89	56.38	26.90
13	22	Mean	146.08	30.42	144.75	29.25
		Range	72.5 – 289.5	22.1 – 37.5	121.0 – 180.0	26.3 – 34.1
		Mode	146.08	30.42	144.75	29.25
14	25	Mean	131.00	32.90	128.50	32.02
		Range	99.5 – 160.5	29.9 – 36.1	85.0 – 189.5	26.8 – 37.2
		Mode	131.00	32.90	128.50	32.02
15	26	Mean	142.20	32.01	136.00	33.38
		Range	99.5 – 171.5	30.5 - 33.7	43.5 – 179.5	31.3 – 35.7
		Mode	142.20	32.01	136.00	33.38

(Continued.....)

Table 12. Secondary Nutrients(.....Continued)

No.	Soil Phase		Surface		Sub – surface	
			Ca (μg g⁻¹)	Mg (μg g⁻¹)	Ca (μg g⁻¹)	Mg (μg g⁻¹)
16	27	Mean	111.07	30.08	129.86	30.64
		Range	11.0 – 254.0	22.0 – 42.5	15.0 – 330.0	24.2 – 38.4
		Mode	55.50	33.90	129.86	24.70
17	30	Mean	205.80	36.85	187.70	34.77
		Range	177.5– 243.0	31.6 – 40.9	123.0 – 238.0	31.2 – 37.4
		Mode	205.80	36.85	187.70	34.77
18	32	Mean	186.06	28.07	203.25	31.09
		Range	54.5 – 367.5	20.2 – 33.8	55.0 – 367.0	22.3 - 39.7
		Mode	186.06	28.07	203.25	31.09
19	33	Mean	125.97	28.72	165.50	31.34
		Range	46.5 – 287.0	16.4 – 33.7	62.0 – 325.5	26.4 – 42.5
		Mode	125.97	32.35	96.00	31.34
20	35	Mean	145.90	29.47	149.00	29.27
		Range	97.5 – 193.5	26.3 – 33.7	82.5 – 229.0	27.4 – 31.9
		Mode	145.90	29.47	149.00	29.27
21	36	Mean	158.58	30.97	214.42	33.23
		Range	59.5 – 356.5	25 .0 – 34.9	111.5 – 339.5	24.4 – 38.2
		Mode	158.58	30.97	214.42	33.23
22	37	Mean	164.07	33.17	154.93	28.67
		Range	50.0 – 276.0	29.6 – 36.6	43.5 – 276.0	16.8- 37.8
		Mode	164.07	33.17	154.93	28.67
23	38	Mean	188.73	29.51	175.06	31.40
		Range	64.0 – 291.0	33.7 – 39.0	88.0 – 249.5	23.6 – 38.5
		Mode	188.73	29.51	175.06	31.40

4.6. Available micronutrients

The content of available micronutrients (manganese, iron, zinc and copper) as extracted using 0.1M HCl and the phase wise data are presented in Table 13.

4.6.1. Available manganese

Manganese content was high in both surface and subsurface soil samples. Manganese values in surface soil ranged from 8.8-184.8 μg g^{-1} soil. The highest value (184.8 μg g^{-1}) was recorded in phase 32 while the lowest manganese content (8.8 μg g^{-1}.) was recorded in phase 33. In the subsurface samples manganese content was slightly lower than surface soil. Content of manganese ranged from 11.1 μg g^{-1} (phase 33) to 151 μg g^{-1}(phase 32).

The data on 0.1M HCl extractable manganese were sorted according to the critical range (1 to 4 μg g^{-1} soil) as reported by (Sims and Johnson, 1991). Accordingly, the number of samples falling below the critical range, those in the critical range and those falling in the range above critical range are given in table 14. The data showed that all the samples analysed were coming far above critical range. In the phase wise evaluation also the manganese content showed the same trend.

4.6.2.Available iron

Iron was also extracted using 0.1M HCl from both the surface and subsurface samples. In the surface samples iron content varied from a lower value of 12.3 μg g^{-1} in phase 27 to a higher value of 98.7 μg g-1 in phase 8. Among the subsurface samples, it recorded a minimum value of 10.3μg g^{-1} in phase 6 and a maximum value of 81.4 μg g^{-1} in phase 8.

The critical level for iron is 0.3-0.5 μg g^{-1} (Sims and Johnson, 1991). All the samples analysed were falling above the critical level. The phase wise mean values were given in Table 14 and showed that all phases were high in fertility status.

4.6.3.Available zinc

With respect to the zinc status of soil, both the surface and subsurface soils contain only low amounts of zinc. In the surface samples most of the phases recorded a low content of 0.1μg g^{-1} , but the highest value was recorded in phase 36 (5.9 μg g^{-1}.). For the subsurface samples it recorded a range of 0.1 μg g^{-1} in six phases to 5.4 μg g^{-1} in phase 32.

The critical range for 0.1MHCl extractable zinc is 1 μg g^{-1} to 5 μg g^{-1} soil (Sims and Johnson, 1991). The data in Table 14 showed that 166 surface samples (83.83%) and 180 subsurface samples (90.9%) were in below the critical range. Twenty eight surface (14.14%) and 16 (8.08%) subsurface samples were in the critical range and four (2.02%) and 2(1.01%) surface and subsurface samples respectively were falling above critical level.

The mean values of available zinc in Table 13 showed that 20 phases were under below critical level for both surface and subsurface soils. In the critical range there falls 3 phases from both the surface and subsurface soils.

4.6.4. Available copper

Copper was another micronutrient, the available fraction of which was extracted using 0.1M HCl and estimated from both the surface and subsurface samples. In the surface samples copper content varied from a value as low as 1.69 $\mu g\ g^{-1}$ in phase 26 to that as high as 38.65 $\mu g\ g^{-1}$ in phase 32. Surface samples recorded a higher content of copper than subsurface samples except in four phases (phase 2,8,11,18,33). Subsurface sample recorded the highest copper content in phase 33 (48.5 $\mu g\ g^{-1}$) and the lowest content in phase 35 (1.71 $\mu g\ g^{-1}$).

The critical range for copper is identified as 1-2 $\mu g\ g^{-1}$ (Sims and Johnson, 1991). Only five samples from surface soil and 3 samples from subsurface soil were in critical range but193 surface and 195 subsurface samples were above the critical range (Table 14).

The phase wise average values given in Table 6 showed all the phases were high in fertility status.

Table13. Micronutrients

No.	Soil Phase		Surface				Sub-surface			
			Mn(μg g-1)	Zn(μg g-1)	Cu(μg g-1)	Fe(μg g-1)	Mn(μg g-1)	Zn(μg g-1)	Cu(μg g-1)	Fe(μg g-1)
1	1	Mean	59.38	0.61	11.98	28.47	53.24	0.59	11.96	25.76
		Range	24.00 – 87.90	0.10 –1.70	3.29 –18.87	21.80 –38.30	28.50 –83.90	0.20 –1.80	3.31 –23.66	17.70 –40.20
		Mode	59.38	0.30	11.98	29.20	53.24	0.60	11.96	25.76
2	2	mean	43.93	0.40	9.41	21.78	51.65	0.43	12.67	19.15
		Range	27.90 –70.10	0.20 –0.80	5.12 –15.49	13.80 –27.30	32.90 –81.10	0.20 –0.60	9.12 –16.88	17.20 –20.70
		Mode	43.93	0.20	9.41	21.78	51.65	0.60	12.67	19.15
3	3	Mean	45.84	0.28	6.15	25.10	48.12	0.20	5.67	24.98
		Range	32.00 – 61.10	0.10 –0.60	1.84 –11.09	16.10 –38.80	32.10 –63.90	0.10 –0.40	3.03 –12.98	17.00 –42.10
		Mode	45.84	0.10	6.15	25.10	48.12	0.20	5.67	24.98
4	4	Mean	50.22	0.54	13.99	26.67	48.00	0.54	10.94	30.64
		Range	20.80 – 72.00	0.10 –1.40	4.23 –26.98	14.25 –36.90	19.70 –81.80	0.20 –1.50	2.62 –23.70	15.50 –49.00
		Mode	50.22	0.30	13.99	26.67	34.40	0.50	10.94	30.64
5	6	Mean	46.50	0.60	13.67	22.45	37.50	0.65	3.53	17.55
		Range	25.90 – 67.10	0.50 –0.70	6.77 –20.56	17.40 –27.50	19.70 –55.30	0.60 –0.70	3.47 –3.58	10.30 –24.80
		Mode	46.50	0.60	13.67	22.45	37.50	0.65	3.53	17.55
6	7	Mean	38.22	0.37	11.23	31.67	42.29	0.39	9.73	25.62
		Range	10.10 – 67.70	0.10 –0.70	3.32 –31.00	17.70 –49.20	25.70 –68.70	0.20 –0.80	2.61 –15.90	13.41 –41.60
		Mode	38.22	0.40	11.23	31.67	42.29	0.40	9.73	25.62
7	8	Mean	68.54	0.71	12.28	38.96	62.92	0.72	12.87	29.70
		Range	29.90 – 130.30	0.30 –1.20	2.81 –23.58	14.80 –98.70	41.60 –80.00	0.40 –2.40	2.52 –23.06	17.00 –81.40
		Mode	68.54	0.50	12.28	38.96	62.92	0.60	12.87	21.20
8	11	Mean	54.55	0.33	8.80	21.80	51.05	0.30	12.40	26.17
		Range	39.30 – 64.90	0.10 –0.60	4.88 –12.20	17.80 –29.00	38.40 –64.70	0.10 –0.80	2.95 –21.88	19.70 –34.50
		Mode	54.55	0.60	8.80	21.80	51.05	0.20	12.40	26.17
9	12	Mean	45.28	0.58	7.72	29.25	50.90	0.60	6.06	30.17
		Range	41.60 – 52.20	0.40 –0.90	3.63 –10.79	23.50 –38.10	34.20 –83.60	0.40 –1.00	2.97 –8.63	16.78 –43.50
		Mode	45.28	0.50	7.72	29.25	50.90	0.40	6.06	30.17
10	13	Mean	63.63	0.62	9.26	21.80	55.09	0.55	7.50	22.36
		Range	24.60 – 126.80	0.30 –1.20	1.86 –20.72	13.30 –30.10	28.10 –83.20	0.30 –0.70	1.81 –24.45	14.70 –45.00
		Mode	63.63	0.40	9.26	21.80	55.09	0.70	7.50	18.30
11	16	Mean	57.88	0.77	7.92	31.37	58.56	0.74	6.54	29.69
		Range	29.80 – 87.50	0.20 –1.30	2.12 –18.94	14.30 –51.00	23.70 –100.20	0.40 –1.10	2.34 –15.53	13.78 –65.70
		Mode	57.88	0.60	7.92	31.37	58.56	0.90	6.54	29.69
12	18	Mean	64.80	0.55	8.67	21.38	46.00	0.53	10.20	33.03
		Range	33.70 –115.00	0.30 –0.70	2.96 –14.20	19.80 –24.40	24.30 –72.70	0.30 –0.80	2.90 –14.26	17.10 –63.50
		Mode	64.80	0.60	8.67	21.38	46.00	0.50	10.20	33.03

Table13. Micronutrients (.....Continued)

No.	Soil Phase		Surface				Sub-surface			
			Mn (μg g-1)	Zn (μg g-1)	Cu (μg g-1)	Fe (μg g-1)	Mn (μg g-1)	Zn (μg g-1)	Cu (μg g-1)	Fe (μg g-1)
13	22	Mean	40.90	0.53	10.92	23.20	51.93	0.33	10.40	26.68
		Range	20.20 –59.50	0.20 –1.30	4.90 –15.99	17.90 –28.40	22.40 –80.70	0.20 –0.50	4.03 –21.22	17.8 –50.00
		Mode	40.90	0.40	10.92	23.20	51.93	0.30	10.40	26.68
14	25	Mean	69.68	0.50	9.14	26.70	56.14	0.48	7.06	32.14
		Range	52.70 – 92.30	0.20 –0.70	2.80 –14.11	17.80 –33.80	32.00 –91.50	0.20 –0.80	1.79 –13.81	27.00 –44.00
		Mode	69.68	0.70	9.14	26.70	56.14	0.48	7.06	27.00
15	26	Mean	69.58	0.26	3.97	38.44	48.32	0.26	3.83	39.26
		Range	44.80 –100.40	0.10 –0.50	1.69 –6.13	24.20 –51.00	28.50 –65.00	0.10 –0.60	2.36 –4.83	29.80 –48.3
		Mode	69.58	0.10	3.97	38.44	48.32	0.10	3.83	39.26
16	27	Mean	67.51	1.10	10.46	29.28	65.95	0.75	10.08	29.71
		Range	26.00 – 134.30	0.10 – 5.60	3.85 –17.66	12.30 –68.30	29.40 –119.20	0.10 –3.30	1.82 –23.40	12.00 –88.70
		Mode	46.20	0.50	7.90	18.90	65.95	0.60	10.08	16.10
17	30	Mean	49.84	2.36	12.17	25.60	46.26	1.48	9.69	38.52
		Range	23.40 – 84.60	0.40 –5.10	4.66 –27.43	17.30 –40.20	16.60 –80.10	0.40 –5.10	4.32 –14.68	20.30 –50.00
		Mode	49.84	2.36	12.17	25.60	46.26	1.48	9.69	38.52
18	32	Mean	80.14	0.51	14.91	29.11	91.78	1.60	13.55	29.93
		Range	30.50 – 184.80	0.20 –0.80	3.22 –38.65	17.50 –54.60	32.60 –151.00	0.10 –5.40	1.83 –30.47	15.70 – 64.00
		Mode	80.14	0.30	14.91	29.11	91.78	0.30	13.55	29.93
19	33	Mean	61.35	0.53	10.25	19.83	57.13	0.60	12.92	22.04
		Range	8.80 –110.60	0.10 –1.40	2.11 –27.04	13.30 –36.10	11.10 –118.40	0.20 –1.30	5.35 – 48.5	12.30 –39.10
		Mode	61.35	0.40	10.25	20.60	57.13	0.60	12.92	22.04
20	35	Mean	76.56	0.50	10.07	23.12	77.56	0.34	5.51	18.70
	.	Range	53.90 – 103.70	0.20 –1.10	4.28 –17.17	13.90 –51.80	50.90 –93.10	0.10 –0.60	1.71 –9.40	12.30 –38.70
		Mode	76.56	0.20	10.07	23.12	77.56	0.30	5.51	18.70
21	36	Mean	64.30	1.14	10.50	23.42	57.88	1.20	10.09	25.25
		Range	31.70 – 98.00	0.20 –5.90	4.30 –17.5	15.0 –32.30	23.70 –96.50	0.30 –6.0	4.36 –21.83	13.80 – 43.00
		Mode	64.30	0.60	10.50	23.42	57.88	0.80	10.09	25.25
22	37	Mean	64.79	0.74	9.78	21.66	61.71	0.64	8.55	24.24
		Range	33.80 – 107.90	0.30 – 2.00	2.77 –23.85	13.30 –29.50	25.70 –101.20	0.30 –0.80	2.92 –13.37	15.70 – 39.40
		Mode	64.79	0.30	9.78	21.80	61.71	0.80	8.55	24.24
23	38	Mean	55.73	0.70	10.30	22.97	53.23	0.57	8.02	19.24
		Range	29.30 – 85.60	0.50 –0.90	2.32 –14.39	17.10 –29.40	24.10 –88.30	0.40 –0.90	2.95 –20.21	14.90 –24.20
		Mode	55.73	0.70	10.30	22.97	53.23	0.40	8.02	20.90

Table 14. Micronutrient Rating of Soil Samples

Sl. No.	0.1M HCl Extractable	Critical Range ($\mu g\ g^{-1}$)	Rating	No. of Samples		No. of Phases	
				Surface	Subsurface	Surface	Subsurface
1	Fe	0.3 - 0.5	Below Critical Range	0	0	0	0
			Critical Range	0	0	0	0
			Above Critical Range	198	198	23	23
2	Mn	1-4	Below Critical Range	0	0	0	0
			Critical Range	0	0	0	0
			Above Critical Range	198	198	23	23
3	Zn	1-5	Below Critical Range	166	180	20	20
			Critical Range	28	16	3	3
			Above Critical Range	4	2	0	0
4	Cu	1-2	Below Critical Range	0	0	0	0
			Critical Range	5	3	0	0
			Above Critical Range	193	195	23	23

4.7.Phosphorus fixing capacity

Phosphorus fixing capacities of soil samples were given in Table 15. Relatively high phosphorus fixing capacity was observed in our soils. There is slight variation in the phosphorus fixing capacity of surface and subsurface soils. In the surface samples the highest value was recorded in phase 3(90.09%) and the lowest value was recorded in phase 6 (43.02%) while in the subsurface samples the highest value recorded in phase 26 (88.65%) and the lowest value was recorded in phase 6 (40.9%).

Table 14. Micronutrient Rating of Soil Samples

Sl. No.	0.1M HCl Extractable	Critical Range ($\mu g\ g^{-1}$)	Rating	No. of Samples		No. of Phases	
				Surface	Subsurface	Surface	Subsurface
1	Fe	0.3 - 0.5	Below Critical Range	0	0	0	0
			Critical Range	0	0	0	0
			Above Critical Range	198	198	23	23
2	Mn	1-4	Below Critical Range	0	0	0	0
			Critical Range	0	0	0	0
			Above Critical Range	198	198	23	23
3	Zn	1-5	Below Critical Range	166	180	20	20
			Critical Range	28	16	3	3
			Above Critical Range	4	2	0	0
4	Cu	1-2	Below Critical Range	0	0	0	0
			Critical Range	5	3	0	0
			Above Critical Range	193	195	23	23

4.7.Phosphorus fixing capacity

Phosphorus fixing capacities of soil samples were given in Table 15. Relatively high phosphorus fixing capacity was observed in our soils. There is slight variation in the phosphorus fixing capacity of surface and subsurface soils. In the surface samples the highest value was recorded in phase 3(90.09%) and the lowest value was recorded in phase 6 (43.02%) while in the subsurface samples the highest value recorded in phase 26 (88.65%) and the lowest value was recorded in phase 6 (40.9%).

4.8.1.Exchangeable calcium

Among the exchangeable cations, calcium was the dominant divalent cation both in surface and subsurface layers. The highest calcium was noted in phase 3 with a value of 826.00 μg g^{-1} and the lowest was in phase 33 with a value of 35.00 μg g^{-1} in the case of surface samples. It varied from an average of 120.00 μg g^{-1} in phase 18 to 548.60 μg g^{-1} in phase 26.

In subsurface samples a minimum of 49.00 μg g^{-1} and a maximum of 954.30 μg g^{-1} were noted in phase 18 and phase 3 respectively. The average value ranged from 123.10μg g^{-1} (phase 18) to 596.30 μg g^{-1} (phase 3).

4.8.2.Exchangeable magnesium

Another important exchangeable cation present in soil was magnesium. Exchangeable magnesium was also determined from 0.1M $BaCl_2$ extract and presented in Tables 16 and 17. In surface samples its value ranged from 11.90 μg g^{-1} (phase 18) to 109.80 μg g^{-1} (phase 3). The phase wise lowest average was noted in phase 18 with a value of 34.95 μg g^{-1} and highest was noted in phase 3 with a value of 82.66μg g^{-1}. Among the sub surface samples, the magnesium content varied from 14 μg g^{-1} in phase 18.00 to 116 .50 μg g^{-1} in phase 32. The phase wise mean was lowest in phase 18(43.48μg g^{-1}) and the highest of the means was in phase 3 (80.92μg g^{-1})

4.8.3.Exchangeable potassium

Potassium being the important monovalent cation, it was also extracted using 0.1 M $BaCl_2$ and estimated. Among the surface samples analysed, the values ranged from a maximum of 162.00μg g^{-1} (phase 36) to a minimum 22.00 μg g^{-1} in phase 38. The highest and the lowest mean values were recorded in phase 3 and phase 38 (123.60 μg g^{-1} and 76.67 μg g^{-1} respectively). In the subsurface samples exchangeable potassium value ranged from 52.00 μg g^{-1} (phase 33) to 164.00μg g^{-1} (phases 3and 4). The average values ranged from 70.00 μg g^{-1} (phase 18) to 131.20(phase 3). More than 50% of phases showed a higher content of K in subsurface samples than surface samples.

4.8.4.Exchangeable sodium

The content of exchangeable sodium was comparatively higher in this extract in comparison with that of potassium and this increase in content of sodium was found to be more in surface than in subsurface soil. In surface samples the exchangeable sodium ranged from 46.00μg g^{-1} (phase 38) to 230.00 μg g^{-1} (phase 3). The highest mean value was recorded in phase 3 (175.20 μg g^{-1}) and the lowest was 101.00 μg g^{-1} in phase 18. In subsurface samples the respective values were 72.00 μg g^{-1} in phase 27 and 228.00μg g^{-1} in phase 3. Here also more than 50% of phases showed a higher content of sodium in subsurface samples than surface samples.

4.8.5.Exchangeable manganese

Exchangeable manganese present in soil was determined using 0.1M $BaCl_2$ extract and found that the manganese content was uniformly very high in both surface and subsurface samples and it was higher than the exchangeable magnesium. For surface samples the minimum value for exchangeable manganese was 8.00μg g^{-1} (phase 32) and the maximum value was 289.30μg g^{-1} (phase 3). The highest mean value was found to be as 176.40 μg g^{-1} in phase 3 and the lowest was found to be as 68.35 μg g^{-1} in phase 6.
In the subsurface samples, the exchangeable manganese ranged from 3.10 μg g^{-1} to 278.30 μg g^{-1} (phase 27 and phase 3 respectively). But the lowest average was noted in phase 6 with a value of 66.10 μg g^{-1} and the highest value was noted in phase 3 as 167.64 μg g^{-1} .

4.8.6.Exchangeable iron

Using 0.1M $BaCl_2$ exchangeable iron was also extracted and estimated in both surface samples and subsurface samples. For surface samples, the highest value was noted in phase 4, 7.70 μg g^{-1} and the lowest value was noted in phase 33, 1.00 μg g^{-1}. The highest average value was 4.42μg g^{-1} (phase 3) and the lowest average value was 1.80 μg g^{-1} (phase 18) in surface samples.

For subsurface samples, the exchangeable iron content ranged from 0.10-9.00 μg g^{-1} (phase 3 and phase 27 respectively). Here the highest average was noted in phase 12 (3.25 μg g^{-1}) and the lowest was noted in phase 32(1.73 μg g^{-1}).

4.8.7.Exchangeable aluminium

One of the important trivalent ion present in acid soils was aluminium and the exchangeable aluminium was estimated using 0.1M $BaCl_2$ extract. The value ranged from 10.38 μg g^{-1} (phase 36) to 67.75 μg g^{-1} (phase 33) for surface samples. The average minimum value was 18.91 μg g^{-1} in phase 12 and the maximum average was 50.10 μg g^{-1} in phase3, for surface samples.

For subsurface samples, phase 33 recorded the minimum value of 7.25 μg g^{-1} and phase 37 recorded the maximum value of 73.38 μg g^{-1}. Phase 22 recorded the average lowest (14.46 μg g^{-1}) and phase 18 recorded the average highest value (41.26 μg g^{-1}). Normal ammonium acetate (pH 7) failed to extract aluminium to any detectable limits.

Table 16. Exchangeable Cations in Surface soils (cmol kg^{-1})

No.	Phase		*Ex.Fe*	*Ex.Mn*	*Ex.Ca*	*Ex.Mg*	*Ex.Na*	*Ex.K*	*Ex.Al*
1	1	Mean	2.81	142.42	308.61	59.18	126.89	94.00	35.65
		Range	2.50 – 3.10	38.50 – 263.00	127.40 – 667.80	35.90 – 81.30	110.00 – 170.00	76.00 – 128.00	16.38 – 59.88
		Mode	3.00	142.42	308.61	52.80	126.89	76.00	51.25
2	2	mean	3.00	84.85	303.93	68.05	133.50	88.50	22.72
		Range	2.90 – 3.10	61.00 – 115.50	203.20 – 432.20	56.80 – 80.90	122.00 – 146.00	72.00 – 106.00	16.75 – 27.38
		Mode	3.00	84.85	303.93	68.05	122.00	88.50	22.72
3	3	Mean	4.42	176.46	548.60	82.66	175.20	123.60	50.10
		Range	2.90 – 6.60	94.70 – 289.30	104.10 – 826.00	42.80 – 109.80	118.00 – 230.00	90.00 – 156.00	36.75 – 60.00
		Mode	4.42	176.46	548.60	82.66	175.20	123.60	50.10
4	4	Mean	3.56	113.85	444.09	70.61	136.00	101.69	31.72
		Range	2.20 – 7.70	43.40 – 241.30	149.40 – 749.50	16.61 – 109.30	106.00 – 180.00	64.00 – 146.00	17.63 – 53.75
		Mode	3.60	78.00	444.09	74.40	136.00	101.69	22.50
5	6	Mean	2.60	68.35	279.60	68.40	120.00	93.00	30.26
		Range	2.40 – 2.80	35.20 – 101.50	155.30 – 403.90	68.00 – 68.80	108.00 – 132.00	72.00 – 114.00	27.88 – 32.63
		Mode	2.60	68.35	279.60	68.40	120.00	93.00	30.26
6	7	Mean	2.99	94.55	346.12	72.18	128.91	88.36	29.06
		Range	2.40 – 3.50	47.80 – 148.00	95.80 – 630.00	59.10 – 83.40	108.00 – 192.00	72.00 – 116.00	12.50 – 50.88
		Mode	3.30	94.55	346.12	72.18	110.00	82.00	33.13
7	8	Mean	2.26	90.25	292.17	71.63	129.00	85.20	35.64
		Range	1.30 – 2.80	61.50 – 159.00	113.70 – 577.60	50.20 – 96.30	116.00 – 140.00	66.00 – 106.00	15.63 – 44.00
		Mode	2.80	90.25	292.17	71.63	140.00	85.20	33.75
8	11	Mean	2.92	98.37	378.60	69.47	120.00	88.67	30.34
		Range	2.70 – 3.20	77.40 – 133.30	145.80 – 494.90	52.40 – 80.50	100.00 – 134.00	76.00 – 102.00	18 – 38.13
		Mode	2.80	98.37	378.60	69.47	120.00	82.00	30.34
9	12	Mean	3.30	74.68	330.58	75.38	131.50	89.50	18.91
		Range	3.20 – 3.50	52.10 – 94.10	157.30 – 459.70	69.80 – 82.70	126.00 – 136.00	78.00 – 108.00	13.13 - 25.38
		Mode	3.20	74.68	330.58	75.38	132.00	89.50	18.91
10	13	Mean	2.01	93.24	285.45	58.20	125.20	89.87	37.45
		Range	1.10 – 3.40	30.20 – 137.50	91.40 – 631.00	24.20 – 86.40	100.00 – 156.00	66.00 – 122.00	12.63 – 56.63
		Mode	1.50	93.24	285.45	58.20	108.00	96.00	37.45
11	16	Mean	2.65	101.15	374.25	64.31	119.47	85.33	33.89
		Range	1.40 – 4.00	17.80 – 173.00	93.60 – 728.80	25.80 – 98.20	102.00 – 146.00	64.00 – 114.00	16.38 – 53.88
		Mode	3.20	101.15	374.25	64.31	132.00	84.00	36.13

(Continued.....)

Table 16. Exchangeable Cations in Surface soils (cmol kg^{-1})(.....Continued)

No.	Phase		*Ex.Fe*	*Ex.Mn*	*Ex.Ca*	*Ex.Mg*	*Ex.Na*	*Ex.K*	*Ex.Al*
12	18	Mean	1.80	78.38	120.10	34.95	101.00	91.50	38.78
		Range	1.10 – 2.60	33.50 – 165.40	45.00 – 220.30	11.90 – 62.30	98.00 – 106.00	66.00 – 130.00	22.50 – 60.25
		Mode	1.80	78.38	120.10	34.95	98.00	91.50	38.78
13	22	Mean	2.72	105.37	434.32	65.05	135.67	92.00	19.88
		Range	2.50 – 3.20	61.70 – 178.10	215.10 – 529.10	52.30 – 84.90	114.00 – 152.00	70.00 – 122.00	13.63 – 36.13
		Mode	2.50	105.37	434.32	65.05	136.00	92.00	19.88
14	25	Mean	2.62	140.06	496.30	73.34	136.00	94.80	24.33
		Range	2.20 – 3.10	106.30 – 177.20	332.80 – 695.80	64.80 – 85.90	122.00 – 154.00	78.00 – 114.00	15.38 – 52.50
		Mode	2.50	140.06	496.30	73.34	136.00	94.80	24.33
15	26	Mean	2.90	73.70	508.00	79.34	143.60	93.60	44.85
		Range	2.50 – 3.60	40.40 – 108.60	413.60 – 573.90	68.50 – 89.50	136.00 – 154.00	82.00 – 102.00	24.13 – 54.13
		Mode	2.70	73.70	508.00	79.34	144.00	93.60	44.85
16	27	Mean	2.05	84.58	218.60	60.16	113.64	81.18	40.42
		Range	1.10 – 3.40	13.10 – 160.90	110.00 – 445.20	36.00 – 103.40	82.00 – 148.00	50.00 – 120.00	14.75 – 67.50
		Mode	2.20	84.58	218.60	60.16	108.00	72.00	40.42
17	30	Mean	2.48	87.36	362.44	75.82	115.60	76.80	28.55
		Range	2.00 – 2.80	38.00 – 114.30	188.60 – 559.80	58.60 – 95.40	102.00 – 128.00	62.00 – 88.00	19.50 – 44.75
		Mode	2.60	87.36	362.44	75.82	115.60	76.80	19.50
18	32	Mean	2.06	85.95	253.00	54.75	138.25	96.25	42.31
		Range	1.10 – 2.90	8.00 – 219.00	92.00 – 380.00	37.40 – 72.60	100.00 – 180.00	66.00 – 132.00	14.63 – 67.25
		Mode	2.00	85.95	253.00	54.75	138.25	86.00	62.75
19	33	Mean	2.46	88.81	187.63	56.83	129.13	86.75	36.99
		Range	1.00 – 4.80	12.20 – 156.20	35.00 – 352.00	20.20 – 80.90	108.00– 158.00	60.00 – 118.00	13.38 – 67.75
		Mode	2.00	88.81	247.00	56.83	124.00	86.00	18.75
20	35	Mean	2.32	117.00	196.40	53.72	116.80	88.00	34.80
		Range	1.80 – 2.70	87.30 – 160.70	146.00 – 262.00	39.30 – 60.60	106.00– 126.00	62.00 – 116.00	20.13 – 49.88
		Mode	2.60	117.00	196.40	53.72	116.80	88.00	34.80
21	36	Mean	2.16	114.46	273.19	63.73	128.83	91.08	25.85
		Range	1.30 – 2.90	18.20 – 187.70	143.80 – 445.40	43.50 – 90.70	108.00– 192.00	66.00 – 162.00	10.38 – 43.25
		Mode	2.50	114.46	273.19	63.73	122.00	72.00	25.85
22	37	Mean	2.29	98.90	350.51	65.89	137.71	88.86	31.16
		Range	1.50 – 2.80	48.00 – 141.10	158.00 – 649.00	46.10 – 98.50	100.00– 152.00	60.00 – 124.00	17.75 – 49.88
		Mode	1.50	98.90	350.51	65.89	138.00	88.86	31.16
23	38	Mean	2.06	90.86	323.06	76.08	120.22	76.67	27.63
		Range	1.60 – 2.60	47.80 – 136.50	141.30 – 585.30	49.90 – 93.80	46.00 – 158.00	22.00 – 98.00	11.88 – 53.75
		Mode	1.60	90.86	323.06	89.00	120.22	94.00	27.63

Table 17. Exchangeable Cations in Subsurface soils (cmol kg[-1])

No.	Phase		*Ex.Fe*	*Ex.Mn*	*Ex.Ca*	*Ex.Mg*	*Ex.Na*	*Ex.K*	*Ex.Al*
1	1	Mean	2.80	113.49	270.00	57.46	123.78	96.00	33.63
		Range	2.50 – 3.00	57.50 – 198.00	146.60 – 479.80	30.90 – 81.30	114.00 – 140.00	78.00 – 126.00	23.75 – 49.13
		Mode	2.80	113.49	270.00	57.46	124.00	84.00	33.63
2	2	Mean	2.80	102.65	288.03	67.43	137.50	91.00	25.13
		Range	2.00 – 3.20	71.60 – 152.20	143.60 – 427.00	46.80 – 78.20	110.00 – 180.00	76.00 – 100.00	20.50 – 37.00
		Mode	2.80	102.65	288.03	67.43	130.00	91.00	25.13
3	3	Mean	3.10	167.64	596.30	80.92	184.40	131.20	39.30
		Range	0.60 – 4.60	63.50 – 278.30	127.90 – 954.30	43.40 – 103.10	130.00 – 228.00	98.00 – 164.00	26.25 – 51.25
		Mode	3.10	131.80	596.30	80.92	184.40	131.20	39.30
4	4	Mean	3.07	87.18	422.90	67.70	137.23	100.46	34.18
		Range	0.80 – 5.50	46.00 – 201.70	131.30 – 685.70	18.60 – 100.30	98.00 – 180.00	72.00 – 164.00	15.25 – 53.75
		Mode	3.40	87.18	422.90	67.70	134.00	82.00	34.18
5	6	Mean	2.75	66.10	155.45	47.40	112.00	78.00	34.57
		Range	2.60 – 2.90	33.20 – 99.00	148.80 – 162.10	40.60 – 54.20	108.00 – 116.00	66.00 – 90.00	26.63 – 42.50
		Mode	2.75	66.10	155.45	47.40	112.00	78.00	34.57
6	7	Mean	3.01	102.99	345.65	72.99	123.27	85.64	24.89
		Range	2.50 – 3.50	46.50 – 176.40	259.80 – 510.80	50.40 - 86.80	110.00 – 160.00	68.00 – 100.00	13.63 – 37.50
		Mode	2.50	102.99	345.65	72.99	114.00	82.00	24.13
7	8	Mean	2.18	98.45	341.93	70.86	127.80	82.80	23.52
		Range	1.10 – 3.20	31.00 – 147.60	110.70 – 508.70	46.60 – 88.00	102.00 – 154.00	66.00 – 138.00	13.5 – 39.38
		Mode	2.18	98.45	341.93	70.86	124.00	82.00	23.52
8	11	Mean	2.95	99.53	298.43	55.80	119.33	85.67	25.67
		Range	2.70 – 3.30	70.00 – 126.80	135.10 – 476.50	38.20 – 74.00	94.00 – 162.00	72.00 – 104.00	10.88 – 36.75
		Mode	2.70	99.53	298.43	55.80	119.33	85.67	25.67
9	12	Mean	3.25	95.50	332.28	70.55	129.50	91.00	25.10
		Range	3.00 – 3.50	68.50 – 112.20	264.00 – 398.60	66.90 – 75.30	122.00 – 146.00	78.00 – 100.00	13.25 – 42.88
		Mode	3.25	95.50	332.28	70.55	129.50	91.00	25.10
10	13	Mean	2.37	85.00	203.37	56.25	119.73	84.53	39.71
		Range	1.10 – 5.50	44.80 – 140.50	62.00 – 511.50	25.90 – 85.20	98.00 – 142.00	68.00 – 120.00	10.38 – 58.00
		Mode	2.40	85.00	210.00	56.25	128.00	78.00	39.71
11	16	Mean	2.73	108.01	369.58	62.92	118.80	77.47	29.28
		Range	1.30 – 3.50	24.80 – 187.10	71.10 – 759.30	21.70 – 98.70	102.00 – 146.00	60.00 – 104.0	12.50 – 59.00
		Mode	2.73	108.01	369.58	62.92	106.00	68.00	16.25
12	18	Mean	2.30	74.83	123.10	43.48	102.00	70.00	41.26
		Range	1.00 – 3.50	28.40 – 145.80	49.00 – 183.00	14.00 – 65.40	80.00 – 110.00	64.00 – 76.00	34.13 – 51.63
		Mode	2.30	74.83	123.10	43.48	102.00	70.00	41.26

(Continued.....)

Table 17. Exchangeable Cations in Subsurface soils (cmol kg^{-1})(.....Continued)

No.	Phase		*Ex.Fe*	*Ex.Mn*	*Ex.Ca*	*Ex.Mg*	*Ex.Na*	*Ex.K*	*Ex.Al*
13	22	Mean	2.35	81.48	402.45	65.10	130.67	82.00	14.46
		Range	1.90 – 2.70	43.40 – 115.20	238.50 – 619.50	51.00 – 80.30	112.00 – 152.00	74.00 – 96.00	11.13 – 16.38
		Mode	2.35	81.48	402.45	65.10	130.67	78.00	14.46
14	25	Mean	2.76	114.44	501.84	73.52	140.00	96.00	29.93
		Range	2.40 – 3.40	74.70 – 172.70	350.10 – 599.70	55.50 – 95.80	130.00 – 148.00	82.00 – 108.00	12.50 – 48.88
		Mode	2.76	114.44	501.84	73.52	140.00	82.00	29.93
15	26	Mean	2.72	101.70	547.32	76.08	150.40	107.20	36.28
		Range	2.20 – 3.10	58.30 – 152.60	367.20 – 758.90	66.90 – 89.10	128.00 – 180.00	82.00 – 126.00	24.13 – 41.25
		Mode	2.72	101.70	547.32	76.08	150.40	107.20	36.28
16	27	Mean	2.95	72.15	209.52	62.10	117.55	84.73	35.42
		Range	1.40 – 9.00	3.10 – 144.00	88.00 – 541.70	29.70 – 106.70	72.00 – 162.00	60.00 – 140.00	13.88 – 60.13
		Mode	2.70	72.15	305.00	62.10	102.00	74.00	35.15
17	30	Mean	2.50	75.40	384.94	73.82	124.40	76.00	29.75
		Range	2.20 – 2.60	29.20 – 141.90	171.00 – 657.40	30.60 – 99.80	118.00 – 130.00	66.00 – 90.00	16.13 – 40.00
		Mode	2.60	75.40	384.94	73.83	124.00	66.00	29.75
18	32	Mean	1.73	76.16	252.38	62.74	134.50	106.75	40.68
		Range	0.10 – 2.80	4.30 – 153.80	98.00 – 377.00	38.80 – 116.50	100.00 – 178.00	62.00 – 154.00	17.50– 63.88
		Mode	1.00	76.16	252.38	62.74	134.50	104.00	63.88
19	33	Mean	2.19	109.56	247.69	63.58	128.75	88.50	24.80
		Range	0.90 – 2.90	12.80 – 218.10	148.00 – 364.00	42.10 – 115.90	74.00 – 168.00	52.00 – 142.00	7.25 – 49.25
		Mode	2.40	109.56	259.00	63.58	126.00	64.00	24.80
20	35	Mean	2.20	110.76	220.20	56.90	130.40	92.00	33.95
		Range	2.00 – 2.30	34.40 – 182.40	154.00 – 309.00	47.40 – 69.50	96.00 – 168.00	70.00 – 114.00	14.88 – 48.13
		Mode	2.30	110.76	220.20	56.90	130.40	92.00	33.95
21	36	Mean	1.77	106.37	366.57	72.74	137.33	92.17	25.33
		Range	1.10 – 2.80	14.00 – 204.20	152.00 – 608.00	40.20 – 98.70	112.00 – 188.00	68.00 – 118.00	11.00 – 45.13
		Mode	1.60	106.37	366.57	72.74	144.00	84.00	25.33
22	37	Mean	2.19	108.13	321.53	64.73	141.14	90.86	36.63
		Range	1.40 – 2.60	42.90 – 157.30	78.00 – 629.30	33.40 – 86.70	102.00 – 172.00	68.00 – 124.00	17.63 – 73.38
		Mode	2.60	108.13	321.53	64.73	141.14	90.86	36.63
23	38	Mean	2.10	97.04	337.33	70.71	131.56	82.22	25.42
		Range	1.00 – 2.70	41.80 – 160.60	152.80 – 597.30	45.40 – 93.10	94.00 – 168.00	60.00 – 102.00	11.88 – 55.38
		Mode	2.40	97.04	337.33	70.71	131.56	82.22	25.42

Table 18 Comparison of Exchangeable ions in surface soils extracted by Neutral 1Normal Amm.Acetate and 0.1M $BaCl_2$ (cmol (+) kg^{-1})

Sl. No	phase	Neutral Normal Amm.Acetate				0.1 M $BaCl_2$ Extract			
		K	Na	Ca	Mg	Ca	Mg	Na	K
1	1	0.165	0.136	0.647	0.257	1.54	0.49	0.55	0.24
2	2	0.306	0.126	0.961	0.241	1.52	0.56	0.58	0.23
3	3	0.136	0.142	0.748	0.245	2.74	0.68	0.76	0.32
4	4	0.199	0.146	0.844	0.257	2.22	0.58	0.59	0.26
5	6	0.137	0.072	0.180	0.233	1.40	0.56	0.52	0.24
6	7	0.212	0.153	0.855	0.248	1.73	0.59	0.56	0.23
7	8	0.145	0.125	0.834	0.261	1.46	0.59	0.56	0.22
8	11	0.153	0.097	0.556	0.222	1.89	0.57	0.52	0.23
9	12	0.063	0.094	0.534	0.209	1.65	0.62	0.57	0.23
10	13	0.209	0.148	0.532	0.256	1.43	0.48	0.54	0.23
11	16	0.162	0.132	0.746	0.260	1.87	0.53	0.52	0.22
12	18	0.130	0.110	0.290	0.265	0.60	0.29	0.44	0.23
13	22	0.162	0.137	0.938	0.274	2.17	0.54	0.59	0.24
14	25	0.193	0.164	0.765	0.272	2.48	0.60	0.59	0.24
15	26	0.143	0.146	0.299	0.277	2.54	0.65	0.62	0.24
16	27	0.192	0.148	0.834	0.249	1.09	0.50	0.49	0.21
17	30	0.174	0.191	1.109	0.271	1.81	0.62	0.50	0.20
18	32	0.192	0.138	0.906	0.258	1.27	0.45	0.60	0.25
19	33	0.176	0.134	0.785	0.249	0.94	0.47	0.56	0.22
20	35	0.209	0.199	1.242	0.281	0.98	0.44	0.51	0.23
21	36	0.179	0.154	0.733	0.266	1.37	0.52	0.56	0.23
22	37	0.199	0.151	0.799	0.263	1.75	0.54	0.60	0.23
23	38	0.144	0.176	0.696	0.297	1.62	0.63	0.52	0.20

Table 19 Comparison of Exchangeable ions in subsurface soils extracted by Neutral 1Normal Amm.Acetate and 0.1M $BaCl_2$ (cmol (+) kg^{-1})

Sl. No	phase	Neutral Normal Amm.Acetate				0.1 M $BaCl_2$ Extract			
		K	Na	Ca	Mg	Ca	Mg	Na	K
1	1	0.146	0.160	0.694	0.260	1.35	0.47	0.54	0.25
2	2	0.159	0.118	0.799	0.253	1.44	0.55	0.60	0.23
3	3	0.163	0.114	0.519	0.216	2.98	0.67	0.80	0.34
4	4	0.153	0.130	0.660	0.237	2.11	0.56	0.60	0.26
5	6	0.143	0.066	0.185	0.249	0.78	0.39	0.49	0.20
6	7	0.174	0.194	1.203	0.281	1.73	0.60	0.54	0.22
7	8	0.159	0.162	0.764	0.243	1.71	0.58	0.56	0.21
8	11	0.189	0.132	0.652	0.227	1.49	0.46	0.52	0.22
9	12	0.146	0.120	0.848	0.264	1.66	0.58	0.56	0.23
10	13	0.183	0.145	0.505	0.267	1.02	0.46	0.52	0.22
11	16	0.191	0.145	0.813	0.261	1.85	0.52	0.52	0.20
12	18	0.204	0.114	0.274	0.257	0.62	0.36	0.44	0.18
13	22	0.133	0.134	0.776	0.273	2.01	0.54	0.57	0.21
14	25	0.169	0.141	0.535	0.260	2.51	0.61	0.61	0.25

Sl. No	phase	Neutral Normal Amm.Acetate				0.1 M $BaCl_2$ Extract			
		K	Na	Ca	Mg	Ca	Mg	Na	K
15	26	0.169	0.194	0.367	0.283	2.74	0.63	0.65	0.27
16	27	0.152	0.126	0.813	0.246	1.05	0.51	0.51	0.22
17	30	0.198	0.189	0.902	0.261	1.92	0.61	0.54	0.19
18	32	0.156	0.130	0.625	0.241	1.26	0.52	0.59	0.27
19	33	0.166	0.129	0.757	0.246	1.24	0.52	0.56	0.23
20	35	0.123	0.154	0.694	0.210	1.10	0.47	0.57	0.24
21	36	0.147	0.130	0.656	0.255	1.83	0.60	0.60	0.24
22	37	0.170	0.138	0.759	0.254	1.61	0.53	0.61	0.23
23	38	0.183	0.163	0.664	0.279	1.69	0.58	0.57	0.21

4.9.Cation exchange capacity (CEC)

Cation exchange capacity is an important property of the soil which decides the exchange properties and other characteristics of soil such as nutrient supplying power, the solubility characteristics of different ions in soil solution and thus ultimately the fertility and nutrient use efficiency of different crops. The CEC was estimated by summing up the values for exchangeable cations in cmol (+) kg^{-1} soil. The exchangeable cations extracted using 0.1M $BaCl_2$ were used to find out the cation exchange capacity of the soil. The data are provided in table 20. The CEC was generally low in both surface and sub surface soils.

Cation exchange capacity of the surface soil ranged from 1.55 cmol (+) kg^{-1} soil (phase 18) to 8.04 cmol (+) kg^{-1} soil (phase 3) with a minimum average of 2.28 cmol (+) kg^{-1} soil (phase 18) to a maximum average of 5.72 cmol (+) kg^{-1} soil(phase 3).

Cation exchange capacity of the subsurface samples varied from 1.56 cmol (+) kg^{-1} soil (phase 18) to 8.54 cmol (+) kg^{-1} soil (phase 3). But the lowest average was noted in phase 18 (2.34 cmol (+) kg^{-1} soil) and the highest average was noted in phase 3(5.84 cmol (+) kg^{-1} soil). Only slight variations was noticed between surface and subsurface cation exchange capacity of soil.

4.10. Sodium saturation

Since the exchangeable sodium content in the soil was comparatively high, sodium saturation was considered as an important soil parameter. The data are presented in table 20. In surface samples the value varied from 5.54% (phase 38) to 28.66% (phase 18). 12.67% (phase 25) and 20.76% (Phase 18) were found to be the lowest and the highest mean values respectively observed regarding the sodium saturation .In the case of subsurface samples the value ranged from 8.99% (phase 4) to 24.82% (phase 38). But the lowest average of 13.06%

and the highest average 19.73% of were noticed in phases 26 and 6, respectively. About 50% of the phases showed higher sodium saturation in surface samples than subsurface samples.

4.11.Aluminium saturation

In acidic soil it is important to know the content of aluminium present in soil since it contribute to soil reaction. So aluminium saturation was worked out and given in the table 20. In the case of surface samples the percentage varied from 2.69%(phase 38) to 36.25% (phase 18). The average values ranged from 5.46% in phase 22 to 20.25% in phase 18. For the subsurface samples the content varied from 2.63% (phase 16) to 29.15% (phase 27). Here the average value ranged from 4.42% in phase 22 to 20.55% in phase 18. There was no definite trend between surface and subsurface soil layers.

In the case of surface samples sodium saturation and aluminium saturation were found to be minimum in the same phase i.e. in phase 38 and the corresponding maximum values were also in a single phase (phase18).

4.12. Percentage base saturation (PBS)

Percentage base saturation is a soil parameter, which is mainly decided by the major exchangeable bases present in the soil. The data on this parameter was given in table 20. Percentage base saturation in the surface samples ranged from 53.52% (phase 18) to 94.12% (phase 36) with a lowest mean of 68.05% in phase 18 and the highest value of 85% in phase 22. In the case subsurface samples percentage base saturation varied from 57.64% in phase 18 to 94.10% in phase 38. However the lowest average of 67.19% was recorded in phase 18 and the highest average (87.09) was recorded in phase 22.

Table 20. Exchange capacity & Cation saturation of soils

No.	Soil Phase		Surface				Sub - surface			
			CEC cmol kg^{-1}	Na sat. %	BSP	Al sat. %	CEC cmol kg^{-1}	Na sat. %	BSP	Al sat. %
1	1	Mean	3.75	15.31	73.89	11.44	3.40	16.35	75.94	11.56
		Range	2.32 – 5.42	11.23 - 20.62	58.50 - 93.76	3.45 – 20.80	2.30- 4.87	12.50 - 21.57	64.16 - 81.71	5.42 - 16.50
		Mode	3.75	14.00	70.00	7.00	3.40	18.00	82.00	11.00
2	2	mean	3.46	17.15	83.38	7.39	3.49	17.27	80.04	8.00
		Range	2.75 – 4.46	14.05 - 19.33	82.65 - 84.35	6.79 - 9.12	2.57 - 4.47	15.04 - 18.62	69.12 - 83.90	6.43 - 9.20
		Mode	3.46	17.15	83.00	7.00	3.49	18.00	84.00	9.00
3	3	Mean	5.72	14.35	77.32	11.05	5.84	14.95	81.03	8.61
		Range	2.46 – 8.04	11.17 - 20.83	67.47 - 86.40	6.63 – 18.12	2.47 - 8.54	11.61 - 22.88	75.02 - 87.05	4.80 - 15.19
		Mode	5.72	11.00	77.00	11.05	5.84	12.00	81.03	8.61
4	4	Mean	4.43	14.00	82.07	8.04	4.23	14.48	82.29	9.23
		Range	2.26 – 6.25	9.88 - 20.76	70.27 - 90.53	4.60 – 11.85	2.44 - 5.71	8.99 - 17.49	60.33 - 89.89	4.32 - 17.18
		Mode	4.43	15.00	82.07	10.00	4.23	15.00	82.29	9.23
5	6	Mean	3.32	15.96	80.68	10.62	2.49	19.73	74.97	15.27
		Range	2.73 – 3.89	14.73 - 17.19	72.83- 88.54	7.96– 13.28	2.31 - 2.67	17.59 - 21.87	68.46 - 81.47	12.84 - 17.70
		Mode	3.32	15.96	80.68	10.62	2.49	19.73	74.97	15.27
6	7	Mean	3.79	15.21	81.35	8.80	3.75	14.45	82.34	7.34
		Range	2.41– 5.28	10.55 - 19.88	71.99 - 90.91	3.40 – 17.05	3.10 - 4.84	11.15 - 18.99	76.37 - 88.91	4.46 - 10.73
		Mode	3.79	15.00	78.00	7.00	3.75	16.00	84.00	7.00
7	8	Mean	3.56	16.26	78.49	11.82	3.69	15.37	82.21	7.35
		Range	2.59 – 5.04	11.21- 23.20	69.87 - 86.50	4.28 – 18.16	2.20 - 4.48	12.13 - 20.14	70.34 - 89.49	3.36 - 12.64
		Mode	3.56	17.00	76.00	7.00	3.69	15.00	79.00	5.00
8	11	Mean	3.92	13.53	81.12	8.94	3.35	15.86	78.55	9.58
		Range	2.67 – 4.48	11.65 - 16.27	66.95 - 87.29	5.09 – 14.52	2.37 - 4.25	12.74- 18.38	66.40 - 89.71	2.85 - 15.51
		Mode	3.92	12.00	82.00	9.00	3.35	17.00	78.55	3.00
9	12	Mean	3.57	16.62	85.95	6.08	3.68	15.38	82.77	7.50
		Range	2.51 – 4.35	13.60 - 21.80	83.88 - 87.03	4.15 - 8.08	3.19 - 3.96	13.86- 16.63	77.06 - 85.27	4.02 - 12.24
		Mode	3.57	16.62	87.00	6.08	3.68	15.38	84.00	7.00
10	13	Mean	3.44	16.30	76.35	13.20	2.98	17.88	73.55	15.62
		Range	2.21 – 5.53	11.90 - 21.28	61.92 - 87. 90	2.89 – 24.56	1.81 - 4.62	13.38 - 23.54	62.54 - 87.73	4.39 - 25.42
		Mode	3.44	17.00	88.00	7.00	2.98	17.00	85.00	22.00
11	16	Mean	3.89	14.93	80.09	10.62	3.81	15.02	79.08	10.09
		Range	1.87 – 6.35	9.50 - 24.93	67.13 - 87.24	3.98 – 19.79	2.05 - 6.54	9.19- 22.60	60.41 - 89.70	2.63 - 27.87
		Mode	3.89	10.00	83.00	10.00	3.81	12.00	82.00	10.00

(continued.....)

Table 20. Exchange capacity & Cation saturation of soils (.....continued)

No.	Soil Phase		Surface				Sub - surface			
			CEC cmol kg^{-1}	Na sat. %	BSP	Al sat. %	CEC cmol kg^{-1}	Na sat. %	BSP	Al sat. %
12	18	Mean	2.28	20.76	68.05	20.25	2.34	19.49	67.19	20.55
		Range	1.55 - 3.26	14.15 - 28.66	53.52 - 75.70	12.34 - 36.25	1.566 - 2.798	16.788 - 22.224	57.643 - 75.487	13.715 - 27.62
		Mode	2.28	20.76	68.05	16.00	2.34	22.00	67.19	20.55
13	22	Mean	4.15	14.58	84.92	5.46	3.79	15.43	87.09	4.42
		Range	2.89 - 5.08	11.55 - 19.82	78.71 - 89.42	2.98 - 9.39	2.768 - 4.943	12.353 - 18.533	83.242 - 92.966	2.664 - 5.542
		Mode	4.15	14.00	84.92	5.00	3.79	15.00	84.00	5.00
14	25	Mean	4.71	12.67	82.82	5.79	4.73	13.07	84.01	6.92
		Range	3.75 - 5.79	11.57 – 14.15	76.39 - 87.79	3.58 – 12.36	3.572 - 5.435	11.845 - 15.829	76.031 - 90.999	2.975 - 11.002
		Mode	4.71	12.00	82.82	4.00	4.73	12.00	84.01	6.92
15	26	Mean	4.83	12.99	84.00	10.27	5.07	13.06	84.64	8.02
		Range	4.28 - 5.48	11.43 – 14.23	81.27 - 90.84	5.78 – 12.59	3.779 - 6.646	11.781 - 14.734	81.928 - 87.034	6.717 - 9.707
		Mode	4.83	13.00	83.00	10.27	5.07	13.00	84.64	7.00
16	27	Mean	3.05	16.30	74.32	15.23	2.95	17.57	76.08	14.45
		Range	2.26 - 4.06	11.77 – 20.62	57.65 - 87.15	5.46 – 26.85	1.994 - 4.861	13.643 - 24.257	57.729 - 93.25	4.206 - 29.149
		Mode	3.05	17.00	74.00	14.00	2.95	16.00	72.00	10.00
17	30	Mean	3.78	13.59	82.00	8.85	3.88	14.67	83.75	8.91
		Range	2.88 - 4.89	11.39 – 16.28	73.47 - 88.80	5.27 - 17.25	2.699 - 4.893	11.201 - 19.983	75.386 - 90.573	5.733 - 13.909
		Mode	3.78	13.00	82.00	7.00	3.88	14.67	83.75	6.00
18	32	Mean	3.35	18.05	75.37	14.89	3.37	17.49	76.98	14.20
		Range	2.29 - 4.21	14.36- 22.27	60.04 - 86.17	5.71 – 32.61	2.341 - 3.978	13.355 - 19.682	63.51 - 90.159	5.16 - 30.352
		Mode	3.35	16.00	71.00	7.00	3.37	19.00	76.98	18.00
19	33	Mean	2.93	19.41	73.82	14.54	3.23	17.31	78.62	8.55
		Range	2.32 - 3.85	15.68 - 25.27	57.07 - 87.27	5.10 – 27.71	2.402 - 3.867	10.157 - 20.574	65.396 - 93.131	2.871 - 17.728
		Mode	2.93	16.00	74.00	10.00	3.23	17.00	86.00	6.00
20	35	Mean	2.98	17.05	72.29	13.12	3.16	17.91	74.52	12.60
		Range	2.79 - 3.09	16.06 - 18.00	63. 80 - 81.38	7.25 – 18.82	2.636 - 3.775	15.84 - 23.472	68.773 - 86.864	4.385 - 20.309
		Mode	2.98	18.00	72.29	13.12	3.16	16.00	69.00	12.60
21	36	Mean	3.40	16.73	78.59	8.78	3.94	15.87	81.60	7.57
		Range	2.71 - 3.92	12.90 - 25.83	66.66 - 94.12	3.27– 15.98	2.845 - 5.033	9.769 - 22.935	63.885 - 93.143	3.311 - 14.225
		Mode	3.40	19.00	67.00	11.00	3.94	12.00	73.00	4.00
22	37	Mean	3.84	16.01	80.03	9.85	3.80	16.67	76.23	12.78
		Range	2.81 - 4.95	13.36 - 21.57	70.35 - 92.30	3.99 – 19.75	2.157 - 5.152	12.157 - 21.377	60.267 - 92.996	3.806 - 28.089
		Mode	3.84	15.00	70.00	9.85	3.80	15.00	76.23	7.00
23	38	Mean	3.61	15.15	79.95	9.85	3.69	16.13	80.90	8.54
		Range	2.62 - 4.91	5.54 - 22.55	64.27 - 93.58	2.69 – 22.46	2.734 - 5.102	12.714 - 24.822	66.629 - 94.099	2.692 - 21.822
		Mode	3.61	15.15	78.00	3.00	3.69	13.00	80.90	4.00

4.13. Soil Nutrient Interactions

Soil properties and different direct and derived parameters there of, were subjected to mutual correlation. In the correlation studies one hundred and thirteen samples each from surface and subsurface layer of both eastern and western parts of the main campus were used and correlation coefficients were worked out separately for surface and sub surface samples.

4.13.1.Correlation of exchangeable ions with soil parameters

4.13.1.1.Surface samples

Exchangeable ions under study were calcium, magnesium, sodium, potassium, iron, manganese and aluminium. Correlation coefficients for these exchangeable ions with soil parameters have been worked out and given in Table 21.

Table 21. Correlation coefficients of exchangeable ions with soil parameters (Surface samples)

Sl. No.		Exch. Ca	Exch. Mg	Exch. Na	Exch. K	Exch. Fe	Exch. Mn	Exch. Al
1	p^H	-0.122	-0.072	-0.131	0.077	0.078	-0.086	0.035
2	Org. C (%)	-0.009	-0.008	0.079	0.072	0.042	-0.207*	0.006
3	P- Fix. Cap	0.141	-0.009	-0.034	-0.013	0.108	0.021	-0.015
4	Clay (%)	0.126	0.088	0.051	0.380*	0.093	0.088	-0.01
5	Silt (%)	0.087	0.093	-0.021	0.089	0.148	-0.007	-0.041
6	CEC	0.624*	0.491*	0.467*	0.423*	-0.002	0.37*	-0.161
7	Na -sat	-0.350*	-0.221*	0.353*	0.169	-0.277*	-0.351*	-0.124
8	Al- sat	-0.641*	-0.553*	-0.486*	-0.436*	0.149	-0.064	0.739*
9	BSP	0.579*	0.520*	0.468*	0.421*	-0.179	-0.299*	-0.645*

Exchangeable ions have no significant correlation with soil pH. With respect to organic carbon, only exchangeable manganese was correlated significantly and negatively. None of the other ions have any significant correlation with organic carbon. Further, these exchangeable ions have no significant correlation with phosphorus fixing capacity. In the case of percentage clay content, only exchangeable potassium was significantly correlated with it. With respect to silt, no exchangeable ions were found to be correlated significantly. Regarding cation exchange capacity, except exchangeable iron and aluminium, all other ions were highly correlated. With respect to sodium saturation, except exchangeable potassium and aluminium, all other ions were significantly and negatively correlated. Exchangeable calcium, magnesium, iron and manganese were having negative correlation with sodium saturation. Exchangeable ions other than iron and manganese were having significant correlation with aluminium saturation. All these correlations were negative except that for exchangeable aluminium for which it was significant and positive. Similarly all ions were significantly correlated with per cent base saturation except iron. Of these, exchangeable manganese and aluminium were negatively correlated.

4.13.1.2.Subsurface samples

Unlike in the case of surface samples, exchangeable potassium of subsurface samples had significant correlation with pH (Table 22). Here the exchangeable ions have no significant correlation with organic carbon. Exchangeable calcium was significantly correlated with phosphorus fixing capacity. None of the exchangeable ions were significantly correlated with clay per cent. In subsurface samples only exchangeable iron was correlated with silt. For CEC, exchangeable calcium, magnesium, sodium, potassium and manganese were found to be highly correlated. Exchangeable sodium, calcium, magnesium, iron and manganese were correlated significantly with sodium saturation. Among these correlations, only exchangeable sodium was correlated positively while the others were having negative relation. In the correlation study of exchangeable ions with Aluminium saturation, except iron, all other ions have been significantly correlated.

Table 22. Correlation coefficients of exchangeable ions with soil parameters (Subsurface samples)

Sl. No.	Parameters	Exch. Ca	Exch. Mg	Exch. Na	Exch. K	Exch. Fe	Exch. Mn	Exch. Al
1	p^H	0.011	0.072	0.113	0.291*	0.126	0.045	-0.097
2	Org. C (%)	0.176	-0.036	0.078	0.095	-0.042	0.120	-0.048
3	P-Fix. Cap	0.230*	0.068	0.12	0.156	0.122	0.042	-0.086
4	Clay (%)	0.143	0.061	0.167	0.116	-0.044	-0.033	-0.029
5	Silt (%)	0.152	0.145	-0.018	0.001	0.200*	0.174	-0.021
6	CEC	0.649*	0.512*	0.472*	0.430*	0.040	0.390*	-0.191
7	Na –sat	-0.362*	-0.323*	0.274*	0.130	-0.196*	-0.274*	-0.133
8	Al- sat	-0.649*	-0.621*	-0.612*	-0.430*	0.163	0.195*	0.732*
9	BSP	0.609*	0.558*	0.544*	0.413*	-0.145	-0.228*	-0.616*

Only exchangeable manganese and aluminium were correlated positively while the significant correlations for exchangeable calcium, magnesium, sodium and potassium were negative. The correlations were significant for all ions with percentage base saturation except for exchangeable iron. These correlations were negative for manganese and aluminium but positive for the remaining ions.

4.13.2. Correlation of 0.1M HCl extractable micronutrients and phosphorus fixing capacity with soil parameters

4.13.2.1.Surface samples

With respect to soil pH, only iron was found to be correlated significantly. Other micronutrients have no significant correlation with pH (Table 23). Neither the available micronutrients nor the phosphorus fixing capacity was correlated significantly with organic carbon. With respect to cation exchange capacity, micronutrients were not at all correlated significantly, but phosphorus fixing capacity was significantly and positively correlated. None of the available micronutrients were significantly correlated with either silt or clay. Phosphorus fixing capacity was correlated significantly with per cent silt and clay. With exchangeable ions only a few micronutrients were correlated significantly; *viz.* iron was negatively correlated with exchangeable sodium; manganese correlated with exchangeable manganese positively and zinc with exchangeable aluminium in a negative manner.

Table 23. Correlation coefficients of 0.1M HCl extractable micronutrients and P-fixing capacity with soil parameters (Surface samples)

Sl. No.	Parameters	Mn	Zn	Cu	Fe	P-fixing Cap.
1	pH	0.009	0.151	0.051	0.235*	0.033
2	Org. C (%)	0.073	0.084	-0.021	0.042	0.131
3	CEC	0.135	0.155	0.088	-0.002	0.281*
4	Silt (%)	0.118	0.181	0.006	0.147	0.415*
5	Clay (%)	0.051	0.067	-0.080	0.093	0.302*
6	Exch. Na	-0.068	0.095	-0.109	-0.251*	-0.034
7	Exch. K	-0.094	0.043	-0.132	-0.111	-0.013
8	Exch. Ca	0.158	0.117	0.056	-0.089	0.141
9	Exch. Mg	0.035	0.150	0.034	-0.059	-0.009
10	Exch. Mn	0.410*	-0.024	0.040	0.121	0.021
11	Exch. Al	-0.075	-0.234*	-0.009	0.169	-0.015

4.13.2.2.Subsurface samples

In the subsurface samples, available zinc was correlated significantly with pH. Phosphorus fixing capacity was also found to be correlated with pH (Table 24). Available manganese, copper and phosphorus fixing capacity were having significant correlation with subsurface organic carbon, which was absent in surface soil. But, with reference to CEC, in a similar manner as that in the surface samples, only phosphorus fixing capacity was significantly correlated. With per cent silt both iron and phosphorus fixing capacity were correlated significantly. Micronutrients and phosphorus fixing capacity had no significant correlation with clay. Available iron was having negative correlation with exchangeable sodium. Zinc and phosphorus fixing capacity were significantly correlated with exchangeable calcium. Zinc was having positive correlation with exchangeable magnesium and negative correlation with exchangeable aluminium. Available manganese was positively correlated with exchangeable manganese.

Table 24. Correlation coefficients of 0.1M HCl extractable micronutrients and P-Fixing capacity with soil parameters (Subsurface samples)

Sl. No.	Parameters	Mn	Zn	Cu	Fe	P-fixing Cap.
1	pH	0.059	0.224*	0.152	0.047	0.224*
2	Org. C (%)	0.208*	0.114	0.202*	-0.042	0.345*
3	CEC	0.135	0.137	0.009	0.040	0.213*
4	Silt (%)	0.158	0.111	0.064	0.200*	0.285*
5	Clay (%)	0.074	-0.020	-0.064	-0.044	0.165
6	Exch. Na	0.028	0.186	-0.097	-0.217*	0.120
7	Exch. K	0.009	0.152	-0.051	-0.169	0.156
8	Exch. Ca	0.137	0.300*	0.054	-0.052	0.230*
9	Exch. Mg	0.035	0.250*	0.017	-0.069	0.068
10	Exch. Mn	0.539*	0.013	-0.043	0.058	0.042
11	Exch. Al	-0.121	-0.221*	0.013	0.125	-0.086

4.13.3.Correlation of different ionic ratios with soil parameters

The ratios $K/(Ca+Mg)^{1\backslash2}$, $K/((Mn)^{1\backslash2}+(Al)^{1/3})$, $K/(Ca+Mn)^{1\backslash2}$, $K/((Ca+Mn)^{1\backslash2}+(Al)^{1/3})$ and $K/((Fe+Mn)^{1\backslash2}+(Al)^{1/3})$ and $Na/(Ca+Mg)^{1\backslash2}$, $Na/(Mn)^{1\backslash2}+(Al)^{1/3})$, $Na/(Ca+Mn)^{1\backslash2}$, $Na/((Ca+Mn)^{1\backslash2}+(Al)^{1/3})$ and $Na/((Fe+Mn)^{1\backslash2}+(Al)^{1/3})$ were also considered in evaluating the intensity of monovalent ions. These ratios were correlated with exchange properties for comparison. The results are presented in the table (25-28).

Table 25. Correlation coefficient of different ionic ratios with respect to K with soil parameters (surface)

Sl. No.	Parameters	$K/(Ca+Mg)^{1/2}$	$K/((Mn)^{1/2}+(Al)^{1/3})$	$K/(Ca+Mn)^{1/2}$	$K/((Ca+Mn)^{1/2}+(Al)^{1/3})$	$K/((Fe+Mn)^{1/2}+(Al)^{1/3})$
1	CEC	0.014	0.202*	0.024	0.103	0.206*
2	Exch. K	0.623*	0.842*	0.772*	0.863*	0.85*
3	Exch. Na	0.406*	0.651*	0.531*	0.609*	0.655*
4	Exch. Ca	-0.434*	0.199*	-0.3*	-0.171	0.199*
5	Exch. Mg	-0.319*	0.313*	-0.094	0.025	0.313*
6	Exch. Mn	-0.066	-0.453*	-0.292*	-0.266*	-0.466*
7	Exch. Fe	-0.006	-0.213*	-0.09	-0.11	-0.209*
8	Exch. Al	0.138	-0.436*	-0.033	-0.169	-0.437*
9	Na. sat	0.296*	0.326*	0.42*	0.396*	0.326*
10	Al. Sat	0.007	-0.418*	-0.078	-0.203*	-0.421*
11	BSP	0.001	0.554*	0.183	0.281*	0.553*

Table 26. Correlation coefficient of different ionic ratios with respect to K with soil parameters (subsurface)

Sl. No.	Parameters	$K/(Ca+Mg)^{1/2}$	$K/((Mn)^{1/2}+(Al)^{1/3})$	$K/(Ca+Mn)^{1/2}$	$K/((Ca+Mn)^{1/2}+(Al)^{1/3})$	$K/((Fe+Mn)^{1/2}+(Al)^{1/3})$
1	CEC	-0.039	0.195*	0.044	0.063	0.199*
2	Exch. K	0.212*	0.798*	0.752*	0.855*	0.809*
3	Exch. Na	0.152	0.675*	0.499*	0.611*	0.68*
4	Exch. Ca	-0.196	0.257*	-0.271*	-0.123	0.258*
5	Exch. Mg	-0.239	0.253*	-0.144	-0.009	0.25*
6	Exch. Mn	0.173	-0.461*	-0.314*	-0.275*	-0.455*
7	Exch. Fe	-0.049	-0.163	-0.104	-0.141	-0.164
8	Exch. Al	0.103	-0.429*	0.015	-0.137	-0.428*
9	Na. sat	0.183	0.258*	0.445*	0.402*	0.258*
10	Al. Sat	0.082	-0.382*	0.021	-0.135	-0.383*
11	BSP	-0.189	0.556*	0.100	0.226*	0.555*

Table 27. Correlation coefficient of different ionic ratios with respect to Na with soil parameters (surface)

No	Parameters	$Na/(Ca+Mg)^{1/2}$	$Na/(Mn)^{1/2} +(Al)^{1/3})$	$Na/(Ca+Mn)^{1/2}$	$Na/((Ca+Mn)^{1/2} + (Al)^{1/3})$	$Na/((Fe+Mn)^{1/2} + (Al)^{1/3})$
1	CEC	-0.29*	0.177	-0.243*	-0.111	0.185
2	Exch. K	0.248*	0.407*	0.354*	0.435*	0.416*
3	Exch. Na	0.235*	0.479*	0.388*	0.507*	0.491*
4	Exch.Ca	-0.258*	0.192*	-0.162	-0.039	0.199*
5	Exch. Mg	-0.255*	0.217*	-0.101	0.01	0.224*
6	Exch. Mn	-0.072	-0.156	-0.218	-0.171	-0.155
7	Exch. Fe	0.146	-0.166	-0.155	-0.206*	-0.169
8	Exch. Al	0.07	-0.346*	-0.079	-0.177	-0.349*
9	Na. sat	0.595*	0.376*	0.714*	0.683*	0.378*
10	Al. Sat	0.196*	-0.384*	0.044	-0.112	-0.389*
11	BSP	-0.213*	0.514*	0.048	0.177	0.518*

Table 28. Correlation coefficient of different ionic ratios with respect to Na with soil parameters (subsurface)

Sl. No.	Parameters	$Na/(Ca+Mg)^{1/2}$	$Na/(Mn)^{1/2} +(Al)^{1/3})$	$Na/(Ca+Mn)^{1/2}$	$Na/((Ca+Mn)^{1/2} + (Al)^{1/3})$	$Na/((Fe+Mn)^{1/2} + (Al)^{1/3})$
1	CEC	-0.206*	0.174	-0.134	-0.057	0.178
2	Exch. K	0.236*	0.282*	0.365*	0.412*	0.288*
3	Exch. Na	0.258*	0.398*	0.395*	0.465*	0.405*
4	Exch. Ca	-0.189	0.167	-0.083	-0.009	0.172
5	Exch. Mg	-0.185	0.121	-0.093	0.004	0.124
6	Exch. Mn	-0.03	0.23*	-0.151	-0.147	-0.226*
7	Exch. Fe	-0.182	-0.292*	-0.292*	-0.337*	-0.294*
8	Exch. Al	0.002	-0.12	-0.005	-0.073	-0.122
9	Na. sat	0.581*	0.252*	0.631*	0.608*	0.255*
10	Al. Sat	0.123	-0.262	0.05	-0.068	-0.266*
11	BSP	-0.171	0.462*	0.024	0.14	0.463*

* - Significance at 5% level

4.13.3.1.Correlation of different ionic ratios of K with soil parameters

The data pertaining to the ratios of K of surface (Table 25) and subsurface (Table 26) soils are given. The CEC was found to be significantly and positively correlated only with $K/((Mn)^{1/2}+(Al)^{1/3})$ and $K/((Fe+Mn)^{1/2}+(Al)^{1/3})$ ratios in both surface and subsurface soils. Exchangeable Potassium was correlated significantly with all the ratios but the "r" value was highest for $K/((Ca+Mn)^{1/2}+(Al)^{1/3})$ in both the surfaces (r=0.863) and subsurface (r=0.855) soils and the same was lowest for $K/(Ca+Mg)^{1/2}$ (r = 0.623 and 0.212 for surface and subsurface soils respectively). Multiple regression equations with parameters having significant correlation plus the different ratios in the surface soil are given below:

$$Exch.K = 9.14CEC - 0.87PBS + 7.89K/(Ca + Mg)^{1/2} - 48.23 \quad (R^2 = 0.693) \quad (1)$$

$$Exch.K = 11.65CEC - 0.74PBS + 8.89K/(Mn)^{1/2}+(Al)^{1/3} + 45.35 \quad (R^2 = 0.804) \quad (2)$$

$$Exch.K = 11.41CEC + 0.37PBS + 11.86K/(Ca + Mn)^{1/2} - 35.71 \quad (R^2 = 0.765) \quad (3)$$

$$Exch.K = 10.48CEC + 0.13PBS + 16.25K/(Ca + Mn)^{1/2} + (Al)^{1/3} - 24.18 \quad (R^2 = 0.856) \quad (4)$$

$$Exch.K = 11.49CEC - 0.74PBS + 9.26K/(Fe + Mn)^{1/2} + (Al)^{1/3} + 44.55 \quad (R^2 = 0.816) \quad (5)$$

With respect to subsurface samples, multiple regression equations are as follows:

$$Exch.K = 1.57P + 9.07CEC + 6.67K/(Mn)^{1/2}+(Al)^{1/3} - 11.08 \quad (R^2 = 0.725) \quad (6)$$

$$Exch.K = -0.53P + 16.72CEC + 4.68K/(Ca + Mn)^{1/2} + 33.10 \quad (R^2 = 0.481) \quad (7)$$

$$Exch.K = -0.93P + 14.68CEC + 13.6K/(Ca + Mn)^{1/2} + (Al)^{1/3} + 30.98 \quad (R^2 = 0.55) \quad (8)$$

$$Exch.K = -0.33P + 11.79CEC + 6.42K/\sqrt{}(Fe + Mn)^{1/2} + (Al)^{1/3} + 53.65 \quad (R^2 = 0.681) \quad (9)$$

With respect to exchangeable sodium, all the ratios were significantly correlated in surface soil with a minimum "r" value of 0.406 for $K/(Ca+Mg)^{1/2}$. In the case of subsurface samples, exchangeable sodium failed to get significant correlation with $K/(Ca+Mg)^{1/2}$, but it is significantly correlated with all other ratios.

Multiple regression equations for different ratios with exchangeable sodium are represented as follows:

$$\text{Exch.Na} = 10.86\text{CEC} + 1.03\text{PBS} + 5.45\text{K}/(\text{Ca} + \text{Mg})^{1\backslash 2} - 7.58 \qquad (R^2 = 0.44) \qquad (10)$$

$$\text{Exch.Na} = 12.61\text{CEC} - 0.095\text{PBS} + 6.21\text{K}/((\text{Mn})^{1\backslash 2} + (\text{Al})^{1/3}) + 57.36 \qquad (R^2 = 0.53) \qquad (11)$$

$$\text{Exch.Na} = 12.44\text{CEC} + 0.678\text{PBS} + 8.23\text{K}/(\text{Ca} + \text{Mn})^{1\backslash 2} - 0.896 \qquad (R^2 = 0.51) \qquad (12)$$

$$\text{Exch.Na} = 11.78\text{CEC} - 0.514\text{PBS} + 11.18\text{K}/((\text{Ca} + \text{Mn})^{1\backslash 2} + (\text{Al})^{1/3}) + 9.05 \ (R^2 = 0.54)(13)$$

$$\text{Exch.Na} = 12.49\text{CEC} - 0.095\text{PBS} + 6.44\text{K}/((\text{Fe} + \text{Mn})^{1\backslash 2} + (\text{Al})^{1/3}) + 56.69 \ (R^2 = 0.53) \ (14)$$

For the subsurface soil the multiple regression values are as given below:

$$\text{Exch.Na} = 11.49\text{CEC} + 0.088\text{PBS} + 5.95\text{K}/((\text{Mn})^{1\backslash 2} + (\text{Al})^{1/3}) + 50.18 \qquad (R^2 = 0.57) \qquad (15)$$

$$\text{Exch.Na} = 10.65\text{CEC} + 0.89\text{PBS} + 8.73\text{K}/(\text{Ca} + \text{Mn})^{1\backslash 2} - 16.9 \qquad (R^2 = 0.55) \qquad (16)$$

$$\text{Exch.Na} = 9.94\text{CEC} + 0.804\text{PBS} + 12\text{K}/((\text{Ca} + \text{Mn})^{1\backslash 2} + (\text{Al})^{1/3}) - 8.01 \qquad (R^2 = 0.60) \qquad (17)$$

Exchangeable Calcium is significantly correlated with all ratios except $K/((Ca+Mn)^{1/2}+(Al)^{1/3})$ in both surface and subsurface soils. Such correlations were negative wherever Calcium was included in the ratio.

Exchangeable magnesium was correlated significantly only with $K/(Ca+Mg)^{1\backslash 2}$, $K/((Mn)^{1\backslash 2}+(Al)^{1/3})$ and $K/((Fe+Mn)^{1\backslash 2}+(Al)^{1/3})$ both in surface and subsurface soil of which $K/(Ca+Mg)^{1\backslash 2}$, was negative.

Exchangeable Manganese was significantly and negatively correlated with ratios involving Manganese in both the surface and subsurface samples. The magnitude of correlation was found to be less as Calcium was included in the ratio.

Exchangeable Iron was significantly and negatively correlated with $K/((Mn)^{1\backslash 2}+(Al)^{1/3})$ and $K/((Fe+Mn)^{1\backslash 2}+(Al)^{1/3})$ in surface soil, but failed to get any significant correlation in subsurface soil .

Exchangeable aluminium was having significant negative correlation with $K/((Mn)^{1\backslash 2}+(Al)^{1/3})$ and $K/((Fe+Mn)^{1\backslash 2}+(Al)^{1/3})$, both in the case surface and subsurface soils. Percentage sodium saturation was significantly correlated with almost all the ratios in surface and subsurface soils except $K/(Ca+Mg)^{1\backslash 2}$ in subsurface samples.

Percentage aluminium saturation showed almost the same trend of exchangeable aluminium. Percentage base saturation was significantly correlated with, $K/((Mn)^{1/2}+(Al)^{1/3})$, $K/((Ca+Mn)^{1/2}+(Al)^{1/3})$ and $K/((Fe+Mn)^{1/2}+(Al)^{1/3})$ in both surface and subsurface soils.

4.13.3.2.Correlation coefficients of different ionic ratios with respect to sodium to exchange properties of surface and subsurface samples

In order to draw a general on the monovalent to divalent and/or trivalent ionic ratios which would better represent the intensity of monovalent ions, the ratios pertaining to sodium were also computed and correlated with different exchangeable ions. The data are given in Table (27 and 28).

Cation exchange capacity was correlated negatively with $Na/(Ca+Mg)^{1/2}$, $Na/(Ca+Mn)^{1/2}$, in surface samples and only with $Na/(Ca+Mg)^{1/2}$ in subsurface samples.

Exchangeable K and exchangeable Na were significantly correlated with all the ratios; but the" r" values were highest for $Na/((Ca+Mn)^{1/2}+(Al)^{1/3})$ in both surface and subsurface layers.

Multiple regression equations with respect to exchangeable sodium in surface samples are furnished below:

Exch. Na = 14.82CEC + 1.15PBS + 5.42 $Na/(Ca+Mg)^{1/2}$ – 44.37 (R^2=0.46) (18)

Exch. Na = 1.69CEC – 0.69PBS + 7.91 $Na/(Ca+Mn)^{1/2}$ – 32.33 (R^2=0.51) (19)

Exch. Na = 15.67CEC – 0.53PBS + 10.74 $Na/((Ca+Mn)^{1/2}+(Al)^{1/3})$ – 24.03 (R^2=0.54) (20)

The similar equations developed in the case of sub surface soils are,

Exch. Na = - 0.36Av.Fe + 18.03CEC + 7.17 $Na/(Ca+Mn)^{1/2}$ +34.26 (R^2 = 0.43) (21)

Exch. Na = - 0.26Av.Fe + 16.93CEC + 9.84 $Na/((Ca+Mn)^{1/2}+(Al)^{1/3})$ + 26.57 (R^2 = 0.46) (22)

The regression equations for exchangeable K in surface with the inclusion of ratios of sodium to multivalent cations are given below:

Exch.K = 12.97CEC + 0.98PBS + 5.07 $Na/(Ca + Mg)^{1/2}$ – 65.58 ($R^2 = 0.40$) (23)

Exch.K = 10.26CEC + 0.39PBS + 1.99 $Na/((Mn)^{1/2} + (Al)^{1/3})$+ 10.43 ($R^2 = 0.28$) (24)

Exch.K = 14.5CEC + 0.58PBS + 6.77 $Na/(Ca + Mn)^{1/2}$ – 49.78 ($R^2 = 0.41$) (25)

Exch.K = 13.18CEC + 0.46PBS + 8.66 $Na/((Ca + Mn)^{1/2} + (Al)^{1/3})$ – 40.18 ($R^2 = 0.42$) (26)

Exch.K = 10.21CEC + 0.37PBS + 2.13 $Na/((Fe+Mn)^{1/2} + (Al)^{1/3})$ + 10.47 ($R^2 = 0.29$) (27)

And for the sub surface samples, the equations are,

Exch.K = 2.78Av.P +10.8CEC + 0.78PBS + 3.24 $Na/(Ca + Mg)^{1/2}$ – 31.96 ($R^2 = 0.39$) (28)

Exch.K = 3.24Av.P + 9.69CEC + 0.47PBS + 1.25 $Na/((Mn)^{1/2} + (Al)^{1/3})$ + 7.87 ($R^2 = 0.30$) (29)

Exch.K = 2.73Av.P +11.68CEC + 0.55PBS + 5.9 $Na/(Ca + Mn)^{1/2}$ –35.12 ($R^2 = 0.43$) (30)

Exch.K = 2.67Av.P + 11.44CEC + 0.44PBS + 7.48 $Na/((Ca + Mn)^{1/2} + (Al)^{1/3})$ – 29.09 ($R^2 = 0.42$) (31)

Exch.K = 3.24Av.P + 9.68CEC + 0.47PBS + 1.32 $Na/((Fe+Mn)^{1/2} + (Al)^{1/3})$ + 7.75 ($R^2 = 0.30$) (32)

Exchangeable calcium and exchangeable magnesium gave significant correlation with $Na/(Ca+Mg)^{1\backslash 2}$ (-ve), $Na/((Mn)^{1\backslash 2}+(Al)^{1/3})$ and $Na/((Fe+Mn)^{1\backslash 2}+(Al)^{1/3})$ in surface soil, but failed to give any significant correlation with any of the ratios in subsurface soil.

Exchangeable manganese did not yield significant correlations with the ratios in surface soil except with $Na/(Ca+Mn)^{1\backslash 2}$. In subsurface soil exchangeable manganese significantly and positively correlated with $Na/((Mn)^{\backslash 2}+(Al)^{1/3})$ and negatively with $Na/((Fe+Mn)^{1\backslash 2}+(Al)^{1/3})$.

Only $Na/((Ca+Mn)^{1\backslash 2}+(Al)^{1/3})$ gave significant negative correlation with exchangeable iron in surface soil while all the ratios except $Na/(Ca+Mg)^{1\backslash 2}$ were significantly and negatively correlated with exchangeable iron in subsurface samples.

Exchangeable aluminium gave significant negative correlation with $Na/(Ca+Mn)^{1\backslash 2}$ and $Na/((Fe+Mn)^{1\backslash 2}+(Al)^{1/3})$ in surface samples where as it failed to give any significant correlation with these ratios in subsurface samples.

Percentage sodium saturation was significantly correlated with all the ratios in both surface and subsurface soil and " r" value was the highest for the ratio $Na/(Ca+Mn)^{1\backslash 2}$ (0.714 and 0.631 respectively).

Aluminium saturation was significantly correlated with $Na/(Ca+Mg)^{1\backslash 2}$, $Na/((Mn)^{1\backslash 2}+(Al)^{1/3})$ and $Na/((Fe+Mn)^{1\backslash 2}+(Al)^{1/3})$ in surface samples of which the latter two were negatively correlated. In subsurface soil it failed to give significant correlation with $Na/(Ca+Mg)^{1\backslash 2}$, but was having the same significant correlation with $Na/((Mn)^{1\backslash 2}+(Al)^{1/3})$ (r=0.262) and with $Na/((Fe+Mn)^{1\backslash 2}+(Al)^{1/3})$ (r=0.266), as in the case of surface soil.

Percentage base saturation was positively correlated with $Na/(Mn)^{1\backslash 2} + (Al)^{1/3}$ and $Na/(Fe+Mn)^{1\backslash 2}+(Al)^{1/3}$ in both surface and subsurface soils. In addition to this percentage base saturation was negatively correlated with $Na/(Ca+Mg)^{1\backslash 2}$ in both the soils, but it was significant only in surface soil.

4. 14. Soil Fertility Maps

Even though the soil sampling and chemical analysis of the fertility components were on the basis of 80m grid points, data were compiled as most frequently occurring values (mode) for each soil phase. These data are presented in various tables above. Mode values of soil fertility parameters namely organic carbon, available phosphorus, available potassium, and available micronutrients (iron, copper, manganese, and zinc) were attached to the attribute tables of the PC ARC/INFO coverage of the soil map (soil phase map). Thematic maps on each parameter were generated through reclassification

Figure 4.

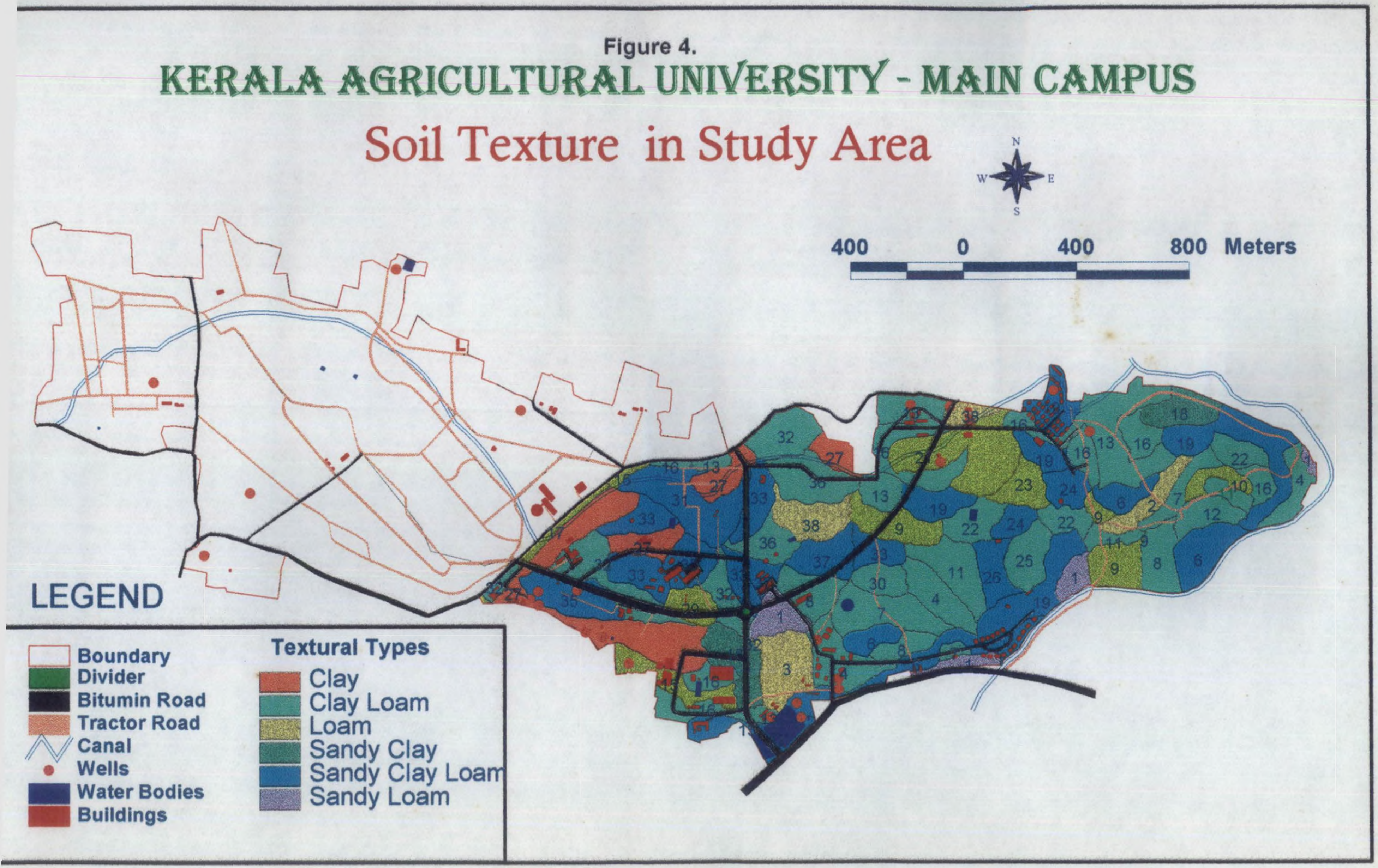

KERALA AGRICULTURAL UNIVERSITY - MAIN CAMPUS
Soil Texture in Study Area
N
W
E
S
400 0 400 800 Meters
LEGEND
Boundary
Divider
Bitumin Road
Tractor Road
Canal
Wells
Water Bodies
Buildings
Textural Types
Clay
Clay Loam
Loam
Sandy Clay
Sandy Clay Loam
Sandy Loam

Figure 5.

KERALA AGRICULTURAL UNIVERSITY - MAIN CAMPUS

Organic Carbon Status in Study Area

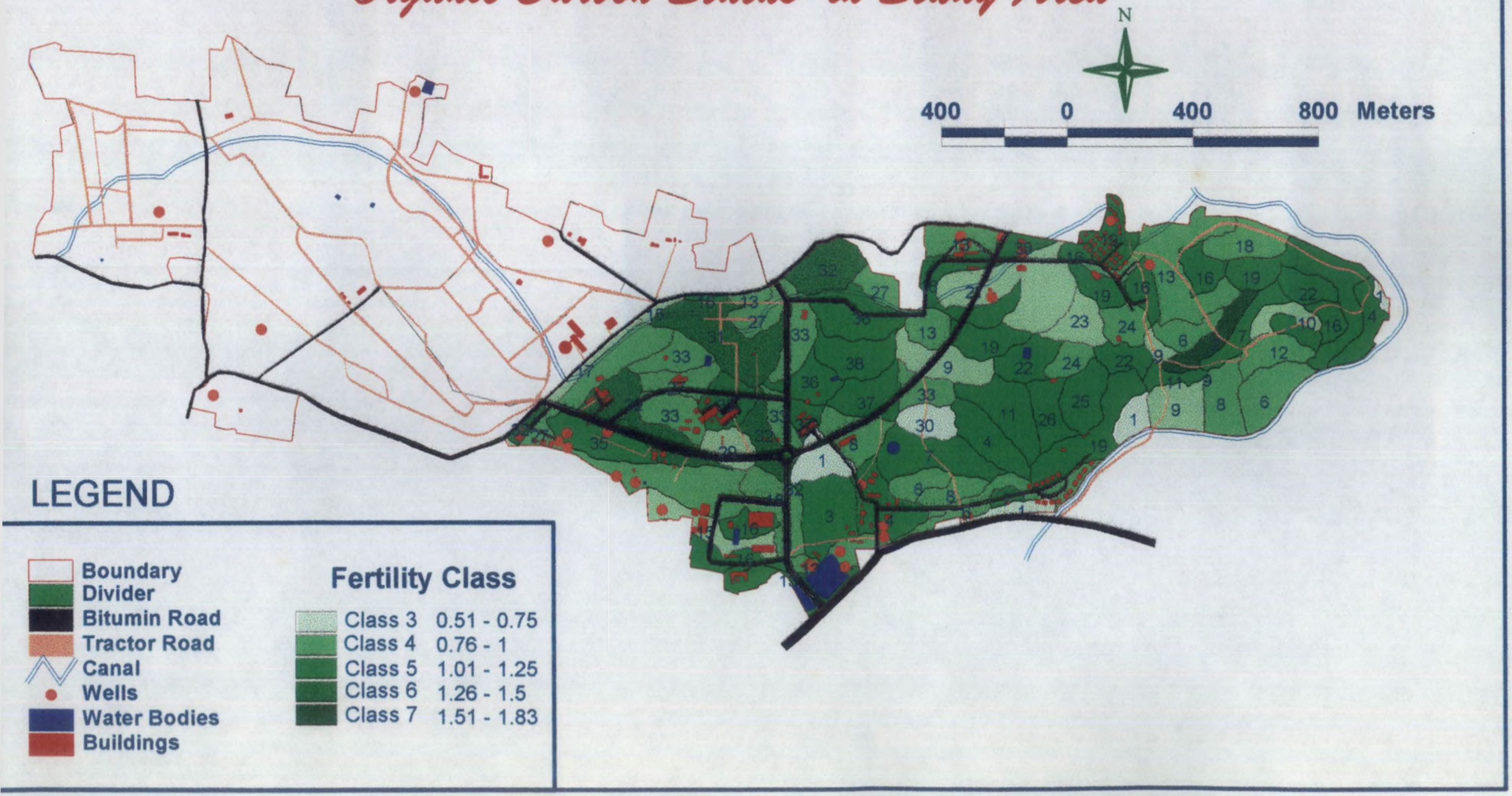


Figure 6.

KERALA AGRICULTURAL UNIVERSITY - MAIN CAMPUS

Available Phosphorus Status in Study Area

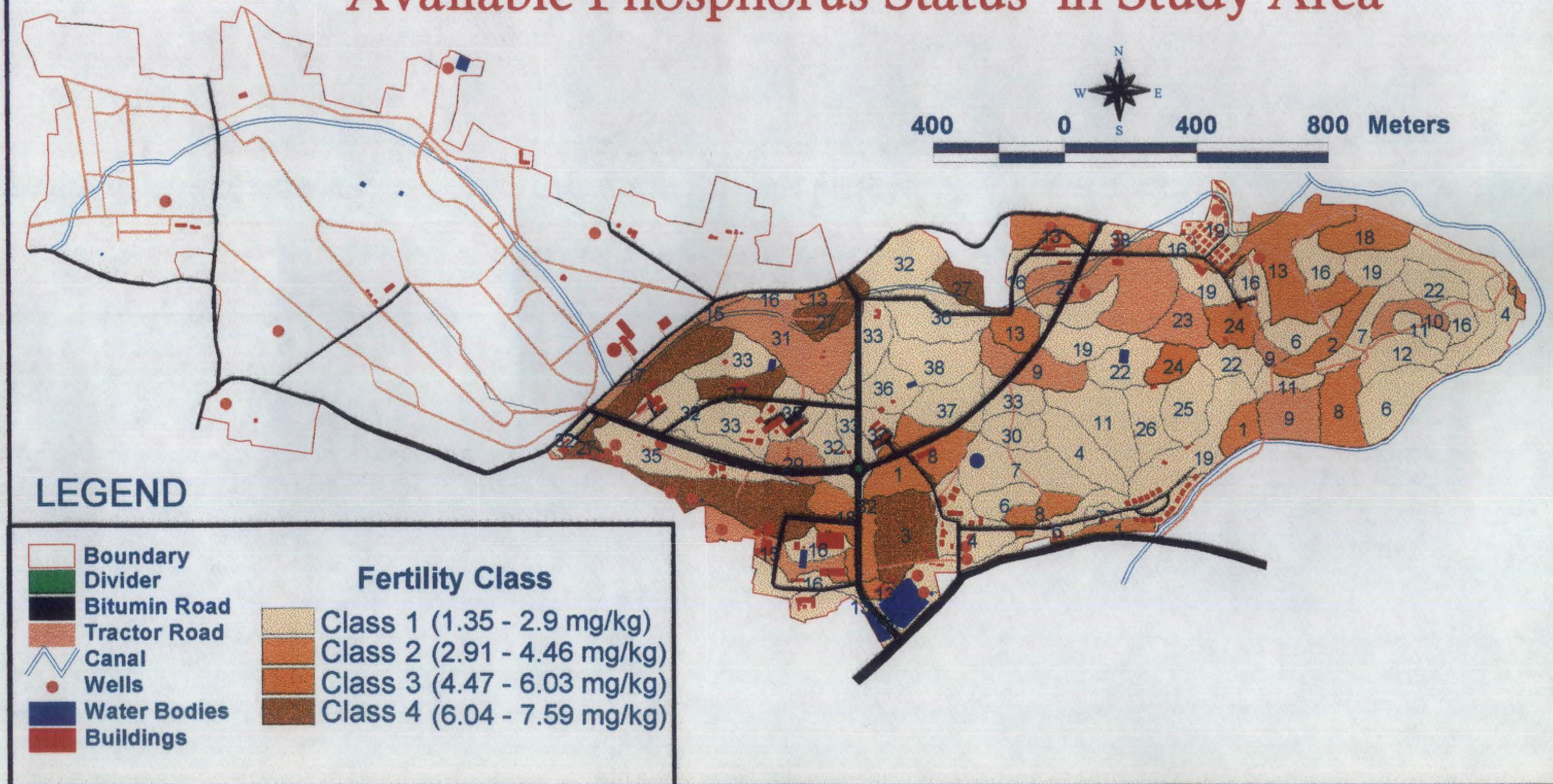
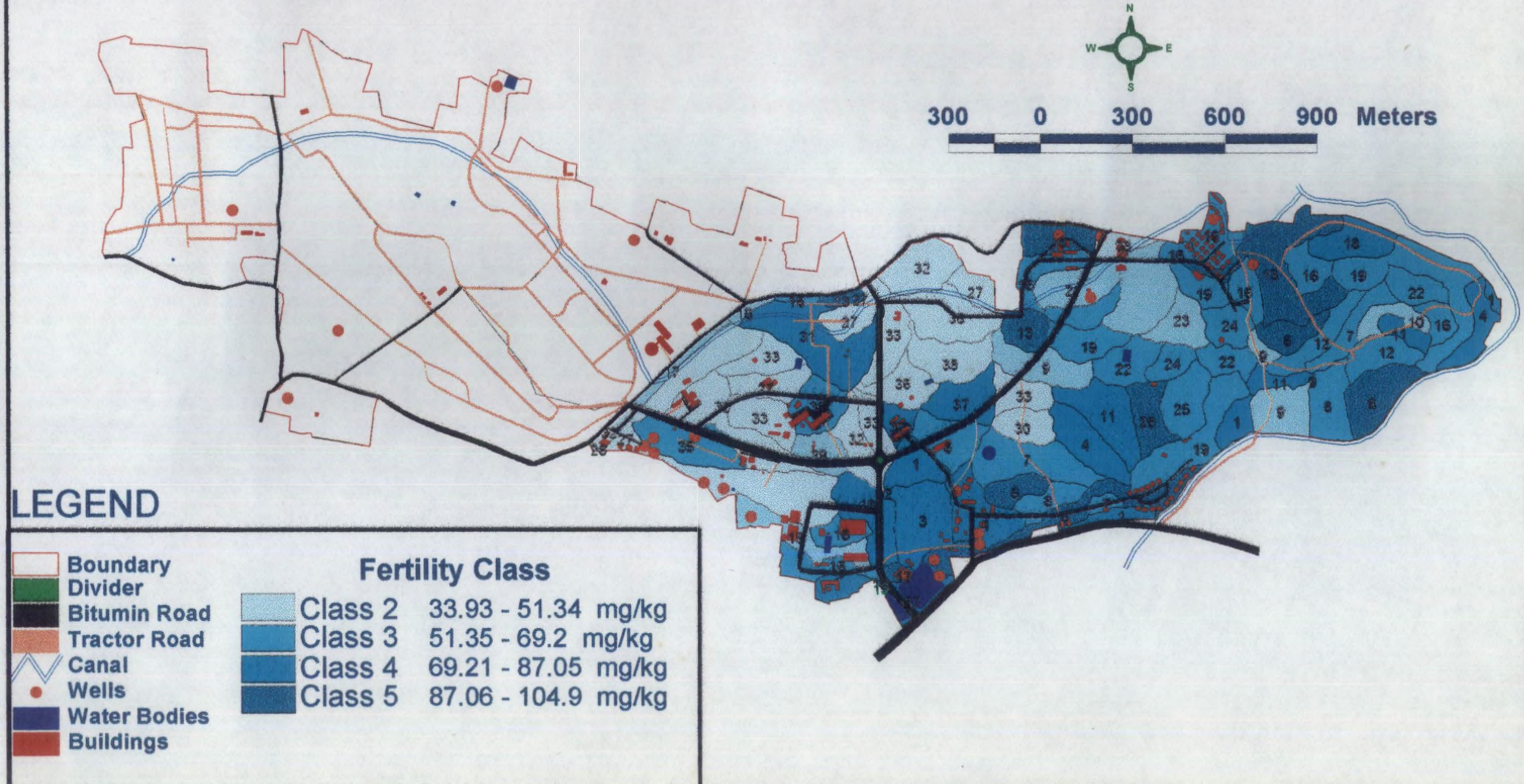


Figure 7.

KERALA AGRICULTURAL UNIVERSITY - MAIN CAMPUS

AVAILABLE POTASSIUM STATUS IN STUDY AREA



technique in the GIS. Range values for reclassification was same as the criteria for soil fertility ratings, presented earlier.

4.13. Fertility Capability Classification (FCC)

Relevant parameters leading to FCC of the soils of the study area are compiled from the data generated and presented in Table 29. Different phases that have FCC limitations with respect to various parameters and the FCC unit for each phase are given in table 30. The Eastern part of the campus poses several limitations for crop production in terms of high gravelliness, 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.

Surface texture of most of the phases was clay loam as derived from mean values of data generated through mechanical analysis of grid samples. Clayey texture was observed on the surface and subsoil parts of phase 27. The substrata type (sub-soil texture) did not vary from type (surface soil texture) except in the case of phases 1, 18, 26, and 32.

Gravel content in both surface and subsurface for all the soil samples were above 35%. CEC was below 4 me/100g in all the phases except phase numbers3, 4, 22, 25, and 26. Aluminium saturation on the topsoil was above 10% in 8 phases out of 23 studied. The mean values for P-fixing capacity were above 50% in all the soil phases. K reserves in exchange complex were below 0.2 me/100g in none of the soil phases. However the values exceeded the FCC limit of 0.2 me/100g only marginally in most of the cases. Another interesting observation was the high Na saturation of the exchange complex. Percentage Na saturation of the effective CEC was less than 15% only in phases 1, 3, 11, 16, 22, 25, 26 and 30. Na saturation exceeded the FCC limit in all other phases.

Moisture regime in the study area was rated ustic since 'the soil moisture control section in 6 or more out of 10 years is dry in some or all parts for 90 or more cumulative days per year. But moisture control section is moist in some part either for more than 180 cumulative days per year or for 90 or more consecutive days'. This criteria is adopted because the mean annual temperature in the study area is above 22^0C. (Soil Survey Staff, 1992). Data on the climatic parameters of the study area are provided in Appendix III.

The slope percentage of the study area is class B (1-3%) to class class G (>33%). The criteria for assigning slope limitations to field crop production (annuals and seasonals) was decided as above 3% slope (class C and above) in the current investigation. Accordingly, several phases in the campus (Table 29) have shown slope limitations as per FCC.

Table . 29. Fertility Capability Classification

.	Phase	Texture		Gravel %		CEC me/100g		Al. Sat. %		P fix. %		Ex.K me/100g		Na sat. %		Moilsture	Slope
		Surface	Sub surface	Surface	Sub Surface	Surface	Sub surface	Surface	Sub surface	Surface	Sub Surface	Surface	Sub surface	Surface	Sub surface		
	1	sl	scl	70.00	44.57	3.75	3.40	7.00	11.00	88.05	86.81	0.240	0.250	14.00	18.00	Ustic	B
	2	l	l	52.75	67.84	3.46	3.49	7.00	9.00	86.91	84.24	0.230	0.230	17.15	18.00	Ustic	B
	3	l	l	57.00	43.97	5.72	5.84	11.05	8.61	90.09	88.40	0.320	0.340	11.00	12.00	Ustic	B
	4	cl	cl	60.00	44.11	4.43	4.23	10.00	9.23	85.21	88.59	0.260	0.260	15.00	15.00	Ustic	C
	6	scl	scl	50.00	25.65	3.32	2.49	10.62	15.27	52.47	54.36	0.240	0.200	15.96	19.73	Ustic	C
	7	cl	cl	70.91	46.03	3.79	3.75	7.00	7.00	88.18	88.09	0.230	0.219	15.00	16.00	Ustic	D
	8	cl	cl	60.00	32.66	3.56	3.69	7.00	5.00	91.18	85.93	0.220	0.210	17.00	15.00	Ustic	D
	11	cl	cl	61.00	47.20	3.92	3.35	9.00	3.00	87.83	88.30	0.230	0.220	12.00	17.00	Ustic	F
	12	cl	cl	81.50	45.43	3.57	3.68	6.08	7.00	87.77	87.50	0.230	0.230	16.62	15.38	Ustic	G
0	13	cl	cl	54.00	32.00	3.44	2.98	7.00	22.00	86.22	84.58	0.230	0.220	17.00	17.00	Ustic	B
1	16	cl	cl	64.00	48.42	3.89	3.81	10.00	10.00	87.95	84.41	0.220	0.200	10.00	12.00	Ustic	C
2	18	sc	scl	40.00	43.39	2.28	2.34	16.00	20.55	72.82	67.13	0.230	0.180	20.76	22.00	Ustic	C
3	22	cl	cl	50.00	46.78	4.15	3.79	5.00	5.00	85.92	88.06	0.240	0.210	14.00	15.00	Ustic	E
4	25	cl	cl	50.00	48.54	4.71	4.73	4.00	6.92	87.06	86.43	0.240	0.250	12.00	12.00	Ustic	F
5	26	scl	cl	68.20	54.05	4.83	5.07	10.27	7.00	88.47	88.65	0.240	0.270	13.00	13.00	Ustic	G
6	27	c	c	58.00	42.66	3.05	2.95	14.00	10.00	76.00	82.67	0.210	0.220	17.00	16.00	Ustic	B
7	30	cl	cl	59.00	38.00	3.78	3.88	7.00	6.00	87.42	86.64	0.200	0.190	13.00	14.67	Ustic	C
8	32	cl	c	61.00	55.30	3.35	3.37	7.00	18.00	87.28	87.42	0.250	0.270	16.00	19.00	Ustic	C
9	33	scl	scl	70.00	46.00	2.93	3.23	10.00	6.00	87.03	85.28	0.220	0.230	16.00	17.00	Ustic	D
0	35	scl	scl	53.00	32.00	2.98	3.16	13.12	12.60	86.74	85.43	0.230	0.240	18.00	16.00	Ustic	D
1	36	cl	cl	61.00	39.67	3.40	3.94	11.00	4.00	85.89	87.85	0.230	0.240	19.00	12.00	Ustic	E
2	37	scl	scl	63.00	34.27	3.84	3.8	9.85	7.00	87.26	86.1	0.230	0.230	15.00	15.00	Ustic	E
3	38	l	l	64.00	44.00	3.61	3.69	3.00	4.00	86.96	87.79	0.200	0.210	15.15	13.00	Ustic	F

DISCUSSION

DISCUSSION

5.1. Gravelliness of the soil samples

The data on percentage gravel in surface soils given in Table 6 indicated that majority of the soil samples varying across the phases were containing substantial amount of gravel. The mean values above 60 per cent would point towards this fact. This would suggest that the surface soil is extremely gravelly in nature , which might be the weathered fragments of crystalline oxides of iron, aluminium and manganese, especially in acid soils. This gravelly nature, though a hindrance to cultivated annual crops, are reported to be productive for growing trees (Miller and Donahue, 1997). The gravelly nature enhances infilteration rate. In cultivated soils the gravelliness might have caused movement of finer soil particles of clay and silt to the sub surface layers. The data in Table 2, with reference to phase 1, which showed that the clay percentage in surface was only 11.69% while that of subsurface layer was 20.88%, provided ample proof for such migration of clay from surface to sub surface layer. This migration even changed the texture from sandy loam to sandy clay loam.

In comparison to the surface samples, the gravelliness of sub surface samples was generally low.

Fine earth percentage also varied accordingly. In the surface layer highest mean value of fine earth percentage was recorded in phase18 (57.5%). Fine earth percentage was comparatively higher in sub surface layer than in surface layer, the highest being in phase 4(82%). This would further support that the migration of fine earth also was more in soils with more gravel in surface soil.

Gravelliness of the soil is one factor which determines the fertility of the soil. Available nutrients will be more in the areas with high content of fine earth but at the same time it was also reported that exchange properties as well as the nutrient release pattern from the total content were dictated by the coarse mineral fragments.

5.2.Textural class

The data are given in Table 7. Twelve phases out of the 23 are clay loam in texture with respect to surface samples while 12 were clay loam in subsurface samples indicating little variations in the textural classes of surface and subsurface soils. There was one sandy loam class in surface soil (phase1), and the corresponding subsurface soil texture was sandy clay loam suggesting migration of clay to a significant degree from surface to subsurface layer as evidenced by the clay contents of surface and sub surface soils of phase 1. This might be favoured by the highest sand content(57.75%) of the sandy loam surface soil. Sandy loam texture was absent in subsurface samples. In almost all other soils, the texture of the surface and subsurface soils were same indicating the migration of clay in phase 1 was exclusively due to its highest content of sand. Due to the occurrence of heavy rainfall mostly clay particles will be migrating downward and sand particle will be dominating in the surface.

5.3.Elecro chemical properties

The data on soil reaction, in table 8 showed that all the soils are acidic in nature in 1:2.5 soil water suspension. The pH of the surface soil ranged from 4.5-6.5 and that of the sub surface soil ranged from 4.2 -6.4. There was no definite trend between surface and sub surface soils in pH. In surface soil, the lowest pH was noticed in phases 22 and 26(4.5). In the case of sub surface soil lowest pH was noticed in phase 26(4.21).

The electrical conductivity (EC) values were very low in most of the soil samples. The buffer pH and the corresponding lime requirement of both surface and sub surface soils given in table 8 suggest that a variation in buffer pH from 6.6 to 5.1 demanded an increase in quantity of pure $CaCO_3$ from 5.3 tonnes to 30.2 tonnes per hectare. This would mean that an increase, in buffer pH, which is an indication of the buffering capacity of the soil with respect to soil acidity, by 1.5 units, increased the lime requirement by 24.9 tonnes per hectare. This lime requirement is the amount of lime required to bring the pH to 7. Many of the crops grown in Kerala prefer slightly acidic range of pH (KAU, 1996)and hence the lime requirement calculated here will be an over estimation. Further, the pH in 1:2.5 soil water suspension, being the measure of intensity or active acidity, the buffer pH in addition will include the capacity or the reserve acidity also. Thus it is evident from the data that though the variation in pH(1:2.5 soil water suspension) was not considerable, the buffer pH and the respective lime requirement varied to a great extent among the soils. In surface samples the highest buffer pH was recorded in phase 33(6.6) and the lowest was in phase 27 (5.2). Buffer pH of the subsurface were also recorded and the highest value was noted in phase 32(6.6) while the lowest was again in phase 27(5.1). Accordingly, the lime required to raise pH of the surface soil to neutrality was highest in phase 27(28.5t ha^{-1}) and was lowest in phase 33(5.3 t ha^{-1}). The lime requirement of the subsurface soil varied from 5.3 t ha^{-1} in phase 32 to 30.2 t ha^{-1} in the same phase that of surface soil, phase27.

5.4. Major nutrients

The data on organic carbon, available phosphorus and available potassium content in surface and subsurface soils are given in Table 9.

5.4.1. Organic carbon

Organic carbon contents in sub surface samples were lower than surface samples except in four phases(Phases25,26,30 and 35). This is so since the maximum deposition of organic matter will be on the surface soil. However the higher content of organic carbon in the sub surface in a few phases as mentioned above might lead to the conclusion that in areas of seasonal crops like vegetables, the manures were applied in pits in sub surface layer. More over when these areas were fallowed after the cropping season organic carbon might have lost by oxidation under tropical climate from the surface layer. Further, the loose texture of the surface layer, namely sandy loam or sandy clay loam with more gravel content as in these phases mentioned above, might have caused easy leaching of humus and its subsequent accumulation in lower layers. Deepa (1995) also reported such accumulation of organic matter in sub surface layers of soils of RARS campus, Pattambi. Organic carbon in the surface soil ranged from 0.105 -2.035% with a highest average of 1.78% in phase 2. In the sub surface layer organic carbon ranged from 0.424-2.095%. Highest organic carbon content was recorded in phase 2 both in the case of surface and sub surface soil (2.035 and 2.095, respectively). The lowest content of organic carbon was recorded in phase 1 with respect to surface (0.417%) and in phase 27 with respect to subsurface soils (0.424%). The higher level of organic carbon to the tune of 2% or more was attributed to exclusively rubber plantations where the recycling was higher. In these soils there is not much difference in the organic carbon content between the surface and subsurface soils.

The fertility status with respect to organic carbon as detailed in table 10 would indicate that 91 % of the surface samples were under medium nutrient class in the fertility rating. About 7% were under high and only about 2% were under low fertility classes. In the subsurface samples also about 90% were included in the medium class, about 7% were under high fertility and only 3% were under low fertility class.

On phase based evaluation, the mean values of organic carbon for the surface soils in table 9 showed that no phase was coming under low category; only one phase was there in high level and the remaining 22 phases were categorised as medium. The data on subsurface samples also showed the same trend as that of surface samples.

These results would point to the fact that the soils of the study area are coming mainly under medium fertility with respect to organic carbon. Since the nitrogen status is mainly governed by the organic carbon, it could be concluded that these soils are moderate N suppliers, which is not the general situation of tropical lateritic soils which in turn are generally poor in organic carbon and hence in nitrogen. As these medium levels of organic carbon could be easily deteriorated under tropical warm humid climate, a constant vigil with respect to fertility evaluation and maintenance or improvement of its level becomes inevitable.

5.4.2. Available Phosphorus

The data on available phosphorus content in table 9 ranged across the phases from 1.25 to 19.16 $\mu g\ g^{-1}$ in the surface layer. In the sub surface layer also the available phosphorus content range was in the similar tune as that in the surface layer and the same was 1.04-17.08 $\mu g\ g^{-1}$. A critical analysis of the data showed that the available P content in the surface samples were higher than that of subsurface layers in 12 phases while the reverse trend was true in the remaining 11 phases. However, a comparison of the surface and lower layers would lead to the conclusion that the magnitude of increase in P content was more in case of surface soils having higher P than those of the sub surface ones having higher content. This is further supported by the data on fertility rating (Table 10) which showed that most of the surface and subsurface soils were coming under low class. In the surface soils, 78% of the samples were under low class and in subsurface soils, 84% were under low category. 17% and 13% of the surface and sub surface samples respectively were medium in fertility while 5% of the surface samples and 3% of the subsurface were coming under high fertility class.

The mean values of available phosphorus content of different phases given in table 11 showed that of the 23 phases, 20 were rated as low and only 3 came under medium, both in surface and subsurface soils. There were no phases in high fertility category with respect to phosphorus.

Phosphorus fixing capacity of soil samples was given in table 15. Relatively high phosphorus fixing capacity was observed in our soils. There is only slight variation in the phosphorus fixing capacity of surface and subsurface soils. Irrespective of the layers, the P-fixing capacity varied from 40 to 90 per cent. The mode and mean values for P-fixing capacity, in majority of phases were above 80 per cent.

The low available P status in laterite soils, in spite of continuous application of fertiliser P, was reported by many workers. (Deepa, 1995; Krishnakumar,1991). This was due to the extremely high P- fixing capacity of lateritic soils which in turn resulted from dominance of 1:1 type of clay as well as from high content of sesqui-oxides. Such results reported elsewhere (Deepa, 1995) also, would lead to many practical problems in fertility management. The lack of improvement of available P content from low levels even after continuous application of P fertilizer, might cause lack of response to applied P. This would further lead to the accumulation of phosphorus – though not in readily available form- which in turn cause antogonostic interactions with other elements such as zinc, calcium, magnesium *etc*. This in particular was true for zinc which was reported to be deficient in acid lateritic soils (Sureshkumar, 1999). Since total P status was already accumulated to high levels, skipping of P fertilisers might be chosen as one of the management practices since the applied P is not leached out as in the case of N or K and as the solution concentration of P depletes by plant uptake, some of the fixed P might get released to maintain the equilibrium. This may further reduce the zinc immobilisation and enhance zinc availability. Thus it become necessary to adopt careful and judicious management practices so as to get maximum efficiency with respect to P utilization and to reduce its negative effects of interactions with other elements.

5.4.3. Available Potassium

Available potassium content in the surface layer ranged from a minimum value of 20.00 μg g^{-1} in phase 36 to a maximum of 192.00 μg g^{-1} in the same phase. The contents of available potassium in the subsurface soil varied from 16.00 μg g^{-1} in phases 27 and 36 to 192.00 μg g^{-1} in phase 1.

The fertility classes would indicate that among the soil samples analysed, 64.64% of the surface samples and 62.62% of subsurface samples were under medium fertility. Also 30.3% of surface samples and 33.33% of subsurface sample were coming under low fertility class and 5.05% of surface samples and 4.04% subsurface samples were in high fertility class.

The mean values for available potassium for phases given in table 11 showed that all the 23 phases irrespective of the depth of sampling fall under medium fertility group.

A perusal of the above data points to the fact that at least 65% of the area under the present study is sufficiently supplied with potassium. At the same time about 30% of the samples were analysed low in available K. Phase wise analysis showed that all the phases were medium in fertility. These results might be due to the fact that the area under study are under well managed conditions with application of K fertilisers as per the recommended doses required by different crops. However due to different cropping sequences especially fallowing after a seasonal crop like vegetables, might have caused leaching losses of potassium in loose textured low K-fixing soils which could cause low fertility rating in some of the samples. This would suggest that cropping with good management practices along with fertiliser application could maintain at least, if not improved, the K status of the soil. But, heavy doses of potassium recommended as a management technique for improvement of lateritic environment for better yields was reported by many workers. From this view, the present level of K may have to be improved further. Anyhow this aspect is to be considered in relation to the performance of individual crops.

A comparison of the data from the present study with that of earlier one given in Appendix IV (Soil Survey Staff, 1976), indicate that there is not much variation in organic carbon level or the same could almost be maintained. In case P, the level of which was rated low throughout the area in the earlier study, has improved to medium and high at least in 20% of the area. But the remaining 80% of the area are still under low fertility, which is solely due to high rate of fixation. This would indicate that even after 24 years of continuous application of fertiliser could not improve the available P status. Research should now focus on reviewing and refinement of the management techniques to improve the release pattern of fixed P to the labile pool in these type of soils. With respect to available K the study area was rated low in fertility, has now changed to medium in 65% of the area which indicate that area is under good management practices.

5.5.Secondary nutrients

The data on calcium and magnesium content of the soil extracted by neutral normal ammonium acetate are given in Table 12.

5.5.1.Available calcium

In both surface and subsurface soils calcium was dominating magnesium with respect to the content. The calcium content in the surface soil varied from 11.00 to 367.50 $\mu g\ g^{-1}$ and that of subsurface soil from 15.00-339.50 $\mu g\ g^{-1}$. The lowest calcium content in both the layers were recorded in the same phase. The data shows that there is not much variation in depth wise distribution of calcium. But, between the samples the calcium status varied very widely even to the tune of 22 to 33 times as shown between the minimum and maximum values of both surface and subsurface layers. Such high variation might be due to difference in levels and their combinations of other cations, especially that of potassium, iron, aluminium and manganese and also due to the difference in the degree of leaching which might be a function of slope.

5.5.2. Available Magnesium

The content of magnesium showed that it varied from 16.40 to 46.62 μg g^{-1} in surface soil and from 16.75 to 46.10 μg g^{-1} in subsurface soil. The variation in magnesium content among the soils was comparatively much less than that in case of calcium. The content was also less in majority of samples than that of calcium. The lowest magnesium content was slightly higher than that of calcium; but the values were recorded in different phases.

5.6. Available micronutrients

The available micronutrients were extracted using 0.1M HCl since this extractant was reported to be most widely used in acid soils.(Sims and Johnson, 1991). The DTPA extractant of Lindsay and Norwell (1978) was originally proposed for neutral to alkaline soils and hence not used in the present study.

5.6.1. Available manganese

The content of manganese given in table 13 ranged from 8.80-184.80 μg g^{-1} in surface and 11.10 μg g^{-1} to 151.00 μg g^{-1}in subsurface samples. The results on available manganese in tables 13 and 14 clearly indicate, though there is considerable variation in the content between samples, all the samples recorded a manganese content far above the critical range. The level is so high to expect toxicity and yield limiting influences to crops. This may also cause adverse interactions with other nutrient elements like phosphorus. In the subsurface samples manganese content was slightly lower than surface soil, indicating a trend for accumulation of manganese in the surface soil which is a characteristic of the process of laterisation. In the phase wise evaluation also the manganese content showed the same trend.

5.6.2.Available iron

The data on 0.1M HCl extractable iron (Table 13 and 14) pointed out that it varied from 12.30 to 98.70 μg g^{-1} among the surface samples analysed and the range was from

10.30 to 65.70 μg g^{-1} in sub surface soils. With respect to the rating as per the critical range, all the samples analysed irrespective of the depth, were falling above the critical level.

The phase wise mean values also showed that all phases were above the critical level. The available iron content as in the case of manganese was high which is expected in tropical lateritic soils as these ions accumulate during the process of laterisation. But the available fraction of iron was comparatively less than that of manganese. This might be due to the formation of insoluble iron oxides like haematite, magnetite etc. under aerobic upland condition.

5.6.3.Available zinc

With respect to the zinc status of soil (Table 13), both the surface and subsurface soils contain only low amounts of zinc. In the surface samples available zinc varied from 0.10-5.90 μg g^{-1} and the same was ranging from 0.10- 5.40 μg g^{-1} in subsurface samples. From the data in Table 7, it could be concluded that 83% of the surface and 91% of the subsurface samples were below the critical range. 14% and 8% of the surface and subsurface samples respectively were in the critical range and only 2% and 1% of the surface and subsurface samples respectively were falling above critical level.

The mean values of available zinc in table 13 showed that 20 phases were under below critical level for both surface and subsurface soils. The remaining 3 phases fall in the critical range from both the surface and subsurface soils.

A critical analysis of the data opened up the fact that major parts of the study area are deficient in available zinc. This might be due to lack of application of zinc fertiliser, which is expected here. Further, whatever native zinc or zinc recycled or added through organic manure might get precipitated as zinc phosphates as discussed in 5.4.2. The availability and absorption of zinc was also found to be adversely affected by excess of iron and/or manganese (Sureshkumar, 1999).

5.6.4.Available copper

The variation in copper content as shown in Table 13 was from 1.69 to 38.65 μg g^{-1} in surface soil and was from 1.71 to 48.50 μg g^{-1} in sub surface samples. Surface samples recorded a higher content of copper than subsurface samples except in four phases (phase 2,8,11,18,33).

The critical range for copper is identified as 1.00-2.00 μg g^{-1} (Sims and Johnson, 1991). Only five samples from surface soil and 3 samples from subsurface soil were in critical range but193 surface and 195 subsurface samples were above the critical range. The phase wise average values given in table 13showed all the phases were high in fertility status.

The data indicate that the copper supplying power of the soil was generally high. This would mean that addition of copper through organic manure and copper containing pesticides might be enough to satisfy the requirements. However chances of toxicity to sensitive crops may not be ruled out.

5.7.Exchangeable cations

Exchangeable cations (calcium, magnesium, sodium, potassium, iron, aluminium and manganese) were estimated from 0.1M $BaCl_2$ extract and are given in Tables 16 and 17. The data on exchangeable calcium, magnesium, sodium and potassium extracted by neutral normal ammonium acetate are also provided in table 9 and 12. A comparison of the data with respect to 0.1M $BaCl_2$ and neutral normal ammonium acetate are given in tables 18 and 19.

5.7.1.Exchangeable calcium

Among the exchangeable cations, calcium was the dominant divalent cation both in surface and subsurface layers. The $BaCl_2$ exchangeable calcium content varied between 35.00 μg g^{-1} (0.18 cmol(+) kg^{-1}) and 826.00 μg g^{-1} (4.13 cmol(+) kg^{-1}) in surface soil. In subsurface samples it varied from a minimum of 49.00 μg g^{-1} (0.25 cmol(+) kg^{-1}) to a maximum of 954.30 μg g^{-1} (4.77 cmol(+) kg^{-1}). The corresponding values for ammonium acetate exchangeable calcium were 11.00 to 367.50 μg g^{-1} (0.055 to 1.84 cmol(+) kg^{-1}) in surface soil and 15.00 to 339.50 μg g^{-1} (0.075 to 1.7 cmol(+) kg^{-1})(Table 12).

The data indicate that the exchangeable calcium is low but in comparison with other ions, it is the dominant ion in the exchange phase. The low content of exchangeable calcium is due to the loss of much of this basic cation in the laterites. A perusal of the data on exchangeable calcium extracted by $BaCl_2$ and ammonium acetate (Tables 18 and 19) shows that the latter extracted only about 25 to 50 per cent of that extracted by the former. This data clearly point to the fact that barium being divalent and with better replacing power as against the monovalent NH_4 ion naturally extract more Ca from the exchange complex. More over the calcium held by the pH dependant charges are more loosely held under acidic conditions which can be extracted easily by unbuffered salt solutions like that of $BaCl_2$. At the same time the ammonium acetate is buffered to neutral pH conditions under which Ca is more strongly bound and the extracting ion (NH_4) is weak also.

5.7.2.Exchangeable magnesium

Exchangeable magnesium determined from 0.1M $BaCl_2$ extract presented in table 16 shows that its value ranged from 11.90- 109.80 μg g^{-1} (0.098-0.91 cmol(+) kg^{-1}) in surface samples. Among the subsurface samples the value ranged between 14.00 μg g^{-1} (0.12 cmol(+) kg^{-1}) and 116.50 μg g^{-1} (0.96 cmol(+) kg^{-1}). The exchangeable Mg extracted by neutral normal ammonium acetate ranged from 16.42 to 46.62 μg g^{-1} (0.13 to 0.38 cmol(+) kg^{-1}) in surface and from 16.75 to 46.10 μg g^{-1} (0.14 to 0.38 cmol(+) kg^{-1}) in sub surface samples(Table 12).

The exchangeable Mg is very low and it shows the same trend as that of calcium with respect to the quantity extracted by the two extractants. However the percentage saturation of magnesium in the exchange phase is much less when compared to calcium. It was also observed that in soils with very low amount of exchangeable Ca, the exchangeable magnesium was slightly higher.

5.7.3.Exchangeable potassium

The exchangeable potassium content extracted by both the extractants is given in tables 16,17, 18 and 19 respectively. Among the surface samples analysed, the barium chloride extractable K ranged from a maximum of 162.00 μg g^{-1} (0.41 cmol(+) kg^{-1}) to a minimum 22.00 μg g^{-1} (0.06 cmol(+) kg^{-1}). The corresponding values for ammonium acetate extracted potassium were 20.00 to 192.00 μg g^{-1} (0.05 to 0.50 cmol(+) kg^{-1}). In the subsurface samples exchangeable potassium extracted by $BaCl_2$ ranged from 52.00 μg g^{-1} to 164.00 μg g^{-1} (0.13 to 0.42 cmol(+) kg^{-1}) where as the ammonium acetate extractable potassium varied from 16.00 to 192.00 μg g^{-1} (0.04 to 0.5 cmol(+) kg^{-1}).

A critical evaluation of the data shows that there is not much variation in the exchangeable pool of potassium from which both the reagents extracted K. This would mean that exchangeable potassium is held mainly by pH independent native surface charges.

5.7.4.Exchangeable sodium

The content of exchangeable sodium was comparatively higher in this extract in comparison with that of potassium and this increase in content of sodium was found to be more in surface than in subsurface soil. In the surface samples the 0.1M $BaCl_2$ extractable sodium ranged from 46.00 to 230.00 μg g^{-1} (0.20-1.00 cmol(+) kg^{-1}) and that of ammonium acetate extractable sodium varied from 11.04 to 89.43 μg g^{-1} (0.05 to 0.39 cmol(+) kg^{-1}) as shown in Table 28. In subsurface samples the respective values for sodium extracted by $BaCl_2$ varied from 72.00 μg g^{-1} to 228.00 μg g^{-1} (0.31-0.99 cmol(+) kg^{-1}) and that by ammonium acetate arranged from 11.40 to 99.30 μg g^{-1} (0.05 to 0.432 cmol(+) kg^{-1}).

The data revealed that the fraction of sodium extracted by $BaCl_2$ was 2 to 6 times more than that extracted by ammonium acetate. This would indicate that sodium is either saturated on the pH dependant surface charges as that of calcium which is better replaced by barium or, ammonium ion could not be able to overcome the hydration energy of sodium ion which in turn make it impossible to replace Na^+. (Mengel and Kirckby, 1987).

The latter statement would appear more realistic when the data on exchangeable Na were compared with that of potassium because if the variation were due to pH dependent charges, a corresponding increase in exchangeable potassium with respect to sodium should have been there as in the case of the contents of these elements in ammonium acetate extract. Since the hydration energy of potassium is low in comparison with that of sodium and the same is similar to that of ammonium ion, NH_4^+ could replace potassium but not the sodium ion from the exchange sites. However this can be proved conclusively only by further in depth study of fractions and exchange characteristics of these ions.

5.7. 5.Exchangeable manganese

Exchangeable manganese content extracted by 0.1M $BaCl_2$ as given in Table 16 and 17 shows that it varied from 8.00- 289.30μg g^{-1} (0.03-1.05 cmol(+) kg^{-1}) in surface and from 3.10 to 278.30 μg g^{-1} (0.01-1.01 cmol(+) kg^{-1}) in subsurface samples. Manganese is the second dominant ion after calcium as indicated by the data on exchangeable ions. In acid lateritic soils accumulation of iron, aluminium and manganese is expected as the bases are leached out under high rainfall. Naturally these ions should dominate the exchange phase. In the present study it is manganese out of these ions that is more in exchange surfaces. The data on available micronutrient cations in Table 13 also support this result.

5.7.6.Exchangeable iron

The data on exchangeable iron given in tables 16 and 17 in surface and subsurface samples ranged from 1.00-7.70μg g^{-1} (0.004-0.028 cmol(+) kg^{-1}) and 0.60-9.00 μg g^{-1} (0.002 –0.03 cmol(+) kg^{-1}). Unlike exchangeable manganese, exchangeable iron content is very low in both surface and subsurface layers. Though the total and available iron content are high in laterite soils, the present data would reveal that iron practically does not exist in the exchangeable fraction and it might rather prefer to exist as crystalline oxides especially under aerobic upland conditions. Similar results were reported by Sureshkumar(1993).

5.7.7.Exchangeable aluminium

The content of exchangeable aluminium ranged from 11.88-67.75 $\mu g\ g^{-1}$ (0.13-0.75 cmol(+) kg^{-1}) in surface soil and 7.25-73.38 $\mu g\ g^{-1}$ (0.08-0.82 cmol(+) kg^{-1}). The exchangeable aluminium content were more than that of iron but less than exchangeable manganese.

Normal ammonium acetate (pH 7) failed to extract aluminium to any detectable limits. This result further support the argument that buffered extractants like neutral normal ammonium acetate may not give correct results with respect to exchangeable ions in acid soils and hence the CEC.

Thus on comparison of the data on exchangeable ions it can be concluded that, of the ions contributing the soil acidity manganese is the dominating ion followed by aluminium. The contribution of exchangeable iron to this effect is negligible in the present study area.

In the phase wise determination, exchangeable manganese, exchangeable calcium, exchangeable sodium and exchangeable potassium showed the highest values in phase 3, both in the case of surface samples and subsurface samples ,except for exchangeable magnesium in subsurface . For exchangeable magnesium the highest value was in phase 32.

5.8.Cation exchange capacity (CEC)

Cation exchange capacity of the surface soil ranged from 1.55 cmol(+) kg^{-1} soil to 8.04 cmol(+) kg^{-1} while that of subsurface samples varied from 1.56 cmol(+) kg^{-1} soil to 8.54 cmol(+) kg^{-1} soil. The CEC was generally low in both surface and sub surface soils. Since the soil is dominated by 1:1 type kaolinitic clay minerals the CEC is expected to be low. Further an interesting observation with respect to CEC is that the minimum as well the minimum mean values were in the same phase (phase 18) both in surface and sub surface soils. So also about the respective maximum values noted in phase 3. An in depth analysis of the data indicated that the same trend was observed in the case of exchangeable calcium and since calcium being the dominant ion in exchange phase dictated the CEC also.

5.9. Sodium saturation

The data presented in Table 18 indicate that percentage sodium saturation values were considerably high ranging from 5.56% to 28.66% in surface samples and it was varying from 9 to 25 % in sub surface samples. About 50% of the phases showed higher sodium saturation in surface samples than subsurface samples. The data might cause mis-interpretation since exchangeable sodium percentage in majority of the cases well exceeds 15%, which, is one of the criteria for existence of sodicity. But none of the location in the present study showed any hint for development of sodicity. Such a misleading conclusion arouse because of the fact that, though, the percentage sodium saturation is above 15%, the absolute quantity of sodium in the exchange sites is low especially in comparison with calcium and is not enough to make any impact on properties influencing structural stability and/or pH of the soil. More over the CEC of the soil itself is very low. Thus it becomes very clear that in soils with low CEC and pH, expression of exchangeable sodium in absolute quantities rather than in terms of percentage saturation would be meaningful and appropriate and helps in avoiding misleading conclusions. Cook and Muller (1997) also opined that exchangeable sodium content was a better index of soil sodicity than exchangeable sodium percentage.

5.10.Aluminium saturation

Table 18 provides the data on per cent aluminium saturation. In the case of surface samples the percentage varied from 2.69% to 36.25% . For the subsurface samples the content varied from 2.63% to 28.09%. As in the case of per cent sodium saturation, here also, expression of aluminium saturation on percentage basis, might lead to mis-leading conclusion since the percentage saturation is in relation to the total CEC and hence it might be silent about the actual quantity per unit weight of soil.

In the case of surface samples sodium saturation and aluminium saturation were found to be minimum in the same phase *viz.* in phase 38 and the corresponding maximum values were also in a single phase (phase18). This was also to be looked into in relation to the exchangeable calcium content. The higher the exchangeable calcium content, the lower should be the sodium and/or aluminium content and the same observation was made from the present data.

5.11. Percentage base saturation

Percentage base saturation is an expression of the amount of exchangeable basic cations as percentage of total CEC of the soil. The data on this parameter as presented in table varied in the surface samples from 53.52% to 94.12%. In the case subsurface samples percentage base saturation varied from 57.64% to 94.10%. The mode and mean values in the table would suggest that most of the samples analysed were found to get saturated with bases to the tune of 70 per cent or more of the CEC. A further analysis of the data indicated that of this about 50 percent is by calcium alone and only about 20 per cent or less saturation was by sodium in most of the samples. This calcium saturation levels might be another reason why the percentage sodium saturation, though higher than 15 %, could not affect the aggregate stability as that usually occur in sodic soils, where, the calcium saturation might be very low. This is in accordance with the observations of Brady (1996). However these soils under the present study are acidic and hence the buffering capacity of these soil must be greatly influenced by exchangeable acidic cations such as H^+ and different oxidation states of Al, Mn, and Fe contributing to soil acidity. In the present study, the total contribution of acidic ions to CEC comes to about 20 to 30 percent, which in turn was computed by considering Al as in trivalent, Mn and Fe as in divalent states of oxidation. In actual situation, these ions especially Mn and Al were found to influence the properties to a great extent especially in ionic interactions and hence nutrient availability.

5.12.Studies on interaction of different soil parameters

5.12.1.Surface samples

The correlation coefficients given in Table 21 shows that exchangeable ions have no significant correlation with soil pH. This might be expected since the soils under the present study were acidic in nature and the variation in pH was between 4.5 to 6.5. Though this change in pH of two units might have influenced the pH dependant charges, the variation was not enough to reflect on getting significant correlation with exchange properties. With respect to organic carbon, only exchangeable manganese was correlated significantly and negatively. Exchangeable manganese was the dominant ion in acidic environment of the present study in comparison with other cations. As organic carbon increased in soil which is an indication of increase in organic matter might have complexed the manganese ion from both solution and exchange sites. Regarding cation exchange capacity, except exchangeable iron and aluminium, all other ions were highly correlated. Exchangeable iron content was very low in comparison with other ions and hence failed to get any correlation with CEC. Aluminium was correlated with CEC and only failed to attain significance. All other exchangeable ions contributing to CEC got significant correlation with it. With respect to sodium saturation, except exchangeable potassium and aluminium, all other ions were significantly and negatively correlated. This would indicate that as the exchangeable sodium content increases, it would be at the expense of other ions at the exchange sites, which might get replaced by sodium. This was further clarified by the significant positive correlation of exchangeable sodium with that of percentage sodium saturation. Exchangeable ions other than iron and manganese were having significant correlation with aluminium saturation. All these correlations were negative except that for exchangeable aluminium for which it was significant and positive. As in the case of sodium saturation, the explanations are similar here also. Similarly all ions were significantly correlated with per cent base saturation except iron, of which, exchangeable manganese and aluminium were negatively correlated.

5.12.Subsurface samples

In the case of sub surface samples, exchangeable calcium was significantly correlated with phosphorus fixing capacity. Since calcium occupying the major part of the exchange sites, an increase in calcium content can cause an increase in P fixation in the form of tricalcium phosphate. For cation exchange capacity exchangeable calcium, magnesium, potassium and manganese were found to be highly correlated. Exchangeable aluminium was correlated significantly and negatively with cation exchange capacity. The CEC generally increases with increase in pH due to the consequent increase of pH dependent charges while the exchangeable aluminium, iron and manganese will be more in low pH conditions. Hence these ions could have a negative effect on CEC. With respect to percentage sodium saturation the results shows the same trend as that in surface soil. The interaction of percentage aluminium saturation as well as percentage base saturation followed the same pattern as in the case of surface soil.

5.13.2.Micronutrient interactions with soil parameters

5.13.2.1.Surface samples

With exchangeable ions only a few micronutrients were correlated significantly; *viz.* iron was negatively correlated with exchangeable sodium; manganese correlated with exchangeable manganese positively and zinc with exchangeable aluminium in a negative manner.(Table 23). The negative correlation of iron with exchangeable sodium might be due to the fact that as the exchangeable sodium content increases iron might have got precipitated and made unavailable. The significant correlation of available manganese with exchangeable manganese would indicate that this fraction of exchangeable manganese might have mainly contributing to the available pool.

5.13.2.2.Subsurface samples

Available manganese and copper were having significant correlation with subsurface organic carbon, (Table 24) which was absent in surface soil. The lack of correlation of available micronutrients with CEC remains unexplained. Available iron was having negative correlation with exchangeable sodium. Zinc and phosphorus fixing capacity were significantly correlated with exchangeable calcium. As the exchangeable calcium increases, P fixation also increases by formation of tricalcium phosphate which in turn might have released zinc from insoluble zinc phosphate. Such a conclusion is well supported by the significant positive correlation of zinc with pH. In general the availability of zinc increases with decrease in pH. But in the present study, the trend is in the reverse manner. Thus in soils of high P fixing capacity, it is the P fixing capacity which is rather controlling zinc availability than the pH. The significant positive correlation with exchangeable magnesium and negative correlation with exchangeable aluminium also support this view.

5.13.3. Interaction of P fixing capacity with soil parameters

P fixing capacity was found to be significantly correlated with CEC, silt and clay percentage in both surface and subsurface soils. The influence of CEC on P fixation might be due to the effect of the increase in content of exchangeable calcium and magnesium which is well supported by the positive correlation of P fixing capacity with pH, while that of silt and clay might be due to the increase in 1:1 type of clay mineral which is the dominating secondary mineral in the soils of the present study.

5.13.4.Correlation of different ionic ratios with soil parameters

The ratios of monovalent ions (K^+ and Na^+) to divalent Ca, Mg, Fe and Mn and trivalent Al were calculated separately for the surface and subsurface samples. These ratios attain significance since the availability of these ions to the plants depends on the relative activity of these ions in exchange – solution equilibria, which in turn is governed by the ratio law (Schofield, 1947). The availability is directly related to the intensity factor, more specifically the relative intensity which is nothing but the intensity of one ion in relation to the levels of the other ions which in turn influence the availability of the ion in question . Accordingly, Beckett (1964) observed the intensity factor of K, if expressed as $K/(Ca+Mg)^{1/2}$, is more meaningful and realistic. Similarly, the intensity of sodium is represented as $Na//(Ca+Mg)^{1/2}$. This is true in the case of neutral to alkaline as well as in calcareous soils. However, in acid soils also, these ratios were considered as the respective intensities. But if we consider, Al, Mn and Fe in acid soils as the multivalent ions, – the exchange complex of which is more saturated by these ions- it will give a clearer picture.

5.13.4.1Correlation of different ionic ratios of K with soil parameters

The data pertaining to the ratios of K of surface and subsurface soils are given in Tables 25 and 26.

A comparison of the regression equations 13.1 through 13.5 would indicate that almost 86% of the variation in exchangeable potassium in surface soils could be explained by including $K/((Ca + Mn)^{1/2} + (Al)^{1/3})$ along with CEC and PBS (Equation 13.4). When calcium was removed from the above ratio the resulting equation predicted 80% of the variation (13.2). When calcium was replaced by iron in the equation the prediction value slightly increased to 82%. (13.5). When Al was removed (*viz* $K/(Ca + Mn)^{1/2}$, the regression coefficient was 0.765 and when only the $K/(Ca + Mg)^{1/2}$ was considered the probability of prediction reduced drastically to 61%. Thus it is clear from the above observations that the relative intensity of potassium could be more realistic if computed by considering the dynamics with respect to the content of manganese, aluminium and iron in that order. It was also shown that the commonly considered intensity ratio of $K/(Ca + Mg)^{1/2}$ attained little significance under the acidic environment. The most realistic ratio to express intensity of K appears to be $K/((Ca + Mn)^{1/2} + (Al)^{1/3})$, which means that Ca being the dominant ion could control potassium activity but only in association with Mn and Al.

In sub surface soils, instead of percentage base saturation, available phosphorus was included in the regression equations along with CEC and ionic ratios. However even in the case of $K/((Mn)^{1/2} + (Al)^{1/3})$ the variability could be predicted to 73%.(Equation 6). When calcium was included, the R^2 value reduced 0.55 (Equation 8). When calcium in the equation was replaced by divalent iron R^2 improved to 0.68 (Equation 9). Exclusion of Al and Fe with only considering Ca and Mn could predict only 48 % of the variability(Equation 7).

The above trend would indicate that, when percentage base saturation was significantly correlated with exchangeable potassium, as in surface soils, calcium which was the most dominant ion in the exchange phase could predict the variation in potassium along with Mn and Al. But when this correlation was comparatively not significant, as in sub surface soil calcium became insignificant in controlling exchangeable potassium and it was Mn and Al along with Fe which dictated the amount of potassium. In both cases it is clear that Mn and Al play influencing impact on exchangeable potassium under acid lateritic soil environment.

With respect to exchangeable sodium, all the ratios were significantly correlated in surface soil with a minimum "r" value of 0.406 for $K/(Ca + Mg)^{1/2}$. In the case of subsurface samples exchangeable sodium failed to get significant correlation with $K/(Ca+Mg)^{1/2}$, but it is significantly correlated with all other ratios. In both cases, it was found that the inclusion of Mn and Al resulted in better prediction of variability. Addition of Ca or Fe could not improve the regression coefficient. It was also observed that as in the case of potassium exchangeable Ca and Mg and hence the ratio of K/ $(Ca + Mg)^{1/2}$ had very little or no role in predicting the sodium variability.

5.13.4.2.Correlation coefficients of ratios of different ions with respect to Sodium to exchange properties of surface and subsurface samples

The regression analysis of the data would indicate that CEC, PBS and different ratios could predict the variation in exchangeable sodium in surface samples significantly. Among the ratios, it was found that Na/ $(Ca + Mg)^{1/2}$ could give only 45% of variation while Na/$(Ca + Mn)^{1/2}$ predicted the variation with a better accuracy to the tune of 51% and the same was still improved to 54% when Na/($(Ca + Mn)^{1/2}$ + $(Al)^{1/3}$) was included in the equation. In sub surface soil, the ratio Na/$(Ca + Mg)^{1/2}$ was not able to predict the exchangeable sodium content. These results further substantiate that in the soils of the present study area, a better index of intensity factor of sodium would be either Na/$(Ca + Mn)^{1/2}$ or Na/($(Ca + Mn)^{1/2}$ + $(Al)^{1/3}$). This was exactly similar to the results obtained in the case of relation of exchangeable potassium with ratios with respect to potassium. Thus the dominant ions in the exchange phase or in the solution phase together should be considered in computing the relative intensity of a single ion in that phase which in turn decide the dynamics of that ion

5.15. Fertility Capability Classification

Analytical results of FCC parameter (Table 29) and their rating according to the criteria designed for current study (Table 5) have revealed that the eastern part of main campus requires judicious management of soil fertility. FCC units derived from various parameters are given in Table 30. Soils in these areas are deep to very deep and therefore a root restricting layer is not encountered within 50cm from the surface.

The term topsoil refers to plough layer or the top 20cm of soil and subsoil, encompasses the depth interval between topsoil 50cm depth.

Most of these areas in the eastern side of campus are cultivated. However the subsoil texture did not vary much from the top soil texture, probably because of the plantation crops predominant in the area. Substrata type was considered only in four cases out of 23 soil phases studied. Surface texture was clay loam in 12 of phases studied. Very small patches of clayey soils are also observed. This analysis is based on mechanical analysis of fine earth (<2mm) fractions. But it must be noted that gravel percentage in all the samples were more than 35 which is a fertility modifier according to FCC system of interpretation. This part of the campus experiences draught conditions even if rainfall is not available for a couple of weeks. Owing to the high gravel content in the surface and subsurface, even the clay loam and sandy clay loam are subjected to high infiltration and leaching of nutrients.

The resulting from the above, and due to the rainfall pattern in area (Appendix I), the soil moisture control section remains dry for more than 90 cumulative days in these area. Therefore FCC modifier 'd' (dry) is applicable to this part of the campus, which rubber plantation can withstand periodical irrigation for realizing maximum yield.

The nutrient retention capacity as expressed by CEC was very low in all the phases studied except in phases 3,4,25 and26 where the CEC was marginally above the FCC unit of 4me/100g. The modifier 'e' (low CEC) therefore applies to this area indicating possible leaching of K, Ca and Mg. Heavy applications of these nutrients and nitrogen fertilizers should be in split doses. According to Sanchez *et al.* (1982), low CEC points to potential danger of over liming. However, the study area is acidic in nature (pH 4.5-6.5, Table 5) and the modifier 'h' is introduced since most of the samples comprise >10% Al saturation of the effective CEC both in top soil and subsoil. Even though toxicity of Al is not experienced, high levels of Al in exchange complex contribute to lowering of pH (Brady, 1996) and therefore the modifier 'h' (acidic) is introduced in 10 out of 23 phases studied. Liming may be necessary in these soils, especially if Al sensitive crops are grown.

High iron and aluminium content of these soils lead to fixation of P as phosphate of these elements. P fixing capacity observed in the top soils and sub soils were more than 50% in all the phases. Criteria for counting P fixing capacity as one of the modifiers was taken as more than 50% in the current study. Accordingly all the phases possess limitations leading to the modifier 'i' (high P fixation).

K reserves in the exchange complex in general showed low values (Table 27). But the FCC limit of 0.2me/100g was not observed only in phase 30. This phase along with others which require fertilizer, supplementing potassium especially when oil yielding crops like coconuts are grown.

The percentage sodium saturation of CEC exceeds the FCC limit of 15% in many cases. Even though the soils does not express sodic properties, presence of high amounts of sodium in exchange complex would effect availability of other nutrients like potassium. Even though many of soil phases under study can be grouped under natric as per FCC, this modifier can't be considered for soil amendments, since soil reaction is acidic and soil is well drained. Presence of considerable amounts of sodium in the exchange complex and its consequent influence on nutrient availability and other soil characteristics need further investigation.

Another important modifier observed in 18 out of 23 phases studied was the slope percentage. Since most of the area is under tree crops and other perennials, the current land use may not lead to significant soil degradation. However, if annuals or other field crops are to be grown, these areas should be subjected to soil conservation measures like terracing or contour bunding.

FCC units are derived for each soil phase by combining modifiers identified along with type and substrata (Table 30). This will serve as a composite interpretation guideline for soil fertility management of the eastern part of the campus. The soils are in general, light textured even though they are sandy clay loam, together with high content of gravel these soils are quick drained and have poor moisture retention qualities, resulting in dry conditions for considerable part of the year. Hence if the area is cultivated under rainfed conditions tree crops or draught tolerant crops are recommended. If the area is irrigated, fertilizers and other soil amendments must be administered in split doses. Low CEC, acid condition, high P fixing capacity and low K reserves are the other modifiers which need judicious management.

Table 30. Fertility Capability Classification - Final Table

Sl. No.	Soil Phase	Type	Substrata Type	MODIFIERS															
				Gley	Soil moisture regime	CEC	Aluminium Toxicity	Acidity	P fixation	Allo phane	Verti sol	K reserves	Basic	Salinity	Natric	Cat Clay	Gravel "	Slope %
1	1	S	S	*	d	e	*	*	i	Not studied	Not applicable	k	*	*	*	*	"	*
2	2	L	L	*	d	e	*	*	i			k	*	*	n	*	"	*
3	3	L	L	*	d	*	*	h	i			k	*	*	*	*	"	*
4	4	C	C	*	d	*	*	h	i			k	*	*	n	*	"	%
5	6	S	S	*	d	e	*	h	i			k	*	*	n	*	"	%
6	7	C	C	*	d	e	*	*	i			k	*	*	n	*	"	%
7	8	C	C	*	d	e	*	*	i			k	*	*	n	*	"	%
8	11	C	C	*	d	e	*	*	i			k	*	*	*	*	"	%
9	12	C	C	*	d	e	*	*	i			k	*	*	n	*	"	%
10	13	C	C	*	d	e	*	*	i			k	*	*	n	*	"	*
11	16	C	C	*	d	e	*	h	i			k	*	*	*	*	"	%
12	18	S	S	*	d	e	*	h	i			k	*	*	n	*	"	%
13	22	C	C	*	d	e	*	*	i			k	*	*	*	*	"	%
14	25	C	C	*	d	*	*	*	i			k	*	*	*	*	"	%
15	26	S	C	*	d	*	*	h	i			k	*	*	*	*	"	%
16	27	C	C	*	d	e	*	h	i			k	*	*	n	*	"	*
17	30	C	C	*	d	e	*	h	i			*	*	*	*	*	"	%
18	32	C	C	*	d	e	*	*	i			k	*	*	n	*	"	%
19	33	S	S	*	d	e	*	*	i			k	*	*	n	*	"	%
20	35	S	S	*	d	e	*	h	i			k	*	*	n	*	"	%
21	36	C	C	*	d	e	*	h	i			k	*	*	n	*	"	%
22	37	S	S	*	d	e	*	*	i			k	*	*	*	*	"	%
23	38	L	L	*	d	e	*	*	i			k	*	*	n	*	"	%

SUMMARY

SUMMARY AND CONCLUSIONS

The present study was conducted in the main campus of Kerala Agrl. university, Vellanikkara. The study mainly concentrated on the resource potential of the campus with respect to soil resource. Here an attempt has been made to evaluate the physical, chemical and electrochemical properties of the soil. For that purpose soil samples were collected at $80m^2$ grid size both from surface and subsurface layers. Various analysis were carried out to find out the properties of soil using standard procedures as described in the materials and methods. Important results of the study along with the conclusions are given below:

1. Soil samples collected from different parts of the campus were predominantly gravelly in nature both in the case of surface and subsurface samples.

2. In the textural analysis majority of the phases were coming under the texture clay loam. In majority of the phases irrespective of depth, surface and subsurface were coming under same textural classes.

3. In general almost all the soils were acidic in nature. This may be due to the high rainfall and subsequent leaching.

4. Electrical conductivity of the soil samples was found to be very low both in the case of surface and subsurface soils.

5. Buffer pH was estimated to find out the lime requirement of the soils. it was found that buffer pH varied widely among the samples and so also the lime requirement .

6. Organic carbon content recorded very low values irrespective of the depth of soil analysed. An increase in organic carbon content with depth was observed in a few phases. Almost 91% of the surface and 90% of the sub surface samples analysed were medium in fertility, 7 per cent each of the surface and sub surface samples were coming under high fertility class and the remaining 2 and 3 per cent were low in organic carbon status.

7. Available phosphorus content recorded low values in almost all the samples both in the case of surface and subsurface soils. 78% of surface and 84 %of sub surface samples were

rated as low in fertility while 17 and 13 % were medium in fertility and only 5 and 3 per cent of the samples from surface and sub surface were high in fertility.

8. The results revealed that about 63 to 65 % of soils were coming under medium in soil fertility with respect to available potassium.

9. Available calcium and available magnesium content showed a wide variation depending on the degree of leaching.

10. Available micronutrients namely manganese, zinc, copper, and iron were extracted using 0.1M HCl and contents was in the order as Mn > Fe > Cu > Zn both in the case of surface and subsurface soil layers. Of these Mn, Fe and Cu in almost 98% of the samples showed values far above the critical ranges reported where as available zinc content was below critical range in 80 to 90 % of the samples. Only 8 to 14 % were coming within the critical range.

11. P fixing capacity of the soil was estimated and it was observed that all the soils of the study area were high in P fixing capacity. This is due to the high content of oxides of iron and aluminium under acidic 1:1 mineral dominated soil environment.

12. All the exchangeable ions present in the soil *viz.* Calcium, Magnesium, Sodium, Potassium, Iron, Manganese and Aluminium were determined using 0.1M $BaCl_2$ and found that Calcium formed the predominant cation both in the case of surface and subsurface soils. The exchangeable ions were in the order Ca > Na > Mn > K > Mg > Al >Fe.

13. CEC of the soil ranged widely both in the case of surface and subsurface soils from about 1.5 to 8 cmol (P+) kg^{-1} .

14. Sodium saturation was observed very high in the case of both surface and subsurface soils; in many cases exceeding 15 % and yet not showing any sodicity due to low CEC and pH.

15. Percentage base saturation of the soil vary widely from about 36 to 96 % and it was found that major part was contributed by exchangeable calcium.

16. The regression analysis of the data revealed that the relative factor for exchangeable K and Na with respect to other multivalent ions could be better expressed as $K/(Ca + Mn)^{1/2} + (Al)^{1/3}$ ions.

17. The Eastern part of the campus poses 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.

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* Originals not seen

APPENDICES

APPENDIX - I

MONTHLY AVERAGE WEATHER PARAMETERS OF VELLANIKKARA

(Jan 1990 – April 2000)

1990	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
Max. Temperature	33.5	34.9	36	34.8	31.5	29.7	28.4	29	30.7	31.9	31.2	32.3
Min. Temperature	20.8	21.9	23.8	25.4	24.1	23.3	22.5	23	23.4	23.2	22.6	23.1
Rainfall (mm)	2.5	0	4.4	38.8	583.9	477.3	759.3	356.4	37.5	313.3	69.8	1.8
Rainy days	0	0	1	2	18	25	28	22	8	12	3	0
R H (am)	65	80	81	83	92	93	94	94	91	92	87	72
R H (pm)	34	36	46	53	72	76	82	75	65	69	62	45
Sunshine (hrs)	9	10	9.7	8.3	4.5	3.4	2.4	3.5	6.2	6.5	6	10.2
Wind speed (Km/hr)	10	8.4	5.4	5.2	4.4	4.4	3.9	3.8	2.8	2.4	4.2	9.5
1991												
Max. Temperature	33.6	35.9	36.4	35.6	35.1	29.7	29.1	29	31.5	30.5	31.5	31.9
Min. Temperature	22.2	21.7	24.9	24.5	25.5	23.8	22.8	22.7	23.7	23.2	23	21.7
Rainfall (mm)	3.9	0	1.8	83.3	86.1	993.1	975.6	583.2	61.5	281.7	191.3	0.2
Rainy days	1	0	0	4	5	28	27	24	7	14	9	0
R H (am)	74	74	84	83	85	94	94	95	91	90	87	78
R H (pm)	41	28	47	53	55	82	79	78	64	74	63	49
Sunshine (hrs)	10.9	4.1	8.7	8.9	7.5	4.8	2.5	2.8	7.3	4.3	7.1	8.6
Wind speed (Km/hr)	4.5	4.5	4.9	4.7	4.5	4.8	4.6	3.6	4.2	3.7	6.1	9.8
1992												
Max. Temperature	32.6	35.5	36.9	36.3	33.8	30.5	28.8	28.9	30.1	30.7	31	31.1
Min. Temperature	28.9	21.8	22.8	24.4	24.8	23.7	22.7	23.3	23.1	22.1	23.1	22.3
Rainfall (mm)	0	0	0	48.6	90.6	979.8	874.5	563.9	302.9	386.7	377.5	2
Rainy days	0	0	0	3	6	22	26	25	17	14	12	0
R H (am)	69	87	84	82	85	92	95	94	91	92	86	72
R H (pm)	36	42	38	48	61	77	80	81	73	72	68	49
Sunshine (hrs)	9	9.2	9.2	8.8	7.4	3.3	2.1	2.7	4.1	4.6	5.5	8.9
Wind speed (Km/hr)	11.7	5	5	4.8	4.4	5.3	4.3	4.3	3.8	3.2	5.8	13.7

(Continued..........)

APPENDIX - I (............Continued)

MONTHLY AVERAGE WEATHER PARAMETERS OF VELLANIKKARA

(Jan 1990 – April 2000)

1993	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
Max. Temperature	32.6	34.1	35.4	34.5	34.4	13.1	28.5	29.6	30.6	30.7	31.7	31.6
Min. Temperature	20.7	22	23.7	25	25.8	23.9	22.9	23.4	23.1	23.4	23.6	23.1
Rainfall (mm)	0	6.6	0	32.1	131.1	700.3	661.6	287.7	85.3	519	74.6	18
Rainy days	0	2	0	2	6	22	29	20	9	16	4	2
R H (am)	71	78	81	83	86	94	93	95	93	91	82	76
R H (pm)	35	42	44	55	61	77	80	78	68	74	64	55
Sunshine (hrs)	8.1	9.4	9	9.1	6.5	6.3	2.4	4.8	6.4	4.8	5.8	7.5
Wind speed (Km/hr)	10	7.8	6.	5	5	4.5	4.6	4.5	3.8	3.6	7.4	10.5
1994												
Max. Temperature	32.9	34.8	36.2	34.9	33.6	28.9	28.6	30	31.8	32.3	31.8	32.2
Min. Temperature	22.6	23.1	23.7	24.4	24.7	22.9	22.4	22.8	23.2	23.7	23.3	22.2
Rainfall (mm)	19.4	1.7	21	165.2	624.2	954.1	1002.1	509.2	240.5	358.2	125.3	0
Rainy days	1	0	1	10	7	27	29	20	8	20	5	0
R H (am)	74	79	79	88	88	96	96	95	92	92	77	71
R H (pm)	42	38	38	59	61	83	85	75	64	68	58	45
Sunshine (hrs)	9.1	8.7	9.3	8	8	2.1	1.4	3	7.3	6.7	8.1	10.6
Wind speed (Km/hr)	10.5	6.3	5.6	4.3	4.5	4.2	5	2.1	3.5	3.4	7.9	7.9
1995												
Max. Temperature	32.9	35.4	37.6	36.6	33.5	31.6	29.9	30.6	30.1	33.2	31.3	32.5
Min. Temperature	22.4	23.4	23.8	24.9	23.9	23.1	23.2	23.7	23.5	23.2	22.5	21.3
Rainfall (mm)	0	0.5	2.8	118.1	371.5	500.4	884.7	448.7	282.5	110.4	88.4	0
Rainy days	0	0	0	5	13	19	26	22	13	8	5	0
R H (am)	76	79	83	87	91	94	96	99	94	91	91	71
R H (pm)	41	41	37	55	65	77	81	78	70	65	69	43
Sunshine (hrs)	9.6	10	9.3	9.1	6.5	3.7	2.1	3.7	6.1	8.3	6.5	10.3
Wind speed (Km/hr)	9.1	6.5	4.4	4	3.8	10.1	1.7	2	2	1.8	1.1	6.7

(Continued............)

APPENDIX - I (............Continued)

MONTHLY AVERAGE WEATHER PARAMETERS OF VELLANIKKARA

(Jan 1990 – April 2000)

1996	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
Max. Temperature	33.1	34.7	36.4	34.6	32.8	30.5	28.8	29.1	29.2	30.1	31.5	30.5
Min. Temperature	22.4	23.4	24.3	25	25.2	23.8	23.1	23.6	23.7	22.9	23.6	21.8
Rainfall (mm)	0	0	0	152	95.6	400.3	588.7	310	391.6	219.3	23.1	60.8
Rainy days	0	0	0	7	4	16	25	20	17	12	2	2
R H (am)	71	72	82	87	91	94	96	95	94	93	84	80
R H (pm)	35	34	37	59	63	75	83	78	74	70	59	55
Sunshine (hrs)	9.4	9.9	9.3	8.3	7.7	4.7	2.7	3.7	4.3	6	7.1	6.7
Wind speed (Km/hr)	7.1	5.9	3.6	3	2.4	3	2.7	3	2.7	2	3.7	6.4
1997												
Max. Temperature	32	33.9	35.7	35.2	34.2	31.2	28.6	29	30.6	32.2	31.6	31.7
Min. Temperature	22.9	21.8	24	24.5	24.5	23	21.8	22.8	23.4	23.6	23.2	22.8
Rainfall (mm)	0	0	0	8.2	63	720.5	979.2	636.8	164	194.7	211.3	66.7
Rainy days	0	0	0	1	4	18	28	23	13	12	7	2
R H (am)	78	82	82	83	87	93	95	95	93	88	88	83
R H (pm)	45	39	37	50	57	71	84	78	71	65	67	61
Sunshine (hrs)	9.6	9.3	9.6	9.4	6.7	5.9	1.9	3.4	6.8	7.3	5.3	7.5
Wind speed (Km/hr)	6.9	3.9	4	3.3	3.3	2.7	4.6	2.8	2.5	2.6	2.9	5.9
1998												
Max. Temperature	38.1	34.4	36.2	36.5	35.1	30.2	29.2	29.8	30.2	32.2	31.5	30.1
Min. Temperature	22.8	23.6	23.6	25.6	25.2	23.2	23.6	23.9	23.3	23.6	23.1	22.9
Rainfall (mm)	0	0	11	61.4	203	809.3	752.9	433.6	571.3	194.7	109.4	33
Rainy days	0	0	1	4	9	21	28	18	24	12	9	4
R H (am)	78	77	86	86	90	94	96	95	96	88	92	79
R H (pm)	49	51	47	50	63	79	80	77	78	65	64	58
Sunshine (hrs)	9.3	9.6	10	9	7.6	3.4	3.3	3.6	4.1	7.3	7.2	6.6
Wind speed (Km/hr)	6.6	5.2	3.4	3.1	2.6	2.7	2.8	2.5	2	2.1	1.7	5.7

(Continued............)

MONTHLY AVERAGE WEATHER PARAMETERS OF VELLANIKKARA

(Jan 1990 – April 2000)

1999	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
Max. Temperature	32.4	34.5	35.5	33.4	30.7	29.4	28.4	29.8	31.6	30.5	31.4	30.7
Min. Temperature	21.5	23.3	24.5	25.6	24.7	23	23	22.9	23.4	23.2	22.7	22.7
Rainfall (mm)	0	22.8	0	39	430.5	500.2	823.3	260.1	28.4	506.2	9.1	0
Rainy days	0	1	0	4	18	23	28	12	3	15	1	0
R H (am)	76	77	88	88	92	94	96	94	89	94	81	72
R H (pm)	40	35	48	58	72	75	82	73	63	75	57	48
Sunshine (hrs)	9.3	9.1	8.8	10.3	4.9	5	2.4	4.5	7.1	4.8	8.2	8.8
Wind speed (Km/hr)	6.5	5.1	3	3.3	3	2.5	2.5	2.3	2.1	1.6	3.6	6.6
2000												
Max. Temperature	32.9	33.3	35.6	34	33.7	29.6	28.8					
Min. Temperature	23.2	22.8	23.9	24.6	24.4	22.8	21.9					
Rainfall (mm)	0	4.6	0	67.9	117.2	602.0	354.3					
Rainy days	0	1	0	3	8	21	15					
R H (am)	76	85	87	89	88	94	93					
R H (pm)	43	52	46	59	56	77	70					
Sunshine (hrs)	9.2	8.6	9.7	7.2	8.5	3.3	4.8					
Wind speed (Km/hr)	7.1	3.7	9.7	2.6	2.9	3.1	3.8					

APPENDIX - II

Description of Soil series of Vellanikkara I, II and III

Typifying Pedon:- Vellanikkara I- Clay loam- cultivated

Horizon	Depth (cm)	Description
A1	0-8	Reddish brown(5YR 4/4);clay loam; medium, moderate, sub angular blocky structure: firm, slightly sticky and slightly plastic; plentiful roots; minute quartz gravels present; clear smooth boundary; moderate permeability
B21	8-23	Dark reddish grey (5YR 4/2);clay loam; moderate, medium, sub angular blocky structure; firm, slightly sticky and slightly plastic; plentiful roots; minute quartz gravels present; clear smooth boundary; moderate permeability
B22	23-130+	Yellowish red(5YR 4/6); silty clay; strong coarse, sub angular blocky structure; firm, sticky and plastic ;few fine roots; minute quartz gravels present; moderately slow permeability

Typifying Pedon:- Vellanikkara II- Clay loam- cultivated

Horizon	Depth(cm)	Description
A1	0-15	Dark reddish brown(5YR 3/3);clay loam; medium, moderate, sub angular blocky structure; firm, sticky and plastic ;plentiful roots; clear smooth boundary; moderate permeability
B32	15-60	Yellowish red(5YR 4/6);silty clay ; moderate, medium, sub angular blocky structure: firm, slightly sticky and slightly plastic; difffuse wavy boundary ;moderate permeability
C	60+	Admixture of laterite and weathered gneiss

Typifying Pedon :- Vellanikkara III - clay loam - cultivated.

Horizon	Depth(cm)	Description
A1	0-18	yellowish red(5YR 4/6);silty clay loam; medium, moderate, sub angular blocky structure; firm, slightly sticky and slightly plastic; plentiful roots; moderate permeability; clear smooth boundary
B21	18-64	Reddish brown(5YR 4/4);silty clay; medium, moderate, sub angular blocky structure: firm, slightly sticky and slightly plastic; plentiful roots; moderate permeability; clear smooth boundary
B22	64-100	Yellowish red(5YR 4/8);silty clay; medium, moderate, subangular blocky structure, firm, sticky and plastic ;few roots; moderate permeability; diffuse wavy boundary
C	100+	Laterite mixed with soil.

APPENDIX - III

Raw data generated by physico-chemical analysis

Sample No.	Type	*Code	Phase	Gravel %	Fine earth %	sand %	silt %	clay %	Textural class	pH	EC dS/ m	Buffer pH	Org.C (%)
1	s	1 / 1A	13	67.00	33.00	47.36	15.89	36.74	Sandy Clay	5.10	0.660	6.0	0.98
2	ss	1 / 1B	13	22.66	77.34	52.08	17.22	30.70	Sandy Clay Loam	5.06	0.660	5.8	0.83
3	s	1 / 2A	13	86.00	14.00					5.30	0.220	5.4	0.90
4	ss	1 / 2B	13	26.60	73.40					5.16	0.220	5.8	0.75
5	s	1 / 3A	13	61.00	39.00					4.81	0.880	5.8	0.11
6	ss	1 / 3B	13	48.66	51.34					4.99	0.880	6.0	1.01
7	s	1 / 4A	13	54.00	46.00					4.83	0.660	6.2	0.80
8	ss	1 / 4B	13	32.00	68.00					5.37	0.110	5.9	1.05
9	s	1 / 5A	13	47.00	53.00					5.26	0.990	5.9	0.81
10	ss	1 / 5B	13	33.37	66.63					4.93	0.550	5.7	0.84
11	s	1 / 6A	16	64.00	36.00					4.85	0.770	5.7	1.28
12	ss	1 / 6B	16	55.33	44.67					4.80	0.110	5.5	0.75
13	s	2 / 1A	18	40.00	60.00					4.90	0.660	5.5	0.75
14	ss	2 / 1B	18	37.33	62.67					4.36	0.660	5.7	0.98
15	s	2 / 2A	18	50.00	50.00	46.16	16.40	37.44	Sandy Clay	5.75	0.770	6.3	0.93
16	ss	2 / 2B	18	34.33	65.67	50.88	17.82	31.30	Sandy Clay Loam	5.51	0.880	6.3	0.60
17	s	2 / 3A	16	84.00	16.00					5.59	0.880	6.5	0.65
18	ss	2 / 3B	16	32.00	68.00					4.90	0.220	6.3	0.90
19	s	2 / 4A	16	58.00	42.00					5.20	0.990	6.0	0.90
20	ss	2 / 4B	16	37.30	62.70					4.90	0.880	5.6	1.13
21	s	4 / 1A	27	66.00	34.00					4.54	0.110	5.3	0.98
22	ss	4 / 1B	27	34.66	65.34					4.84	0.077	5.8	0.48
23	s	4 / 2A	27	56.00	44.00	29.60	25.30	45.10	Clay	4.80	0.110	5.2	0.98
24	ss	4 / 2B	27	26.66	73.34	23.80	27.10	49.10	Clay	5.40	0.110	5.6	0.80
25	s	4 / 3A	27	77.00	23.00					4.62	0.088	6.1	0.97
26	ss	4 / 3B	27	42.66	57.34					4.58	0.088	5.7	0.48
27	s	4 / 4A	27	71.00	29.00					4.51	0.033	5.6	0.68
28	ss	4 / 4B	27	52.66	47.34					4.73	0.044	5.5	0.42
29	s	4 / 5A	27	60.00	40.00					4.54	0.022	6.1	1.00
30	ss	4 / 5B	27	40.60	59.40					4.80	0.022	5.6	0.45
31	s	4 / 6A	27	56.00	44.00					4.60	0.044	5.3	0.70
32	ss	4 / 6B	27	35.30	64.70					5.63	0.044	5.3	0.73
33	s	4 / 7A	27	58.00	42.00					4.72	0.066	5.6	0.83

*Sample code: Block No./ Sample site No. Surface (A) or Subsurface (B)

Appendix - III
Raw Data Generated by Physico-Chemical Analysis

Sample No.	Av.P (ppm)	Av.K (ppm)	Av.Na (ppm)	Ca (ppm)	Mg (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)	Fe (ppm)	P fix. %	Ex.Fe (ppm)
1	4.29	98	45	226.50	29.75	60.30	1.20	2.83	30.10	85.14	1.60
2	3.88	60	38	218.00	27.25	65.40	0.70	2.60	28.20	80.50	1.20
3	4.17	95	46	225.50	26.00	53.70	0.60	4.30	14.00		1.50
4	2.04	54	27	50.00	36.40	51.20	0.50	2.50	17.00		2.40
5	3.13	92	34	44.50	36.70	47.70	0.70	4.37	13.30		1.90
6	1.79	93	45	107.00	37.85	56.80	0.70	2.84	15.40		2.00
7	1.25	98	32	57.50	38.35	82.60	0.70	4.51	18.10		1.30
8	1.04	100	34	111.00	33.90	83.20	0.60	1.81	18.30		1.50
9	7.38	110	43	137.50	31.90	126.80	0.90	2.10	23.20		1.50
10	1.71	38	29	90.50	22.00	60.10	0.30	5.54	14.70		1.10
11	3.78	43	31	107.00	30.00	41.30	0.60	6.25	14.30		1.80
12	7.50	29	23	52.50	28.15	36.00	0.40	6.63	18.50		1.30
13	6.46	73	16	18.00	31.00	57.80	0.60	14.20	20.70		2.00
14	3.71	84	16	19.00	27.50	54.00	0.50	13.90	27.20		1.00
15	5.79	149	20	23.00	37.80	52.70	0.60	2.96	19.80	72.82	1.10
16	2.38	39	29	17.00	31.30	24.30	0.30	2.90	63.50	67.13	2.30
17	2.96	51	39	15.00	38.30	47.70	0.90	5.52	20.40		2.20
18	7.67	34	26	18.00	33.70	27.90	0.40	2.34	65.70		2.10
19	5.96	66	28	16.50	31.65	43.60	0.20	2.12	22.10		1.40
20	5.97	90	33	57.50	29.60	83.60	0.90	6.24	17.40		1.90
21	16.12	44	21	55.50	23.30	68.00	0.60	7.90	27.10		1.20
22	5.33	54	28	124.00	30.90	101.90	0.60	4.40	50.50		2.00
23	5.45	108	14	11.00	29.45	79.40	0.60	3.85	68.30	69.31	1.80
24	5.04	116	38	16.50	30.75	74.30	1.10	13.30	43.70	81.16	1.50
25	6.00	83	32	34.00	30.20	57.20	0.90	13.20	24.80		1.90
26	3.33	55	17	15.00	32.35	79.60	0.60	11.07	21.40		1.80
27	3.29	42	15	89.50	42.50	54.80	1.50	9.65	53.80		1.70
28	7.25	43	15	27.50	32.00	119.20	1.10	10.40	37.70		2.30
29	3.96	33	15	56.00	33.90	50.40	0.90	6.50	25.00		2.40
30	3.08	52	16	57.00	24.15	63.00	0.60	20.70	17.70		3.40
31	19.16	71	18	55.50	22.25	68.20	0.90	15.60	45.00		2.50
32	17.08	69	15	46.50	28.40	72.20	0.90	14.30	52.30		2.20
33	10.25	36	21	115.50	28.50	46.20	1.40	10.90	40.40		1.50

Appendix - III

Raw Data Generated by Physico-Chemical Analysis

Sample No.	Ex.Mn (ppm)	Ex.Ca (ppm)	Ex.Mg (ppm)	Ex.Na (ppm)	Ex.K (ppm)	Ex.Al (ppm)	CEC cmol(+)/kg	Na sat. %	BSP %	Al sat. %
1	111.30	287	79.30	144	86	22.36	3.59	17.43	81.64	6.92
2	73.40	246	85.20	128	78	16.88	3.15	17.69	85.41	5.97
3	38.80	280	61.10	142	100	21.25	3.16	19.55	87.88	7.48
4	44.80	191	48.70	126	82	53.88	2.88	19.00	73.27	20.78
5	42.00	153	60.30	124	92	56.63	2.83	19.09	72.05	22.29
6	48.10	215	72.20	128	100	36.25	3.07	18.15	80.91	13.15
7	76.50	140	62.20	108	96	50.38	2.77	16.95	69.56	20.23
8	77.60	210	52.00	114	98	10.38	2.63	18.87	84.65	4.39
9	124.60	261	51.20	128	112	15.00	3.20	17.42	80.42	5.22
10	58.60	210	44.50	120	72	58.00	2.98	17.49	71.11	21.61
11	17.80	115	32.20	102	68	30.63	1.87	23.73	77.97	18.22
12	51.70	119	21.70	106	68	55.63	2.22	20.77	63.44	27.87
13	50.00	45	11.90	98	94	60.25	1.85	23.05	53.52	36.25
14	62.40	49	14.00	80	76	38.88	1.57	22.22	57.64	27.62
15	33.50	51	17.10	102	130	22.50	1.55	28.66	75.70	16.17
16	28.40	183	65.40	108	74	51.63	2.80	16.79	75.49	20.52
17	30.60	283	56.60	132	84	37.75	3.21	17.89	83.20	13.09
18	24.80	174	64.70	108	74	48.75	2.70	17.39	76.31	20.07
19	34.80	146	32.50	108	82	40.13	2.26	20.83	74.37	19.79
20	60.10	205	66.60	102	72	23.38	2.69	16.51	81.92	9.68
21	107.50	131	41.50	108	72	67.50	2.80	16.80	59.01	26.84
22	88.20	147	59.00	102	112	39.00	2.71	16.35	71.91	15.99
23	110.50	110	40.40	82	98	61.63	2.58	13.80	57.65	26.53
24	70.40	88	29.70	72	60	52.25	1.99	15.71	57.73	29.15
25	44.70	218	67.60	114	86	57.75	3.17	15.62	74.42	20.24
26	68.80	130	60.30	106	74	53.50	2.65	17.41	67.83	22.47
27	67.20	159	71.20	108	68	65.00	3.00	15.67	67.52	24.11
28	90.40	136	56.10	102	66	57.75	2.73	16.23	64.16	23.50
29	42.70	132	44.50	100	64	42.39	2.26	19.24	71.88	20.86
30	47.50	131	54.90	104	74	54.50	2.54	17.81	68.84	23.87
31	36.10	133	47.30	108	88	60.00	2.56	18.37	68.41	26.10
32	69.00	111	40.90	102	84	60.13	2.48	17.90	62.55	26.99
33	38.90	207	62.30	120	70	49.13	2.94	17.74	76.43	18.57

APPENDIX - III

Raw data generated by physico-chemical analysis

Sample No.	Type	*Code	Phase	Gravel %	Fine earth %	sand %	silt %	clay %	Textural class	pH	EC dS/ m	Buffer pH	Org.C (%)
34	ss	4 / 7B	27	42.66	57.34					5.07	0.055	6.0	0.55
35	s	4 / 8A	27	52.00	48.00					4.88	0.044	5.2	0.73
36	ss	4 / 8B	27	40.66	59.34					4.74	0.033	5.1	0.98
37	s	4 / 9A	27	58.00	42.00					6.10	0.022	6.4	1.05
38	ss	4 / 9B	27	41.30	58.70					6.20	0.020	6.4	0.66
39	s	4 / 10A	27	56.00	44.00					6.40	0.044	6.2	0.62
40	ss	4 / 10B	27	42.00	58.00					6.30	0.033	6.4	0.55
41	s	4 / 11A	27	58.00	42.00					4.60	0.110	5.9	1.14
42	ss	4 / 11B	27	43.30	56.70					5.02	0.022	5.9	0.92
43	s	5 / 1A	27	48.00	52.00	31.70	27.89	40.41	Clay	4.97	0.033	6.1	1.11
44	ss	5 / 1B	27	49.33	50.67	34.40	25.61	39.99	Clay Loam	4.84	0.088	5.9	1.12
45	s	5 / 2A	27	63.00	37.00					5.13	0.033	5.7	0.67
46	ss	5 / 2B	27	42.00	58.00					4.96	0.055	6.5	0.56
47	s	5 / 3A	27	64.00	36.00					6.50	0.022	5.9	1.24
48	ss	5 / 3B	27	52.66	47.34					5.30	0.022	6.5	0.58
49	s	5 / 4A	27	58.00	42.00					5.23	0.022	6.1	0.73
50	ss	5 / 4B	27	40.66	59.34					6.57	0.011	5.9	0.65
51	s	6 / 1A	33	40.00	60.00					5.25	0.055	6.3	0.80
52	ss	6 / 1B	33	33.33	66.67					5.21	0.022	5.8	0.65
53	s	6 / 2A	37	63.00	37.00					5.03	0.011	5.6	0.59
54	ss	6 / 2B	37	42.66	57.34					4.76	0.022	5.7	1.02
55	s	6 / 3A	33	53.00	47.00					4.60	0.066	5.7	1.24
56	ss	6 / 3B	33	46.60	53.40					4.66	0.110	5.9	0.65
57	s	6 / 4A	33	70.00	30.00					4.70	0.110	6.6	0.88
58	ss	6 / 4B	33	42.60	57.40					5.50	0.044	6.1	1.25
59	s	6 / 5A	33	40.00	60.00	45.70	20.30	34.00	Sandy Clay Loam	6.09	0.066	6.1	1.15
60	ss	6 / 5B	33	40.00	60.00	46.90	21.70	31.40	Sandy Clay Loam	6.30	0.044	6.4	0.83
61	s	6 / 6A	32	82.00	18.00					6.80	0.099	6.5	1.46
62	ss	6 / 6B	32	55.30	44.70					6.90	0.088	5.6	1.32
63	s	6 / 7A	32	50.00	50.00					5.08	0.066	5.5	1.21
64	ss	6 / 7B	32	55.30	44.70					4.53	0.088	5.4	1.32
65	s	6 / 8A	32	45.00	55.00					4.91	0.099	5.4	1.23
66	ss	6 / 8B	32	46.66	53.34					4.72	0.110	5.8	1.30

*Sample code: Block No./ Sample site No. Surface (A) or Subsurface (B)

Appendix - III

Raw Data Generated by Physico-Chemical Analysis

Sample No.	Av.P (ppm)	Av.K (ppm)	Av.Na (ppm)	Ca (ppm)	Mg (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)	Fe (ppm)	P fix. %	Ex.Fe (ppm)
34	11.79	44	30	56.00	29.75	44.80	0.30	8.90	88.70		8.60
35	14.58	129	19	88.00	27.25	69.10	0.70	7.80	19.10		2.80
36	13.00	125	15	85.00	26.00	53.60	0.70	10.90	20.30		1.70
37	8.75	70	38	94.50	36.40	35.10	3.10	9.30	33.50		1.20
38	3.75	68	41	257.50	36.70	34.10	3.30	8.40	23.00		2.20
39	5.04	62	47	254.00	37.85	46.20	2.14	7.90	45.50		1.10
40	5.50	53	49	254.00	38.35	42.60	0.80	6.40	55.20		2.00
41	4.58	136	37	118.00	33.90	80.60	0.60	4.97	18.90		2.20
42	1.83	90	24	22.00	31.90	73.30	0.30	4.38	16.80		3.20
43	6.88	55	15	31.50	22.00	31.40	0.80	4.57	18.90	82.69	3.40
44	1.33	34	26	135.00	30.00	91.50	0.20	1.82	19.10	84.18	2.90
45	2.61	53	26	132.50	28.15	90.20	0.40	5.57	17.90		2.30
46	1.30	106	29	164.00	31.00	70.70	0.40	4.88	16.10		2.50
47	2.50	91	22	108.50	27.50	110.50	1.40	17.00	25.40		2.30
48	2.96	61	44	255.00	37.80	94.80	0.70	7.59	23.40		1.40
49	3.87	66	29	169.00	31.30	134.30	0.50	14.50	31.70		2.10
50	2.00	56	40	258.50	38.30	29.40	1.30	4.35	33.00		2.70
51	2.46	57	27	161.00	33.70	67.50	0.80	11.73	20.80		3.60
52	2.13	43	22	165.50	31.65	71.00	0.40	6.21	39.10		1.40
53	1.66	35	19	111.00	29.60	107.90	0.30	2.77	21.80		1.50
54	2.25	57	15	86.50	23.30	33.10	0.60	2.92	15.70		2.60
55	2.87	34	22	130.50	30.90	108.10	0.80	12.43	36.10		1.30
56	1.71	42	37	176.50	29.45	36.60	0.90	6.46	31.30		1.70
57	2.42	105	24	167.00	30.75	54.60	0.90	13.05	30.30		4.80
58	2.04	163	23	174.00	31.20	53.00	0.90	16.02	27.10		2.40
59	5.54	112	44	287.00	32.35	87.50	0.60	27.04	15.70	89.32	2.00
60	1.46	84	34	325.50	42.50	74.90	0.90	48.50	22.10	87.15	2.60
61	2.08	79	54	358.50	32.00	70.00	0.30	30.10	18.04		1.10
62	1.63	103	57	367.00	33.90	146.50	2.90	23.10	17.04		2.10
63	2.46	64	20	120.00	24.15	96.90	0.70	15.00	33.60		2.00
64	2.66	36	21	55.00	22.25	85.90	0.30	5.53	43.80		1.80
65	2.46	154	21	154.50	28.40	184.80	0.80	38.65	54.60		1.80
66	1.63	155	20	141.00	28.50	151.00	1.30	30.47	64.00		1.00

Appendix - III

Raw Data Generated by Physico-Chemical Analysis

Sample No.	Ex.Mn (ppm)	Ex.Ca (ppm)	Ex.Mg (ppm)	Ex.Na (ppm)	Ex.K (ppm)	Ex.Al (ppm)	CEC cmol(+)/kg	Na sat. %	BSP %	Al sat. %
34	57.10	115	70.80	124	74	41.50	2.59	20.85	72.93	17.85
35	71.70	197	55.60	116	120	47.50	3.05	16.52	73.82	17.30
36	69.90	163	42.70	108	112	37.25	2.60	18.09	74.02	15.95
37	13.10	295	88.20	136	82	43.88	3.54	16.70	84.75	13.78
38	13.60	307	90.10	138	84	31.13	3.50	17.17	88.45	9.91
39	19.80	325	103.40	148	80	37.25	3.81	16.88	87.15	10.86
40	19.50	319	106.70	138	72	31.25	3.68	16.30	88.44	9.44
41	95.80	231	64.70	100	76	38.25	3.10	14.04	74.76	13.73
42	65.40	93	40.10	108	80	52.88	2.31	20.36	63.69	25.49
43	31.20	204	63.10	128	72	26.50	2.70	20.61	84.43	10.91
44	101.70	220	52.70	122	80	20.88	2.88	18.41	78.73	8.06
45	93.30	241	60.90	124	96	14.75	3.00	17.96	82.95	5.46
46	28.30	305	87.90	144	140	18.25	3.55	17.65	91.12	5.72
47	108.80	215	54.40	120	104	38.38	3.14	16.61	73.54	13.59
48	3.30	133	89.10	128	66	13.88	2.30	24.26	92.53	6.73
49	120.00	247	66.00	116	78	25.63	3.21	15.71	77.29	8.88
50	3.10	305	88.90	126	68	17.50	3.19	17.16	93.25	6.09
51	57.60	247	77.40	114	70	13.38	2.92	16.99	87.27	5.10
52	52.50	259	64.50	126	62	7.25	2.81	19.51	90.15	2.87
53	74.90	184	56.80	100	60	49.88	2.81	15.49	70.35	19.75
54	71.00	168	42.40	102	74	73.38	2.91	15.27	62.70	28.09
55	75.50	211	64.10	108	60	45.88	3.00	15.68	73.63	17.04
56	90.70	265	56.10	130	64	17.25	3.04	18.58	82.65	6.30
57	32.40	259	63.20	124	104	26.50	3.05	17.68	85.91	9.66
58	38.40	237	59.00	126	142	25.63	3.02	18.18	85.62	9.45
59	12.20	352	72.10	144	104	49.88	3.85	16.26	84.26	14.40
60	12.80	364	71.00	152	102	43.58	3.87	17.10	86.02	12.54
61	8.00	380	72.60	176	86	62.75	4.21	18.17	82.65	16.56
62	4.30	377	38.80	178	104	63.88	3.98	19.46	81.56	17.86
63	52.50	217	37.40	110	82	58.63	2.93	16.32	70.99	22.25
64	37.70	98	49.00	100	62	63.88	2.34	18.58	63.51	30.35
65	100.90	231	49.70	114	126	62.75	3.45	14.36	68.97	20.21
66	124.50	227	57.90	110	122	55.25	3.47	13.78	69.15	17.69

APPENDIX - III

Raw data generated by physico-chemical analysis

Sample No.	Type	*Code	Phase	Gravel %	Fine earth %	sand %	silt %	clay %	Textural class	pH	EC dS/ m	Buffer pH	Org.C (%)
67	s	6 / 9A	35	47.00	53.00					4.68	0.099	6.0	1.26
68	ss	6 / 9B	35	42.66	57.34					4.70	0.099	6.0	1.26
69	s	6 / 10A	32	72.00	28.00	39.80	22.40	37.80	Clay Loam	4.85	0.033	5.7	1.33
70	ss	6 / 10B	32	42.00	58.00	37.60	21.80	40.60	Clay	4.80	0.044	6.6	1.27
71	s	6 / 11A	33	65.00	35.00					4.70	0.066	5.7	1.23
72	ss	6 / 11B	33	28.66	71.34					5.00	0.055	6.3	1.26
73	s	6 / 12A	33	76.00	24.00					4.94	0.110	6.0	1.33
74	ss	6 / 12B	33	35.30	64.70					4.80	0.110	5.4	1.39
75	s	6 / 13A	35	70.00	30.00	45.10	20.40	34.50	Sandy Clay Loam	4.94	0.077	6.0	1.20
76	ss	6 / 13B	35	32.00	68.00	46.70	21.00	32.30	Sandy Clay Loam	5.17	0.077	5.9	1.26
77	s	7 / 1A	35	71.00	29.00	47.30	18.80	33.90	Sandy Clay Loam	5.04	0.033	6.0	1.24
78	ss	7 / 1B	35	32.00	68.00	50.40	18.40	31.20	Sandy Clay Loam	5.01	0.022	6.1	1.32
79	s	7 / 2A	27	50.00	50.00					4.19	0.044	5.7	1.30
80	ss	7 / 2B	27	34.60	65.40					4.84	0.033	6.2	1.35
81	s	7 / 3A	32	61.00	39.00					5.41	0.407	6.4	1.58
82	ss	7 / 3B	32	34.00	66.00					5.46	0.264	6.4	1.38
83	s	7 / 4A	35	22.00	78.00					4.68	0.242	6.0	1.15
84	ss	7 / 4B	35	30.00	70.00					5.32	0.242	6.0	0.88
85	s	7 / 5A	35	55.00	45.00					5.09	0.022	5.9	1.30
86	ss	7 / 5B	35	27.30	72.70					5.47	0.066	5.4	1.68
87	s	7 / 6A	32	49.00	51.00					6.30	0.066	5.7	1.39
88	ss	7 / 6B	32	28.60	71.40					4.76	0.077	6.2	1.27
89	s	7 / 7A	33	69.00	31.00					4.80	0.374	6.2	1.14
90	ss	7 / 7B	33	26.00	74.00					5.03	0.022	5.9	1.32
91	s	7 / 8A	27	68.00	32.00					5.28	0.011	6.0	1.07
92	ss	7 / 8B	27	40.00	60.00					5.09	0.022	6.0	1.29
93	s	7 / 9A	33	56.00	44.00	45.10	21.10	33.80	Sandy Clay Loam	5.16	0.088	6.2	1.00
94	ss	7 / 9B	33	30.00	70.00	46.00	22.10	31.90	Sandy Clay Loam	5.21	0.022	5.9	1.13
95	s	8 / 1A	32	48.00	52.00					4.51	0.209	5.9	1.17
96	ss	8 / 1B	32	28.00	72.00					6.00	0.022	6.6	0.80
97	s	8 / 2A	33	50.00	50.00					4.69	0.044	5.7	0.95
98	ss	8 / 2B	33	20.00	80.00					5.06	0.077	5.7	0.80
99	s	8 / 3A	33	53.00	47.00					5.19	0.044	6.1	0.88

*Sample code: Block No./ Sample site No. Surface (A) or Subsurface (B)

Appendix - III
Raw Data Generated by Physico-Chemical Analysis

Sample No.	Av.P (ppm)	Av.K (ppm)	Av.Na (ppm)	Ca (ppm)	Mg (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)	Fe (ppm)	P fix. %	Ex.Fe (ppm)
67	1.71	34	33	171.00	30.10	103.70	1.10	6.12	51.80		1.90
68	1.58	86	16	82.50	28.90	91.50	0.60	6.99	38.70		2.00
69	2.96	41	15	54.50	23.42	62.50	0.50	4.17	22.80	87.28	2.20
70	2.87	117	48	312.00	33.40	90.60	1.30	20.50	21.10	87.42	1.00
71	2.42	58	14	46.50	22.90	110.60	0.20	16.61	20.90		1.00
72	2.12	50	26	218.50	30.10	57.80	0.30	6.86	13.40		0.90
73	2.04	80	24	136.50	28.60	78.30	0.30	8.77	17.40		1.40
74	2.21	134	20	163.50	29.30	118.40	0.40	20.90	19.87		2.90
75	2.04	54	20	193.50	33.70	65.90	0.60	13.10	13.90	83.66	2.60
76	1.63	86	29	229.00	31.85	50.90	0.30	9.40	12.50	81.64	2.30
77	1.71	67	13	102.50	29.15	87.90	0.20	9.70	15.10	87.72	1.80
78	2.00	34	14	103.50	28.15	90.80	0.40	7.07	17.00	87.07	2.20
79	1.88	47	11	72.00	26.10	79.50	0.10	6.14	38.40		1.50
80	1.63	84	17	141.00	25.90	74.50	0.50	8.20	34.80		2.70
81	2.04	103	69	269.00	32.05	35.20	0.30	11.07	35.20		2.00
82	1.96	136	29	164.00	33.30	32.60	0.10	1.83	38.30		2.80
83	2.46	59	16	165.00	26.30	53.90	0.40	17.17	18.40	88.83	2.70
84	3.38	53	14	106.50	30.10	61.50	0.10	2.37	12.30	87.57	2.20
85	4.21	64	23	97.50	28.10	71.40	0.20	4.28	16.40		2.60
86	3.75	61	28	223.50	27.35	93.10	0.30	1.71	13.00		2.30
87	3.38	44	28	367.50	33.85	78.80	0.60	8.21	30.00		2.00
88	3.29	40	27	64.00	25.60	74.30	0.30	7.14	15.70		0.10
89	4.96	58	58	181.50	29.75	69.70	0.40	7.94	20.60		2.60
90	2.04	41	18	110.00	27.60	54.80	0.50	13.07	13.20		2.60
91	1.63	39	27	211.50	30.80	85.10	0.50	6.75	15.40		2.80
92	2.08	71	21	137.50	29.95	36.30	0.40	23.40	16.20		2.60
93	1.96	95	16	89.50	26.30	28.60	0.20	2.47	22.20	84.74	2.90
94	1.96	41	21	144.50	27.30	100.00	0.20	12.66	24.60	83.41	2.70
95	1.79	44	13	86.50	20.20	30.50	0.20	3.22	17.50		2.90
96	1.46	57	51	287.00	39.70	41.40	5.40	10.30	18.90		2.50
97	3.13	34	14	94.00	16.40	35.70	0.30	2.11	20.60		2.40
98	2.13	63	25	172.50	30.75	72.40	0.70	7.76	12.30		2.30
99	2.40	35	25	175.50	31.10	68.70	0.60	5.01	13.90		2.00

Appendix - III

Raw Data Generated by Physico-Chemical Analysis

Sample No.	Ex.Mn (ppm)	Ex.Ca (ppm)	Ex.Mg (ppm)	Ex.Na (ppm)	Ex.K (ppm)	Ex.Al (ppm)	CEC cmol(+)/kg	Na sat. %	BSP %	Al sat. %
67	94.50	262	60.20	126	62	20.13	3.09	17.75	81.38	7.25
68	77.10	154	47.40	96	92	48.13	2.64	15.84	68.77	20.31
69	44.20	92	38.10	100	66	67.25	2.29	18.96	60.04	32.61
70	14.60	343	68.00	152	104	43.88	3.75	17.65	85.46	13.03
71	96.20	73	33.20	158	112	67.75	2.72	25.27	59.28	27.71
72	57.90	218	62.60	132	76	18.25	2.79	20.57	85.06	7.27
73	66.90	207	49.90	124	98	48.75	3.03	17.82	73.87	17.92
74	70.60	278	77.10	136	86	25.75	3.39	17.45	83.66	8.45
75	104.40	239	55.00	120	98	24.50	3.08	16.94	78.53	8.84
76	34.40	297	69.50	132	100	27.25	3.32	17.28	86.86	9.12
77	87.30	165	60.60	106	88	41.63	2.80	16.48	71.85	16.55
78	136.20	163	54.80	168	70	39.00	3.11	23.47	69.89	13.93
79	110.60	140	48.20	104	80	40.13	2.61	17.35	67.24	17.12
80	79.90	222	47.50	108	92	39.88	2.95	15.92	74.78	15.04
81	56.60	333	69.30	132	132	26.25	3.65	15.72	86.17	7.99
82	106.80	256	68.30	142	154	17.50	3.45	17.92	82.78	5.65
83	138.10	146	39.30	122	116	49.88	2.95	18.00	63.80	18.82
84	123.70	178	57.30	108	84	40.50	2.95	15.90	69.25	15.25
85	160.70	170	53.50	110	76	37.88	2.98	16.06	65.90	14.14
86	182.40	309	55.50	148	114	14.88	3.77	17.05	77.81	4.38
87	95.60	355	66.90	148	112	25.00	3.89	16.55	83.72	7.15
88	119.80	144	48.70	124	84	41.00	2.77	19.49	67.75	16.48
89	156.20	267	59.30	148	84	19.13	3.47	18.54	77.23	6.13
90	143.70	219	53.70	144	100	35.13	3.34	18.74	72.38	11.69
91	160.90	294	36.00	138	112	25.25	3.53	17.01	75.16	7.96
92	84.80	225	68.30	124	130	28.25	3.19	16.90	80.19	9.85
93	67.50	163	51.10	134	86	36.50	2.70	21.58	75.48	15.03
94	218.10	222	51.80	130	82	26.38	3.41	16.59	67.81	8.61
95	219.00	227	46.10	180	80	21.25	3.55	22.08	70.56	6.67
96	47.80	339	116.50	120	136	18.13	3.91	13.36	90.16	5.16
97	94.90	119	50.30	136	80	18.75	2.37	24.98	76.24	8.81
98	155.00	256	56.60	138	98	16.25	3.35	17.92	77.51	5.40
99	149.70	247	60.20	158	118	18.75	3.48	19.75	78.14	5.99

Appendix - III
Raw Data Generated by Physico-Chemical Analysis

Sample No.	Type	Code	Phase	Gravel %	Fine earth %	sand %	silt %	clay %	Textural class	pH	EC dS/ m	Buffer pH	Org.C (%)
100	ss	8 / 3B	33	37.30	62.70					5.20	0.02	5.40	0.80
101	s	8 / 4A	37	74.00	26.00					5.18	0.01	6.20	0.97
102	ss	8 / 4B	37	37.30	62.70					4.91	0.01	5.50	0.63
103	s	8 / 5A	32	61.00	39.00					5.03	0.02	5.60	0.90
104	ss	8 / 5B	32	50.60	49.40					4.84	0.04	6.00	0.79
105	s	8 / 6A	36	76.00	24.00					5.19	0.07	6.00	0.81
106	ss	8 / 6B	36	46.60	53.40					5.30	0.01	5.90	1.21
107	s	8 / 7A	33	70.00	30.00					4.98	0.02	5.90	1.21
108	ss	8 / 7B	33	46.00	54.00					4.50	0.06	5.60	0.72
109	s	8 / 8A	33	65.00	35.00					4.79	0.08	5.80	0.97
110	ss	8 / 8B	33	48.00	52.00					4.87	0.03	5.80	1.07
111	s	8 / 9A	33	79.00	21.00					5.23	0.02	5.40	1.04
112	ss	8 / 9B	33	48.60	51.40					5.22	0.02	5.40	1.25
113	s	8 / 10A	27	65.00	35.00					4.85	0.06	5.60	0.93
114	ss	8 / 10B	27	46.60	53.40					4.95	0.07	5.80	0.91
115	s	8 / 11A	27	79.00	21.00					4.92	0.03	5.90	1.12
116	ss	8 / 11B	27	41.80	58.20					5.11	0.01	5.10	0.91
117	s	8 / 12A	27	70.00	30.00					5.36	0.02	6.20	1.09
118	ss	8 / 12B	27	43.30	56.70					4.90	0.01	5.90	0.73
119	s	8 / 13A	33	72.00	28.00					4.90	0.04	5.90	1.43
120	ss	8 / 13B	33	50.00	50.00					5.00	0.02	6.00	0.97
121	s	8 / 14A	33	60.00	40.00					5.03	0.01	5.90	1.22
122	ss	8 / 14B	33	48.46	51.54					5.11	0.01	5.90	0.82
123	s	8 / 15A	33	70.00	30.00					4.71	0.03	6.00	0.97
124	ss	8 / 15B	33	46.00	54.00					6.29	0.11	6.40	0.93
125	s	9 / 1A	36	66.00	34.00					5.03	0.01	6.00	0.91
126	ss	9 / 1B	36	54.40	45.60					4.85	0.02	5.90	0.91
127	s	9 / 2A	36	59.00	41.00					5.18	0.01	5.80	1.66
128	ss	9 / 2B	36	44.06	55.94					5.14	0.01	5.40	0.85
129	s	9 / 3A	37	59.00	41.00	46.90	19.10	34.00	Sandy Clay Loam	5.76	0.02	6.10	1.19
130	ss	9 / 3B	37	46.00	54.00	48.90	19.30	31.80	Sandy Clay Loam	4.62	0.02	5.60	1.09
131	s	9 / 4A	37	63.00	37.00					4.60	0.11	6.10	1.40
132	ss	9 / 4B	37	41.33	58.67					5.51	0.03	5.70	1.31

Appendix - III
Raw Data Generated by Physico-Chemical Analysis

Sample No.	Av.P (ppm)	Av.K (ppm)	Av.Na (ppm)	Ca (ppm)	Mg (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)	Fe (ppm)	P fix. %	Ex.Fe (ppm)
100	1.63	46	31	183.50	31.05	65.40	0.40	9.20	15.50		2.60
101	1.46	64	21	50.00	31.00	70.70	0.60	8.26	19.80		2.60
102	3.92	101	14	90.50	25.40	92.20	0.40	3.24	23.90		2.50
103	1.63	99	16	78.00	30.50	82.40	0.70	8.82	21.10		2.50
104	9.88	64	37	236.00	32.05	111.90	1.20	9.49	20.60		2.50
105	7.75	96	36	225.50	33.15	98.00	1.60	11.25	27.80		2.50
106	1.67	31	22	176.50	29.50	81.50	0.50	4.36	18.80		2.50
107	2.54	29	17	74.00	28.95	69.60	0.40	12.52	13.30		2.80
108	11.95	90	17	62.00	26.40	20.60	0.50	9.07	24.50		2.80
109	1.42	32	23	108.50	32.35	8.80	0.40	8.36	16.70		2.80
110	1.83	28	30	96.00	30.80	11.10	0.30	5.35	21.20		2.40
111	1.42	21	18	68.00	26.30	14.00	0.10	10.93	17.10		2.70
112	1.92	25	21	95.00	28.75	15.00	0.20	8.93	19.00		2.40
113	5.13	33	20	144.00	32.00	77.70	0.30	17.41	13.40		2.20
114	2.88	57	27	152.50	30.10	77.00	0.30	9.64	17.00		9.00
115	3.08	25	18	140.00	30.75	78.20	0.20	16.11	12.30		2.70
116	1.38	16	12	62.50	24.70	46.20	0.10	4.36	16.10		2.70
117	7.50	64	20	127.00	27.85	61.30	0.50	11.83	16.80		2.20
118	3.18	51	13	87.50	24.70	59.90	0.30	9.76	12.00		2.70
119	1.92	91	16	130.00	31.75	57.80	0.40	9.20	16.80		3.00
120	1.92	63	23	189.00	34.70	73.50	1.20	10.30	25.00		1.90
121	1.29	43	12	94.50	28.40	70.30	1.40	10.72	15.60		1.40
122	1.63	41	15	96.00	27.55	66.50	0.50	10.21	21.50		2.10
123	2.04	39	15	71.50	29.00	51.80	0.70	5.04	19.30		2.70
124	2.21	68	52	276.00	42.40	23.10	1.30	15.14	23.00		1.40
125	2.04	20	24	121.50	25.30	57.70	0.40	14.94	30.00		2.40
126	2.63	16	22	111.50	24.35	60.00	0.80	21.83	43.00		1.60
127	2.55	43	19	99.50	25.00	45.10	0.20	4.64	15.00		2.40
128	2.30	48	36	245.50	36.70	41.20	0.30	10.42	14.90		1.40
129	1.84	70	34	255.50	36.40	33.80	0.50	10.96	13.30	87.26	2.50
130	1.67	23	12	43.50	16.75	39.70	0.30	10.64	16.50	86.10	1.40
131	2.30	110	29	181.50	32.20	62.60	1.10	9.68	23.50		2.80
132	2.13	65	36	276.00	36.35	25.70	0.80	7.72	16.30		2.40

Appendix - III
Raw Data Generated by Physico-Chemical Analysis

Sample No.	Ex.Mn (ppm)	Ex.Ca (ppm)	Ex.Mg (ppm)	Ex.Na (ppm)	Ex.K (ppm)	Ex.Al (ppm)	CEC cmol(+)/kg	Na sat. %	BSP %	Al sat. %
100	136.80	296	69.30	158	118	18.75	3.76	18.30	80.94	5.55
101	130.60	158	46.10	140	82	31.50	2.82	21.57	70.42	12.41
102	149.50	307	59.70	172	86	26.25	3.84	19.48	77.99	7.60
103	110.80	189	57.90	146	86	14.63	2.85	22.27	79.83	5.71
104	153.80	235	54.70	150	88	21.88	3.31	19.68	75.50	7.34
105	187.70	184	60.00	110	102	34.38	3.23	14.82	66.71	11.85
106	204.20	152	40.20	120	110	28.63	2.96	17.60	63.89	10.74
107	73.40	162	20.20	114	76	56.00	2.57	19.32	64.93	24.27
108	169.40	259	49.10	132	94	15.88	3.32	17.31	75.78	5.33
109	128.00	211	57.70	132	86	28.13	3.11	18.44	74.66	10.05
110	176.50	265	56.70	74	64	21.63	3.17	10.16	71.86	7.59
111	85.00	198	58.90	124	68	22.63	2.76	19.55	79.31	9.12
112	154.00	148	42.10	84	52	22.25	2.40	15.21	65.99	10.31
113	83.30	274	81.90	102	58	22.88	3.20	13.86	82.33	7.95
114	110.00	177	50.10	98	70	22.63	2.59	16.48	73.55	9.73
115	125.30	183	47.00	88	50	22.50	2.53	15.14	71.68	9.90
116	119.50	191	46.00	128	72	37.50	2.94	18.96	70.65	14.21
117	128.00	230	59.40	126	98	39.63	3.35	16.35	72.71	13.15
118	121.00	164	47.60	114	86	27.25	2.68	18.50	71.90	11.31
119	93.00	210	80.90	120	82	39.50	3.24	16.13	75.63	13.58
120	109.70	200	76.00	118	108	39.75	3.26	15.73	74.00	13.55
121	131.00	35	55.20	116	86	43.88	2.32	21.71	58.26	21.00
122	141.20	175	55.80	112	78	49.25	3.09	15.76	65.40	17.73
123	101.40	41	55.60	112	74	56.50	2.35	20.76	57.07	26.79
124	25.60	302	115.90	168	90	13.88	3.68	19.87	93.13	4.20
125	104.50	220	43.50	132	72	41.63	3.07	18.71	72.23	15.09
126	98.00	197.6	45.10	124	70	36.38	2.84	18.96	73.03	14.23
127	92.80	186.7	45.80	118	78	31.00	2.71	18.91	74.53	12.70
128	95.00	566.3	98.70	144	80	18.63	5.03	12.45	88.91	4.12
129	48.00	649	51.40	152	94	17.75	4.95	13.35	92.30	3.99
130	77.80	78	33.40	106	68	51.13	2.16	21.38	60.27	26.37
131	123.10	426.9	72.80	146	124	35.25	4.54	14.00	81.26	8.64
132	42.90	629.3	85.20	144	124	17.63	5.15	12.16	93.00	3.81

Appendix - III

Raw Data Generated by Physico-Chemical Analysis

Sample No.	Type	Code	Phase	Gravel %	Fine earth %	sand %	silt %	clay %	Textural class	pH	EC dS/ m	Buffer pH	Org.C (%)
133	s	9 / 5A	38	60.00	40.00					5.45	0.01	6.00	1.39
134	ss	9 / 5B	38	48.00	52.00					4.64	0.03	6.10	1.13
135	s	9 / 6A	38	58.00	42.00					5.27	0.01	5.70	1.28
136	ss	9 / 6B	38	40.45	59.55					4.89	0.01	5.80	0.97
137	s	9 / 7A	38	64.00	36.00					4.71	0.03	5.80	0.87
138	ss	9 / 7B	38	50.66	49.34					5.45	0.02	5.80	0.88
139	s	9 / 8A	36	61.00	39.00					4.98	0.04	5.90	0.75
140	ss	9 / 8B	36	33.33	66.67					5.13	0.01	5.90	1.03
141	s	9 / 9A	38	58.00	42.00					5.00	0.01	5.90	1.18
142	ss	9 / 9B	38	29.33	70.67					5.10	0.01	5.40	0.91
143	s	9 / 10A	27	54.00	46.00					4.97	0.02	6.00	1.21
144	ss	9 / 10B	27	29.30	70.70					4.90	0.06	6.00	0.91
145	s	9 / 11A	27	61.00	39.00					5.38	0.01	5.90	0.67
146	ss	9 / 11B	27	36.66	63.34					6.70	0.01	6.10	0.88
147	s	10 / 1A	36	59.00	41.00					5.48	0.01	6.30	1.31
148	ss	10 / 1B	36	42.00	58.00					5.34	0.01	5.90	0.61
149	s	10 / 2A	38	64.00	36.00					5.60	0.01	6.00	1.43
150	ss	10 / 2B	38	44.00	56.00					5.30	0.02	5.90	1.58
151	s	10 / 3A	36	61.00	39.00					4.98	0.01	5.80	0.84
152	ss	10 / 3B	36	39.33	60.67					4.90	0.04	5.90	1.31
153	s	10 / 4A	36	61.00	39.00					4.70	0.02	5.70	0.92
154	ss	10 / 4B	36	35.80	64.20					5.30	0.01	6.20	1.10
155	s	10 / 5A	36	44.00	56.00					5.10	0.03	6.10	1.03
156	ss	10 / 5B	36	20.00	80.00					4.90	0.01	5.90	1.10
157	s	10 / 6A	38	54.00	46.00					4.84	0.02	5.80	0.96
158	ss	10 / 6B	38	33.26	66.74					4.93	0.01	6.30	0.69
159	s	10 / 7A	38	49.00	51.00					5.31	0.01	5.90	0.98
160	ss	10 / 7B	38	38.66	61.34					5.20	0.02	6.10	0.89
161	s	10 / 8A	38	56.00	44.00					5.10	0.03	6.30	0.87
162	ss	10 / 8B	38	43.73	56.27					5.31	0.02	6.30	0.71
163	s	10 / 9A	13	53.00	47.00	42.90	22.90	34.20	Clay Loam	4.99	0.01	5.90	1.04
164	ss	10 / 9B	13	36.40	63.60	40.70	24.00	35.30	Clay Loam	5.10	0.02	6.10	1.52
165	s	10 / 10A	13	54.00	46.00					5.07	0.08	6.10	1.64

Appendix - III

Raw Data Generated by Physico-Chemical Analysis

Sample No.	Av.P (ppm)	Av.K (ppm)	Av.Na (ppm)	Ca (ppm)	Mg (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)	Fe (ppm)	P fix. %	Ex.Fe (ppm)
133	2.04	73	44	291.00	39.00	60.60	0.90	14.04	21.60		2.20
134	2.17	33	21	140.00	27.80	71.60	0.70	20.21	17.50		2.60
135	3.63	39	26	200.60	3.65	76.50	0.70	2.32	19.70		2.30
136	2.21	29	16	98.50	23.60	40.80	0.40	4.94	20.90		2.40
137	3.47	39	17	78.50	25.95	44.00	0.50	4.92	22.60		2.40
138	3.09	45	17	235.50	36.40	24.10	0.50	7.02	15.10		1.80
139	2.21	44	19	86.00	27.00	40.60	0.60	9.44	16.80		2.90
140	2.04	59	36	253.50	35.65	23.70	0.70	9.20	13.80		2.80
141	3.29	34	16	64.00	23.85	53.00	0.60	11.63	18.60		2.00
142	1.29	26	13	96.00	24.10	52.60	0.50	3.97	15.40		2.50
143	1.29	41	19	102.50	28.00	55.90	0.50	17.66	17.80		1.40
144	1.46	42	78	172.50	31.65	64.10	1.40	18.39	23.80		2.70
145	1.71	42	32	233.50	31.70	26.00	5.60	15.10	34.70		1.80
146	5.63	69	46	330.00	28.65	47.90	0.60	16.16	14.90		2.00
147	2.58	63	27	179.50	34.85	49.70	0.60	17.50	18.40		2.20
148	2.00	46	19	139.50	31.50	53.20	1.00	14.91	25.60		2.30
149	8.83	88	33	220.00	36.00	70.00	0.70	6.46	29.40		1.60
150	3.13	77	43	249.50	38.50	59.40	0.90	2.95	20.90		2.70
151	1.63	44	27	100.00	26.00	87.70	0.60	6.25	19.60		1.60
152	1.46	82	60	249.00	37.00	34.00	0.90	7.92	25.80		1.60
153	1.63	95	39	149.50	31.65	48.90	0.60	13.50	23.30		2.00
154	1.38	77	56	248.50	35.60	64.50	0.70	8.60	18.90		1.40
155	2.58	79	50	211.50	34.95	80.20	0.90	13.70	20.60		1.70
156	1.71	164	66	251.00	38.15	61.90	0.60	4.68	22.10		1.20
157	1.71	100	68	251.00	34.75	85.60	0.80	12.70	27.60		1.60
158	1.63	86	51	222.00	36.25	61.90	0.60	9.60	23.10		2.40
159	1.46	48	45	196.00	33.95	34.80	0.80	11.90	17.10		2.10
160	2.17	53	36	88.00	25.40	88.30	0.70	7.75	21.20		2.00
161	2.04	100	57	282.00	37.90	29.30	0.60	14.39	26.30		2.60
162	2.21	99	44	246.50	34.40	24.90	0.40	11.94	14.90		1.50
163	2.17	107	50	241.50	33.15	74.90	1.00	16.34	26.30	86.10	2.50
164	2.04	97	36	205.00	35.35	44.50	0.70	11.40	21.40	86.60	1.10
165	2.21	65	43	225.00	30.05	60.70	0.50	16.72	22.10		1.20

Appendix - III

Raw Data Generated by Physico-Chemical Analysis

Sample No.	Ex.Mn (ppm)	Ex.Ca (ppm)	Ex.Mg (ppm)	Ex.Na (ppm)	Ex.K (ppm)	Ex.Al (ppm)	CEC cmol(+)/kg	Na sat. %	BSP %	Al sat. %
133	108.10	246.9	89.00	150	88	19.75	3.47	18.83	82.08	6.34
134	160.60	400.9	52.10	122	94	33.75	4.17	12.71	76.77	8.99
135	136.50	199.4	72.70	130	78	25.38	3.15	17.96	74.98	8.97
136	87.20	159.2	45.40	120	74	55.38	2.82	18.49	66.63	21.82
137	83.40	142.9	51.30	108	72	46.63	2.62	17.92	68.31	19.79
138	58.50	532.9	83.80	136	76	21.50	4.60	12.86	90.03	5.20
139	95.00	355.2	56.10	122	76	38.50	3.75	14.16	79.07	11.43
140	44.30	608	78.30	138	84	14.38	4.83	12.43	93.14	3.31
141	95.00	141.3	49.90	100	62	53.75	2.66	16.34	64.27	22.46
142	96.60	189.5	45.50	110	68	36.63	2.74	17.45	71.99	14.86
143	140.30	197.9	54.30	104	68	41.63	3.04	14.87	67.82	15.22
144	132.00	385.8	78.10	128	78	23.63	4.08	13.64	81.55	6.44
145	111.00	445.2	65.60	110	66	21.63	4.06	11.77	83.98	5.92
146	144.00	541.7	58.60	162	90	18.38	4.86	14.49	84.86	4.21
147	104.70	401.9	79.70	120	82	11.50	3.91	13.34	86.79	3.27
148	99.50	297.8	72.50	128	84	13.38	3.38	16.49	84.62	4.41
149	88.00	496	92.30	128	94	19.38	4.58	12.16	88.17	4.71
150	94.00	569.5	84.10	168	102	19.63	5.10	14.32	88.82	4.28
151	142.00	179.7	57.10	108	66	43.25	3.01	15.60	66.66	15.98
152	55.50	563.1	87.90	144	84	18.13	4.79	13.08	91.45	4.21
153	109.20	237	60.50	122	84	15.50	3.01	17.66	80.80	5.74
154	155.10	511.5	80.10	118	68	18.88	4.68	10.96	83.35	4.48
155	106.30	385.5	71.50	114	72	22.88	3.84	12.90	83.15	6.62
156	93.00	545.8	82.80	112	100	44.13	4.99	9.77	83.28	9.84
157	120.50	361.3	93.80	46	22	30.13	3.61	5.54	78.43	9.27
158	118.00	229.9	72.10	94	60	18.38	2.95	13.87	78.20	6.94
159	53.80	570.5	88.70	120	94	14.75	4.71	11.08	92.20	3.48
160	143.50	204	93.10	130	80	12.25	3.22	17.55	79.34	4.23
161	47.80	585.3	89.00	158	98	11.88	4.91	13.99	93.58	2.69
162	41.80	597.3	90.40	148	96	11.88	4.91	13.11	94.10	2.69
163	120.90	631	86.40	156	122	19.75	5.53	12.28	87.90	3.98
164	92.20	511.5	72.10	142	110	20.38	4.62	13.38	87.73	4.91
165	121.70	538	80.50	154	96	12.63	4.86	13.80	87.89	2.89

Appendix - III
Raw Data Generated by Physico-Chemical Analysis

Sample No.	Type	Code	Phase	Gravel %	Fine earth %	sand %	silt %	clay %	Textural class	pH	EC dS/ m	Buffer pH	Org.C (%)
166	ss	10 / 10B	13	44.66	55.34					4.60	0.07	5.60	1.12
167	s	10 / 11A	36	51.00	49.00					4.50	0.11	5.50	1.30
168	ss	10 / 11B	36	40.60	59.40					6.40	0.10	6.40	1.22
169	s	10 / 12A	36	84.00	16.00	40.70	30.10	29.20	Clay Loam	6.53	0.10	6.40	1.27
170	ss	10 / 12B	36	37.93	62.07	42.10	29.80	28.10	Clay Loam	4.81	0.09	5.80	1.22
171	s	10 / 13A	38	64.00	36.00	41.80	25.10	33.10	Loam	4.55	0.10	6.20	1.46
172	ss	10 / 13B	38	44.00	56.00	43.50	23.90	32.60	Loam	4.90	0.08	6.10	0.90
173	s	10 / 14A	36	65.00	35.00					5.34	0.07	5.80	0.83
174	ss	10 / 14B	36	46.00	54.00					4.99	0.10	5.70	0.81
175	s	10 / 15A	36	60.00	40.00					4.85	0.09	6.40	0.74
176	ss	10 / 15B	36	36.00	64.00					4.86	0.06	6.20	1.04
177	s	10 / 16A	37	59.00	41.00					5.19	0.02	6.30	1.09
178	ss	10 / 16B	37	26.00	74.00					5.65	0.06	6.30	1.19
179	s	10 / 17A	37	56.00	44.00					4.92	0.07	6.20	1.27
180	ss	10 / 17B	37	26.60	73.40					5.20	0.09	6.40	0.69
181	s	10 / 18A	37	60.00	40.00					5.76	0.06	6.40	0.76
182	ss	10 / 18B	37	20.00	80.00					5.92	0.04	6.40	0.81
183	s	10 / 19A	8	60.00	40.00					5.74	0.06	6.20	0.93
184	ss	10 / 19B	8	30.00	70.00					5.18	0.01	6.10	0.89
185	s	10 / 20A	8	65.00	35.00					4.80	0.06	5.80	0.95
186	ss	10 / 20B	8	32.66	67.34					5.27	0.04	6.40	0.62
187	s	10 / 21A	8	60.00	40.00					4.97	0.11	6.10	0.48
188	ss	10 / 21B	8	40.00	60.00					5.18	0.06	5.80	0.52
189	s	10 / 22A	8	74.00	26.00					5.44	0.02	5.60	1.22
190	ss	10 / 22B	8	32.66	67.34					4.82	0.11	6.30	0.56
191	s	15 / 1A	13	60.00	40.00					4.61	0.09	6.00	0.99
192	ss	15 / 1B	13	31.30	68.70					4.89	0.02	6.30	0.81
193	s	15 / 2A	13	84.00	16.00					4.89	0.01	6.10	1.01
194	ss	15 / 2B	13	31.30	68.70					4.61	0.03	5.90	1.04
195	s	15 / 3A	13	59.00	41.00					4.96	0.01	6.10	0.84
196	ss	15 / 3B	13	42.00	58.00					4.96	0.02	6.40	0.89
197	s	15 / 4A	13	59.00	41.00					5.01	0.02	6.30	0.86
198	ss	15 / 4B	13	36.00	64.00					4.80	0.01	6.10	0.99

Appendix - III
Raw Data Generated by Physico-Chemical Analysis

Sample No.	Av.P (ppm)	Av.K (ppm)	Av.Na (ppm)	Ca (ppm)	Mg (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)	Fe (ppm)	P fix. %	Ex.Fe (ppm)
166	2.04	82	89	118.00	23.10	50.40	0.40	4.30	45.00		1.90
167	3.25	39	33	66.50	32.50	56.90	0.50	4.30	27.20		2.50
168	5.71	84	68	339.50	33.10	31.60	6.00	5.30	37.30		1.60
169	3.25	88	69	356.50	33.80	31.70	5.90	4.80	32.30	85.89	2.30
170	2.04	78	52	225.00	27.60	70.70	0.80	9.80	27.70	87.85	1.40
171	12.67	39	40	115.50	30.55	47.80	0.70	14.30	23.80	86.96	1.70
172	4.96	45	36	199.50	36.15	55.50	0.40	3.80	24.20	87.79	1.00
173	3.29	192	45	247.50	33.45	86.30	0.70	13.13	22.60		2.10
174	4.21	92	35	159.00	36.05	96.50	1.20	12.56	29.10		1.10
175	3.13	50	35	59.50	34.00	88.80	1.10	12.55	27.40		1.30
176	2.38	100	38	174.50	33.50	75.70	0.90	11.55	26.00		2.30
177	2.13	90	36	56.00	31.35	74.60	2.00	23.85	21.90		2.70
178	3.38	56	40	226.50	31.80	101.20	0.80	12.18	27.10		1.60
179	4.17	111	59	218.50	36.60	35.90	0.30	8.56	21.80		2.40
180	5.79	41	41	141.50	29.30	74.10	0.80	13.37	30.80		2.20
181	5.95	56	78	276.00	35.05	68.00	0.40	4.37	29.50		1.50
182	2.54	68	37	220.00	37.80	66.00	0.80	9.76	39.40		2.60
183	3.88	81	45	262.00	39.86	69.40	1.00	11.05	40.20		1.60
184	2.00	45	34	202.50	29.80	78.70	2.40	20.09	23.50		1.10
185	2.17	85	36	168.00	30.80	79.50	0.80	11.57	45.60		2.20
186	2.13	52	69	231.50	34.25	80.00	0.60	14.81	23.80		1.40
187	2.88	60	49	110.00	28.45	69.50	0.30	2.81	29.50		2.50
188	2.58	72	39	207.50	34.95	59.20	0.60	14.60	27.30		1.20
189	2.66	90	39	232.50	36.00	66.20	0.70	8.75	24.80		1.30
190	5.42	154	48	244.00	35.15	66.50	0.50	14.56	20.00		1.60
191	5.13	65	45	137.00	27.30	62.40	0.30	1.86	22.40		2.90
192	3.33	49	30	117.00	29.30	77.20	0.40	2.55	25.30		1.80
193	3.82	27	20	55.50	22.95	46.30	0.50	3.35	22.30		2.30
194	5.00	31	23	58.50	25.50	48.00	0.40	4.19	20.60		2.10
195	3.75	51	28	102.50	24.50	65.60	0.40	8.35	24.10	87.42	1.30
196	3.46	43	35	174.00	26.50	59.50	0.50	8.11	20.20	86.64	3.00
197	3.63	91	31	167.00	30.20	57.40	0.40	20.58	19.70		3.40
198	2.46	83	25	88.50	29.60	65.80	0.60	15.50	18.50		3.10

Appendix - III

Raw Data Generated by Physico-Chemical Analysis

Sample No.	Ex.Mn (ppm)	Ex.Ca (ppm)	Ex.Mg (ppm)	Ex.Na (ppm)	Ex.K (ppm)	Ex.Al (ppm)	CEC cmol(+)/kg	Na sat. %	BSP %	Al sat. %
166	100.30	140.9	55.60	128	98	48.88	2.89	19.30	68.26	18.85
167	114.70	445.4	44.90	128	78	12.50	3.92	14.21	85.57	3.55
168	14.00	274.3	74.30	188	106	45.13	3.63	22.52	84.61	13.83
169	18.20	264.3	74.10	192	108	10.38	3.23	25.83	94.12	3.57
170	121.30	201.1	70.10	164	96	11.00	3.11	22.94	81.71	3.93
171	84.60	163.9	58.00	142	82	27.00	2.74	22.55	77.57	10.97
172	73.20	152.8	69.90	156	90	19.38	2.73	24.82	82.24	7.89
173	140.50	143.8	90.70	146	162	32.38	3.39	18.71	74.10	10.61
174	160.20	266.2	78.40	138	118	19.63	3.68	16.29	78.13	5.93
175	157.90	274.8	80.90	134	113	16.25	3.67	15.87	79.30	4.92
176	136.30	215.1	64.50	130	106	35.63	3.34	16.91	73.06	11.85
177	141.10	399.5	69.40	138	84	20.63	4.14	14.51	81.80	5.55
178	140.30	359.5	86.70	150	120	27.38	4.29	15.20	80.87	7.10
179	102.70	280.5	66.20	150	90	34.88	3.60	18.12	78.60	10.78
180	157.30	357.6	80.00	166	84	28.25	4.28	16.88	79.09	7.35
181	71.90	355.7	98.50	138	88	28.25	4.00	15.02	85.45	7.86
182	118.10	351.3	65.70	148	80	32.38	3.95	16.32	79.74	9.13
183	85.10	386.4	96.30	126	92	27.50	4.13	13.27	84.95	7.41
184	137.00	387.3	64.20	128	84	17.50	3.93	14.15	82.27	4.95
185	159.00	229	66.00	136	106	33.75	3.51	16.84	72.61	10.69
186	147.60	397.8	63.10	146	74	30.00	4.21	15.09	79.19	7.93
187	116.00	193	61.10	140	86	43.63	3.21	18.95	71.48	15.10
188	101.90	357.9	81.50	136	88	17.12	3.84	15.39	85.28	4.96
189	101.50	397	80.40	140	100	15.63	4.06	15.00	86.50	4.28
190	111.50	446.7	79.90	154	138	13.50	4.48	14.97	87.45	3.36
191	137.50	206.1	60.80	138	84	37.88	3.28	18.31	71.56	12.85
192	140.50	174.4	55.80	122	74	46.25	3.08	17.21	66.52	16.68
193	79.70	91.4	33.00	108	66	48.75	2.21	21.28	61.92	24.56
194	86.00	102.6	42.30	110	68	47.50	2.36	20.25	64.07	22.36
195	136.00	163.7	55.10	110	72	43.50	2.92	16.40	66.29	16.58
196	117.90	257.1	63.70	122	68	27.75	3.26	16.26	77.06	9.46
197	114.70	236.6	58.50	122	104	31.13	3.24	16.39	76.03	10.70
198	130.00	125.3	39.50	110	120	50.00	2.78	17.23	62.54	20.02

Appendix - III

Raw Data Generated by Physico-Chemical Analysis

Sample No.	Type	Code	Phase	Gravel %	Fine earth %	sand %	silt %	clay %	Textural class	pH	EC dS/ m	Buffer pH	Org.C (%)
199	s	15 / 5A	13	50.00	50.00					4.82	0.01	6.30	1.06
200	ss	15 / 5B	13	28.66	71.34					4.90	0.02	6.20	0.92
201	s	15 / 6A	13	73.00	27.00					5.03	0.01	6.20	1.39
202	ss	15 / 6B	13	32.00	68.00					5.05	0.02	6.10	0.99
203	s	15 / 7A	13	69.00	31.00					4.60	0.01	5.80	1.09
204	ss	15 / 7B	13	24.66	75.34					4.51	0.04	5.90	1.45
205	s	15 / 8A	13	60.00	40.00					4.53	0.06	5.80	1.54
206	ss	15 / 8B	13	21.30	78.70					4.55	0.03	5.70	1.67
207	s	15 / 9A	18	40.00	60.00					5.01	0.01	5.90	0.74
208	ss	15 / 9B	18	48.60	51.40					4.92	0.02	5.80	1.19
209	s	15 / 10A	18	40.00	60.00					4.86	0.04	6.10	0.80
210	ss	15 / 10B	18	53.30	46.70					4.91	0.01	6.10	0.90
211	s	15 / 11A	6	40.00	60.00					4.78	0.02	5.80	1.16
212	ss	15 / 11B	6	26.00	74.00					4.71	0.01	5.70	0.74
213	s	15 / 12A	6	60.00	40.00					5.37	0.02	6.00	0.57
214	ss	15 / 12B	6	25.30	74.70					4.88	0.02	5.80	0.91
215	s	15 / 13A	16	56.00	44.00					4.66	0.07	5.60	1.04
216	ss	15 / 13B	16	52.66	47.34					4.56	0.11	5.50	0.59
217	s	15 / 14A	16	56.00	44.00					4.61	0.06	5.70	1.45
218	ss	15 / 14B	16	61.30	38.70					4.66	0.02	5.70	1.06
219	s	15 / 15A	16	58.00	42.00					5.09	0.02	6.10	1.09
220	ss	15 / 15B	16	21.33	78.67					4.65	0.06	5.70	0.98
221	s	15 / 16A	22	75.00	25.00	45.00	23.40	31.60	Clay Loam	5.31	0.04	6.20	1.27
222	ss	15 / 16B	22	24.66	75.34	43.80	24.80	31.40	Clay Loam	4.85	0.03	6.40	0.62
223	s	15 / 17A	1	70.00	30.00					6.35	0.04	6.50	0.78
224	ss	15 / 17B	1	28.00	72.00					5.60	0.02	6.10	0.74
225	s	15 / 18A	2	52.00	48.00					4.69	0.11	6.20	1.72
226	ss	15 / 18B	2	19.33	80.67					4.65	0.03	6.20	1.57
227	s	15 / 19A	2	50.00	50.00					4.60	0.01	5.60	2.04
228	ss	15 / 19B	2	34.00	66.00					4.53	0.11	6.10	2.10
229	s	15 / 20A	2	64.00	36.00	43.22	29.99	26.79	Loam	4.99	0.11	6.10	1.88
230	ss	15 / 20B	2	26.66	73.34	41.72	31.40	26.88	Loam	4.88	0.09	6.20	1.55
231	s	15 / 21A	2	45.00	55.00					5.31	0.08	6.20	1.48

Appendix - III
Raw Data Generated by Physico-Chemical Analysis

Sample No.	Av.P (ppm)	Av.K (ppm)	Av.Na (ppm)	Ca (ppm)	Mg (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)	Fe (ppm)	P fix. %	Ex.Fe (ppm)
199	3.25	52	18	77.00	21.65	61.80	0.50	19.43	16.00		3.30
200	2.42	18	26	111.00	26.00	58.40	0.50	24.45	18.00		3.20
201	1.83	49	29	124.00	28.55	88.60	0.80	20.72	27.10		1.80
202	1.71	53	20	171.00	31.90	36.10	0.70	9.34	24.40		2.40
203	3.04	47	26	133.00	31.50	41.00	0.40	7.04	29.90		1.10
204	3.54	63	21	58.50	20.30	28.10	0.60	12.74	30.10		5.50
205	4.46	48	25	138.00	27.35	24.60	0.40	6.38	18.40		2.60
206	1.72	58	21	54.00	19.90	41.70	0.60	4.60	18.30		3.30
207	3.75	31	26	123.00	26.55	33.70	0.30	6.40	20.60		1.50
208	4.54	41	22	79.00	20.10	33.00	0.50	14.26	17.10		2.40
209	1.63	56	29	160.50	32.20	115.00	0.70	11.13	24.40		2.60
210	2.04	60	22	110.50	28.70	72.70	0.80	9.73	24.30		3.50
211	1.71	70	29	151.50	32.00	67.10	0.50	6.77	17.40		2.80
212	1.79	36	23	109.50	29.75	55.30	0.60	3.47	10.30		2.60
213	2.33	134	22	248.00	33.15	25.90	0.70	20.56	27.50		2.40
214	4.62	74	20	107.50	30.80	19.70	0.70	3.58	24.80		2.90
215	8.54	65	27	160.50	29.25	50.40	0.60	8.15	40.80		2.10
216	2.04	68	67	180.50	33.75	54.80	0.90	5.24	43.80		2.50
217	1.71	70	44	182.50	30.50	58.70	0.50	7.75	28.50		1.70
218	2.04	41	20	85.50	29.50	34.10	0.70	11.84	24.50		2.10
219	7.08	66	32	186.00	29.80	36.70	0.60	5.14	31.10		1.90
220	8.75	64	28	106.50	26.53	58.80	0.70	15.53	24.80		2.90
221	2.62	92	43	289.50	31.50	59.50	1.30	14.80	28.40	85.92	3.20
222	8.04	78	32	180.00	26.50	41.70	0.30	6.22	17.80	88.06	2.00
223	3.00	124	51	337.50	33.35	51.30	1.00	18.87	30.60		3.00
224	2.48	192	29	165.00	25.60	31.30	0.40	8.40	17.70		3.00
225	2.54	39	35	160.00	33.65	35.00	0.20	6.58	13.80		3.00
226	1.54	63	23	109.50	25.95	81.10	0.60	11.87	19.30		3.20
227	3.79	55	26	151.50	28.25	27.90	0.20	5.12	27.30		3.10
228	2.08	85	87	217.50	31.50	32.90	0.20	12.82	19.40		2.00
229	5.46	88	38	230.00	34.50	70.10	0.80	15.49	26.80	86.91	2.90
230	3.42	93	35	203.00	46.10	55.80	0.60	16.88	20.70	84.24	2.90
231	2.21	70	54	206.50	31.85	42.70	0.40	10.46	19.20		3.00

Appendix - III

Raw Data Generated by Physico-Chemical Analysis

Sample No.	Ex.Mn (ppm)	Ex.Ca (ppm)	Ex.Mg (ppm)	Ex.Na (ppm)	Ex.K (ppm)	Ex.Al (ppm)	CEC cmol(+)/kg	Na sat. %	BSP %	Al sat. %
199	132.00	148.4	51.10	112	90	44.75	2.87	16.97	65.50	17.34
200	132.30	214.6	67.40	120	76	45.00	3.34	15.64	70.23	15.00
201	57.80	313.6	75.60	126	80	51.25	3.73	14.69	78.90	15.28
202	64.30	193.1	59.90	114	72	41.88	2.85	17.42	75.11	16.36
203	74.90	394	24.20	100	68	53.88	3.65	11.90	76.03	16.40
204	56.90	197	58.90	114	74	51.25	2.95	16.80	73.00	19.31
205	30.20	438	33.70	106	80	52.63	3.84	12.01	81.64	15.25
206	52.10	62	25.90	98	78	41.38	1.81	23.54	63.45	25.42
207	64.60	164.1	48.50	98	76	36.25	2.48	17.16	74.08	16.23
208	62.70	110.5	39.40	110	66	40.38	2.21	21.65	68.96	20.32
209	165.40	220.3	62.30	106	66	36.13	3.26	14.15	68.89	12.34
210	145.80	149.9	55.10	110	64	34.13	2.77	17.29	66.66	13.72
211	101.50	155.3	68.00	108	72	32.63	2.73	17.19	72.83	13.28
212	99.00	148.8	54.20	108	66	42.50	2.67	17.59	68.46	17.70
213	35.20	403.9	68.80	132	114	27.88	3.90	14.73	88.54	7.96
214	33.20	162.1	40.60	116	90	26.63	2.31	21.87	81.47	12.84
215	86.30	232.3	63.10	124	90	19.25	2.99	18.06	82.06	7.17
216	92.10	241.9	54.10	146	90	39.13	3.30	19.25	76.38	13.19
217	95.90	93.6	25.80	132	114	36.13	2.30	24.93	67.13	17.45
218	128.70	71.1	29.80	106	68	30.00	2.05	22.54	60.41	16.31
219	49.70	252.1	51.70	116	86	26.50	2.89	17.44	83.32	10.19
220	54.70	176.1	46.90	136	90	28.75	2.62	22.60	79.78	12.22
221	95.80	491.8	61.10	144	102	19.00	4.42	14.17	87.07	4.78
222	87.70	238.5	54.10	124	96	14.50	2.91	18.53	83.24	5.54
223	38.50	667.8	80.40	170	128	16.75	5.40	13.68	93.76	3.45
224	57.50	238.6	49.60	128	126	30.13	3.04	18.34	81.71	11.04
225	76.70	203.2	65.40	122	72	16.75	2.75	19.33	82.65	6.79
226	152.20	143.6	46.80	110	76	20.50	2.57	18.62	69.12	8.87
227	61.00	250.7	56.80	122	80	24.25	2.96	17.93	83.01	9.12
228	85.80	427	70.10	180	96	37.00	4.47	17.51	83.65	9.20
229	115.50	432.2	80.90	144	106	27.38	4.46	14.04	83.51	6.83
230	101.00	341	74.60	130	100	21.75	3.76	15.04	83.51	6.43
231	86.20	329.6	69.10	146	96	22.50	3.67	17.29	84.35	6.82

Appendix - III
Raw Data Generated by Physico-Chemical Analysis

Sample No.	Type	Code	Phase	Gravel %	Fine earth %	sand %	silt %	clay %	Textural class	pH	EC dS/ m	Buffer pH	Org.C (%)
232	ss	15 / 21B	2	48.66	51.34					5.29	0.07	6.10	1.15
233	s	15 / 22A	7	65.00	35.00					4.88	0.02	6.10	1.10
234	ss	15 / 22B	7	52.60	47.40					4.91	0.01	6.30	0.87
235	s	15 / 23A	7	79.00	21.00					5.43	0.03	6.30	1.45
236	ss	15 / 23B	7	30.00	70.00					5.41	0.01	6.40	0.84
237	s	15 / 24A	4	60.00	40.00					5.60	0.06	6.20	1.22
238	ss	15 / 24B	4	32.60	67.40					5.58	0.03	6.10	1.15
239	s	15 / 25A	4	56.00	44.00					4.99	0.08	6.40	0.61
240	ss	15 / 25B	4	24.00	76.00					4.87	0.07	6.40	1.10
241	s	15 / 26A	4	41.00	59.00					5.55	0.01	6.30	0.82
242	ss	15 / 26B	4	18.00	82.00					5.01	0.01	6.20	0.64
243	s	15 / 27A	16	29.00	71.00					5.51	0.02	6.30	1.04
244	ss	15 / 27B	16	36.60	63.40					5.12	0.01	6.30	1.13
245	s	15 / 28A	7	56.00	44.00					4.95	0.10	6.20	1.28
246	ss	15 / 28B	7	35.46	64.54					4.75	0.03	6.30	1.03
247	s	15 / 29A	7	50.00	50.00	45.20	22.65	32.15	Clay Loam	4.86	0.10	5.80	0.82
248	ss	15 / 29B	7	50.80	49.20	41.20	24.26	34.54	Clay Loam	4.58	0.08	5.60	0.88
249	s	15 / 30A	7	70.00	30.00					4.65	0.08	6.30	1.47
250	ss	15 / 30B	7	42.13	57.87					5.42	0.03	6.40	1.51
251	s	15 / 31A	12	70.00	30.00					4.63	0.04	6.10	1.81
252	ss	15 / 31B	12	47.40	52.60					5.36	0.02	6.20	1.72
253	s	15 / 32A	12	85.00	15.00					5.30	0.01	6.30	0.99
254	ss	15 / 32B	12	58.40	41.60					5.23	0.03	6.20	1.42
255	s	15 / 33A	11	70.00	30.00	40.10	23.70	36.20	Clay Loam	5.26	0.04	6.30	1.42
256	ss	15 / 33B	11	36.20	63.80	39.90	24.42	35.68	Clay Loam	5.38	0.06	6.30	0.91
257	s	15 / 34A	11	74.00	26.00					5.11	0.03	6.10	1.30
258	ss	15 / 34B	11	33.06	66.94					5.31	0.07	5.90	1.24
259	s	15 / 35A	7	85.00	15.00					5.19	0.04	6.10	1.42
260	ss	15 / 35B	7	46.60	53.40					5.16	0.02	6.10	1.19
261	s	15 / 36A	12	90.00	10.00					5.39	0.03	6.10	0.99
262	ss	15 / 36B	12	41.53	58.47					5.11	0.02	6.20	0.94
263	s	15 / 37A	12	81.00	19.00	41.34	21.84	36.82	Clay Loam	5.21	0.03	6.50	1.47
264	ss	15 / 37B	12	34.40	65.60	40.64	22.60	36.76	Clay Loam	5.23	0.01	6.30	1.12

Appendix - III
Raw Data Generated by Physico-Chemical Analysis

Sample No.	Av.P (ppm)	Av.K (ppm)	Av.Na (ppm)	Ca (ppm)	Mg (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)	Fe (ppm)	P fix. %	Ex.Fe (ppm)
232	3.42	67	35	256.00	32.65	36.80	0.30	9.12	17.20		3.10
233	1.88	62	29	160.50	33.10	35.40	0.20	12.20	17.70		3.30
234	1.55	54	29	167.00	34.40	54.60	0.40	9.50	17.50		3.30
235	6.54	99	88	222.50	33.15	54.70	0.50	14.40	24.50		3.00
236	2.13	41	24	108.00	28.80	68.70	0.40	15.57	22.30		3.40
237	2.04	84	36	211.00	28.80	46.20	0.30	7.20	21.30		3.60
238	2.63	66	45	247.50	37.80	19.70	0.40	2.86	21.00		3.40
239	1.71	51	32	218.00	32.20	43.30	0.70	11.42	14.25		3.40
240	2.13	45	34	215.50	33.85	44.20	0.50	7.43	24.00		3.40
241	2.13	74	33	216.00	35.25	28.60	0.50	4.57	30.90		3.40
242	2.46	89	35	220.00	28.52	34.40	0.30	2.62	40.50		4.30
243	3.79	56	18	104.50	28.65	29.80	0.40	2.44	22.40		4.00
244	3.66	68	24	144.50	31.35	70.20	0.90	3.10	13.78		3.50
245	3.00	88	57	191.50	31.10	46.40	0.70	4.23	35.00		3.50
246	4.12	50	23	128.50	25.50	33.90	0.40	14.82	29.80		3.50
247	2.67	60	45	209.00	30.70	28.50	0.30	6.68	38.80	88.18	3.20
248	1.83	75	99	255.00	33.00	30.40	0.40	5.78	13.41	88.09	3.30
249	2.04	91	53	222.50	35.80	67.70	0.70	3.41	39.00		3.30
250	2.21	75	31	201.50	34.65	48.50	0.40	2.61	28.50		3.40
251	3.79	41	14	149.50	19.80	41.60	0.50	10.79	38.10		3.50
252	4.29	74	26	178.00	31.70	34.20	0.60	2.97	16.78		3.30
253	1.54	58	28	217.50	31.35	52.20	0.40	3.63	23.50		3.30
254	4.42	79	31	232.00	32.25	83.60	1.00	7.71	43.50		3.50
255	2.04	82	29	202.00	31.35	61.90	0.60	8.34	22.80	87.83	3.10
256	2.96	92	39	240.00	31.45	64.70	0.80	8.49	34.50	88.30	3.20
257	1.46	70	27	162.50	31.50	51.00	0.60	19.80	17.80		3.20
258	1.25	71	28	168.00	32.50	47.10	0.40	17.39	19.90		3.30
259	2.25	112	54	284.50	38.70	30.00	0.40	3.32	26.80		3.00
260	2.17	89	34	198.00	33.90	57.80	0.60	5.22	31.60		3.10
261	2.42	78	29	167.00	33.80	44.80	0.90	8.26	26.60		3.20
262	1.37	52	40	226.00	36.05	37.20	0.40	4.91	34.30		3.00
263	1.42	53	35	244.00	34.60	42.50	0.50	8.19	28.80	87.77	3.20
264	1.88	52	30	159.00	33.75	48.60	0.40	8.63	26.10	87.50	3.20

Appendix - III

Raw Data Generated by Physico-Chemical Analysis

Sample No.	Ex.Mn (ppm)	Ex.Ca (ppm)	Ex.Mg (ppm)	Ex.Na (ppm)	Ex.K (ppm)	Ex.Al (ppm)	CEC cmol(+)/kg	Na sat. %	BSP %	Al sat. %
232	71.60	240.5	78.20	130	92	21.25	3.16	17.92	83.89	7.49
233	132.30	261.9	67.00	118	82	22.50	3.33	15.42	77.65	7.52
234	133.30	289.3	86.80	126	82	24.38	3.69	14.86	79.16	7.36
235	105.30	410.1	83.40	192	116	23.88	4.53	18.44	85.43	5.87
236	82.10	322.3	83.20	140	92	24.13	3.72	16.37	84.42	7.22
237	78.00	366.4	84.80	126	96	22.50	3.87	14.16	85.86	6.47
238	57.10	401.2	100.30	132	82	33.75	4.21	13.64	85.86	8.92
239	78.00	445.3	72.40	138	82	22.50	4.18	14.36	86.92	5.99
240	75.00	390.4	89.40	134	78	15.25	3.92	14.85	88.41	4.32
241	150.00	429	46.70	136	100	20.00	4.16	14.23	81.22	5.35
242	60.90	391.1	33.30	134	104	18.63	3.52	16.55	87.39	5.88
243	50.00	284.1	70.00	128	106	26.38	3.31	16.80	85.22	8.85
244	57.90	208.5	45.80	120	96	22.75	2.66	19.60	82.11	9.50
245	69.00	95.8	68.70	110	82	36.88	2.41	19.88	72.00	17.05
246	46.50	259.8	77.00	114	88	23.88	3.10	15.99	85.57	8.57
247	88.50	354	79.00	124	92	50.88	4.09	13.17	78.03	13.82
248	85.80	346.4	70.40	134	94	24.13	3.73	15.64	84.10	7.20
249	60.60	426.3	69.40	176	96	12.50	4.09	18.74	90.91	3.40
250	59.80	381.3	50.40	160	94	15.88	3.66	18.99	88.91	4.82
251	52.10	157.3	69.80	126	78	18.25	2.51	21.80	83.88	8.08
252	111.20	310.5	67.90	146	100	42.88	3.90	16.30	77.06	12.24
253	83.00	335.7	70.30	132	88	13.13	3.52	16.33	86.92	4.15
254	112.20	356	66.90	124	88	13.25	3.66	14.72	84.49	4.02
255	101.00	420.6	72.50	130	102	22.50	4.16	13.61	84.86	6.02
256	83.80	476.5	71.00	134	104	10.88	4.25	13.70	89.71	2.85
257	79.10	386.8	80.50	134	98	18.00	3.93	14.83	87.29	5.10
258	99.10	421.4	74.00	162	90	11.38	4.15	16.98	87.97	3.05
259	47.80	284.6	65.20	124	92	21.25	3.16	17.09	86.65	7.49
260	113.60	289.9	68.70	110	80	33.75	3.50	13.68	77.13	10.73
261	69.50	369.6	78.70	132	108	25.38	3.89	14.75	85.95	7.25
262	68.50	264	75.30	122	98	18.88	3.19	16.63	85.27	6.58
263	94.10	459.7	82.70	136	84	18.88	4.35	13.60	87.03	4.83
264	90.10	398.6	72.10	126	78	25.38	3.96	13.85	84.28	7.14

APPENDIX - III

Raw data generated by physico-chemical analysis

Sample No.	Type	*Code	Phase	Gravel %	Fine earth %	sand %	silt %	clay %	Textural class	pH	EC dS/m	Buffer pH	Org.C (%)
265	s	15 / 38A	8	72.00	28.00					5.34	0.011	6.1	1.30
266	ss	15 / 38B	8	32.13	67.87					4.95	0.011	6.0	1.21
267	s	15 / 39A	8	80.00	20.00					5.17	0.022	6.5	1.12
268	ss	15 / 39B	8	32.00	68.00					4.57	0.110	6.0	1.49
269	s	15 / 40A	8	60.00	40.00					4.95	0.033	5.7	1.64
270	ss	15 / 40B	8	28.00	72.00					4.94	0.011	6.2	1.01
271	s	16 / 1A	30	59.00	41.00					4.75	0.011	5.8	1.16
272	ss	16 / 1B	30	45.93	54.07					5.12	0.011	6.0	0.70
273	s	16 / 2A	30	59.00	41.00					5.45	0.110	6.0	0.52
274	ss	16 / 2B	30	40.00	60.00					5.62	0.055	6.2	1.08
275	s	16 / 3A	30	46.00	54.00					5.26	0.033	6.2	0.52
276	ss	16 / 3B	30	32.26	67.74					5.09	0.022	6.4	1.16
277	s	16 / 4A	30	67.00	33.00					5.48	0.022	6.4	0.60
278	ss	16 / 4B	30	33.53	66.47					5.02	0.033	6.5	0.71
279	s	16 / 5A	7	59.00	41.00					5.15	0.033	6.5	0.60
280	ss	16 / 5B	7	41.00	59.00					5.47	0.011	6.0	0.72
281	s	16 / 6A	7	99.00	1.00					4.82	0.110	6.2	0.72
282	ss	16 / 6B	7	40.06	59.94					4.93	0.033	5.7	1.57
283	s	16 / 7A	7	76.00	24.00					5.12	0.011	5.9	1.03
284	ss	16 / 7B	7	42.53	57.47					4.79	0.110	6.0	0.84
285	s	16 / 8A	8	77.00	23.00					4.93	0.033	6.9	1.03
286	ss	16 / 8B	8	61.20	38.80					4.14	0.011	6.1	0.91
287	s	16 / 9A	8	80.00	20.00	43.61	22.70	33.69	Clay Loam	4.79	0.110	6.2	0.84
288	ss	16 / 9B	8	45.40	54.60	41.28	24.10	34.62	Clay Loam	4.93	0.033	6.3	1.10
289	s	16 / 10A	8	59.00	41.00					5.40	0.055	5.9	0.54
290	ss	16 / 10B	8	66.66	33.34					5.29	0.044	5.9	1.43
291	s	16 / 11A	4	68.00	32.00					4.89	0.033	5.5	1.06
292	ss	16 / 11B	4	47.66	52.34					5.14	0.011	5.9	1.03
293	s	16 / 12A	4	80.00	20.00					5.55	0.033	6.4	0.91
294	ss	16 / 12B	4	51.20	48.80					5.31	0.011	6.0	0.90
295	s	16 / 13A	30	52.00	48.00	43.40	23.28	33.32	Clay Loam	5.50	0.011	5.9	0.87
296	ss	16 / 13B	30	38.30	61.70	41.97	22.84	35.19	Clay Loam	5.71	0.022	6.2	1.15
297	s	16 / 14A	4	68.00	32.00					5.67	0.055	6.4	1.12

*Sample code: Block No./ Sample site No. Surface (A) or Subsurface (B)

Appendix - III
Raw Data Generated by Physico-Chemical Analysis

Sample No.	Av.P (ppm)	Av.K (ppm)	Av.Na (ppm)	Ca (ppm)	Mg (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)	Fe (ppm)	P fix. %	Ex.Fe (ppm)
265	1.67	53	28	154.00	46.62	40.60	0.50	3.58	14.80		2.80
266	1.67	59	24	147.50	33.80	56.40	0.50	3.67	21.20		3.20
267	3.29	50	26	151.50	33.15	29.90	0.40	16.19	41.70		2.70
268	2.08	44	22	146.80	26.95	41.60	0.40	8.95	81.40		2.80
269	5.87	41	21	132.00	24.85	44.30	0.50	23.50	98.70		2.80
270	2.04	55	25	136.50	31.15	61.90	0.70	14.94	17.00		3.00
271	1.88	86	45	177.50	31.55	84.60	0.90	11.61	20.60		2.60
272	2.75	63	27	123.00	31.55	47.60	0.40	5.62	20.30		2.60
273	2.63	47	45	243.00	40.95	23.40	4.80	8.95	40.20		2.60
274	2.46	42	46	238.00	31.15	16.60	5.10	11.86	44.40		2.60
275	2.13	85	34	197.50	37.40	46.60	0.60	8.20	25.70		2.80
276	2.04	61	29	172.00	36.50	80.10	0.50	4.32	46.60		2.50
277	2.16	57	33	208.00	36.80	45.80	0.40	4.66	24.20		2.40
278	2.00	40	35	206.50	37.35	33.40	0.80	11.95	50.00		2.20
279	1.96	31	26	116.00	32.75	10.10	0.40	10.98	41.40		2.50
280	1.63	34	34	153.00	32.00	27.30	0.30	6.44	41.60		2.50
281	2.42	64	35	166.50	34.90	25.10	0.30	3.70	29.40		2.60
282	2.13	75	31	205.00	29.50	25.70	0.20	15.90	27.90		2.50
283	2.55	65	26	146.50	27.25	34.70	0.40	31.00	49.20		2.40
284	2.46	56	30	143.00	32.50	26.60	0.20	6.23	24.20		2.50
285	2.46	57	27	139.50	31.50	114.30	0.60	5.29	28.40		2.00
286	2.12	63	22	176.00	39.35	63.20	0.60	11.54	21.20		2.30
287	2.04	59	21	116.00	34.65	130.30	1.20	16.47	26.90	91.18	2.40
288	1.63	38	20	85.50	28.95	78.30	0.40	2.52	30.70	85.93	2.50
289	2.21	83	30	218.50	35.55	41.40	1.10	23.58	39.00		2.30
290	1.41	74	26	168.50	35.95	43.40	0.50	23.06	30.90		2.70
291	1.29	70	21	96.00	29.80	38.90	0.40	25.00	36.90		2.90
292	1.63	62	23	81.50	27.80	32.00	0.20	5.97	49.00		5.50
293	1.71	129	55	175.50	39.55	50.70	0.70	22.87	21.40		2.20
294	1.54	103	55	241.00	38.20	25.50	1.50	13.56	15.50		2.20
295	1.63	47	42	203.00	37.55	48.80	5.10	27.43	17.30	87.42	2.00
296	1.71	36	41	199.00	37.30	53.60	0.60	14.68	31.30	86.64	2.60
297	3.38	32	40	213.50	31.25	20.80	0.30	8.52	20.80		2.60

Appendix - III

Raw Data Generated by Physico-Chemical Analysis

Sample No.	Ex.Mn (ppm)	Ex.Ca (ppm)	Ex.Mg (ppm)	Ex.Na (ppm)	Ex.K (ppm)	Ex.Al (ppm)	CEC cmol(+)/kg	Na sat. %	BSP %	Al sat. %
265	84.90	315.8	76.80	128	84	35.88	3.70	15.04	80.59	10.78
266	108.60	261.8	55.20	124	82	22.88	3.17	16.99	79.16	8.02
267	61.50	194.4	70.20	116	78	42.13	2.96	17.07	76.25	15.85
268	79.00	299.7	72.60	120	78	26.88	3.41	15.29	82.52	8.76
269	82.30	113.7	55.30	138	72	42.25	2.59	23.20	69.87	18.16
270	115.00	110.7	46.60	102	66	20.13	2.20	20.14	70.34	10.17
271	114.30	366.8	80.20	116	82	22.88	3.89	12.98	82.51	6.55
272	51.90	524.8	98.00	130	70	33.50	4.75	11.91	87.97	7.85
273	112.30	270.2	64.50	102	62	19.50	3.12	14.22	79.64	6.95
274	29.20	261	99.80	124	66	16.13	3.13	17.23	90.57	5.73
275	101.00	426.8	80.40	124	74	19.50	4.12	13.09	85.56	5.27
276	141.90	310.5	82.80	118	88	40.00	3.94	13.02	75.39	11.28
277	71.20	188.6	58.60	108	88	44.75	2.89	16.28	73.47	17.25
278	59.00	171	57.90	124	90	33.75	2.70	19.98	77.84	13.91
279	75.00	630	81.00	128	100	33.13	5.28	10.55	87.68	6.98
280	96.70	510.8	86.50	124	100	37.50	4.84	11.15	83.92	8.62
281	148.00	191.8	59.10	110	76	19.50	2.88	16.59	73.47	7.52
282	140.50	342.5	71.90	114	82	18.63	3.74	13.27	80.53	5.54
283	112.90	382	80.10	112	84	33.13	4.06	12.00	80.59	9.08
284	176.40	325.7	67.60	110	80	21.25	3.76	12.74	76.37	6.29
285	82.10	577.6	85.50	130	80	33.75	5.04	11.21	86.49	7.44
286	31.00	508.7	88.00	124	68	31.13	4.45	12.12	89.49	7.78
287	63.20	274.2	74.50	120	66	37.88	3.33	15.65	80.21	12.63
288	69.00	290	75.60	120	68	39.38	3.47	15.06	79.86	12.64
289	66.90	240.6	50.20	116	88	44.00	3.09	16.34	75.99	15.85
290	83.90	358.7	81.90	124	82	16.63	3.72	14.51	86.55	4.98
291	76.50	151.7	89.50	132	90	30.25	2.92	19.63	78.62	11.50
292	56.00	431.9	80.30	126	82	22.50	4.05	13.53	88.31	6.18
293	76.00	749.5	77.30	136	120	24.13	5.84	10.14	90.52	4.60
294	46.00	668.1	88.60	178	112	36.13	5.71	13.57	89.89	7.04
295	38.00	559.8	95.40	128	78	36.13	4.89	11.39	88.80	8.22
296	95.00	657.4	30.60	126	66	25.38	4.89	11.20	86.97	5.77
297	43.40	607	16.61	124	64	21.38	4.28	12.60	90.53	5.56

Appendix - III

Raw Data Generated by Physico-Chemical Analysis

Sample No.	Type	Code	Phase	Gravel %	Fine earth %	sand %	silt %	clay %	Textural class	pH	EC dS/ m	Buffer pH	Org.C (%)
298	ss	16 / 14B	4	40.93	59.07					5.27	0.03	6.10	0.61
299	s	16 / 15A	4	60.00	40.00					4.95	0.11	6.00	0.91
300	ss	16 / 15B	4	61.20	38.80					4.93	0.04	5.70	1.51
301	s	16 / 16A	11	71.00	29.00					4.72	0.10	5.90	1.66
302	ss	16 / 16B	11	63.26	36.74					5.27	0.01	6.00	0.84
303	s	16 / 17A	4	80.00	20.00	41.10	25.71	33.19	Clay Loam	5.09	0.01	5.90	1.06
304	ss	16 / 17B	4	43.46	56.54	39.91	24.98	35.11	Clay Loam	4.98	0.02	5.70	0.58
305	s	16 / 18A	11	61.00	39.00					4.95	0.11	6.00	1.06
306	ss	16 / 18B	11	53.00	47.00					4.90	0.02	5.80	0.91
307	s	16 / 19A	11	61.00	39.00					5.27	0.01	5.90	0.91
308	ss	16 / 19B	11	51.13	48.87					4.86	0.02	5.90	1.09
309	s	16 / 20A	11	61.00	39.00					5.13	0.02	5.90	0.61
310	ss	16 / 20B	11	46.53	53.47					4.91	0.11	6.50	0.81
311	s	16 / 21A	7	57.00	43.00					4.65	0.09	5.80	1.00
312	ss	16 / 21B	7	55.60	44.40					4.89	0.07	5.80	0.81
313	s	16 / 22A	7	84.00	16.00					5.12	0.06	6.00	1.21
314	ss	16 / 22B	7	69.60	30.40					5.19	0.01	5.90	0.99
315	s	16 / 23A	4	84.00	16.00					5.20	0.07	5.90	0.88
316	ss	16 / 23B	4	65.73	34.27					5.06	0.03	5.70	0.75
317	s	16 / 24A	16	60.00	40.00					5.07	0.11	6.20	1.04
318	ss	16 / 24B	16	59.80	40.20					5.49	0.06	6.20	1.10
319	s	16 / 25A	16	64.00	36.00					4.92	0.10	6.40	1.22
320	ss	16 / 25B	16	59.06	40.94					4.92	0.07	5.90	1.03
321	s	16 / 26A	16	57.00	43.00					4.98	0.04	6.00	1.24
322	ss	16 / 26B	16	59.40	40.60					4.86	0.03	6.00	0.79
323	s	16 / 27A	16	57.00	43.00					4.71	0.06	6.20	1.06
324	ss	16 / 27B	16	66.20	33.80					4.77	0.04	6.40	0.58
325	s	16 / 28A	16	68.00	32.00					4.71	0.09	6.10	1.84
326	ss	16 / 28B	16	60.33	39.67					5.02	0.06	6.40	1.18
327	s	16 / 29A	16	52.00	48.00					4.76	0.07	6.20	0.99
328	ss	16 / 29B	16	35.40	64.60					5.31	0.02	6.30	0.94
329	s	16 / 30A	16	78.00	22.00					5.42	0.03	6.40	1.13
330	ss	16 / 30B	16	42.66	57.34					5.04	0.04	6.40	1.60

APPENDIX - III

Raw data generated by physico-chemical analysis

Sample No.	Av.P (ppm)	Av.K (ppm)	Av.Na (ppm)	Ca (ppm)	Mg (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)	Fe (ppm)	P fix. %	Ex.Fe (ppm)
298	1.79	58	31	132.5	32.2	35.2	0.5	20.52	29.30		2.2
299	3.29	102	55	217.0	36.7	72.0	0.6	26.98	23.70		2.3
300	2.83	95	40	137.0	37.1	76.8	0.3	6.90	28.40		2.7
301	8.75	77	45	164.5	33.8	58.6	0.3	13.38	21.80		2.9
302	3.71	52	53	156.0	33.6	60.6	0.2	2.95	19.70		2.7
303	6.96	46	26	57.5	27.4	64.2	0.1	4.23	20.90	85.21	2.7
304	3.46	52	30	51.0	26.9	80.7	0.3	16.15	29.70	88.59	2.6
305	2.00	82	41	136.0	32.5	51.6	0.2	15.98	20.60		2.7
306	3.71	90	23	66.5	25.5	53.5	0.1	15.05	27.70		2.7
307	6.96	73	31	124.5	35.0	39.3	0.2	10.82	18.80		2.8
308	3.46	86	28	66.0	29.1	38.4	0.2	21.88	27.00		2.9
309	2.04	54	24	51.5	27.5	64.9	0.1	4.88	29.00		2.8
310	1.54	68	31	50.0	28.0	42.0	0.1	8.66	28.20		2.9
311	1.33	62	32	37.0	29.8	40.5	0.1	11.56	19.40		2.8
312	2.37	57	36	134.0	31.6	43.4	0.2	12.86	20.60		2.7
313	1.96	82	38	59.0	35.9	47.3	0.1	22.05	27.20		3.3
314	1.54	73	35	47.0	34.1	48.3	0.8	12.10	24.40		2.9
315	2.21	119	48	72.0	36.2	41.3	1.4	22.48	26.30		2.9
316	1.92	100	42	37.0	37.2	34.4	0.9	23.70	42.00		3.3
317	1.58	71	89	56.5	40.3	87.5	1.0	10.80	24.20		3.2
318	1.50	26	26	95.5	40.3	100.2	0.9	4.53	21.70		3.0
319	1.63	31	31	51.5	35.5	73.3	0.9	12.92	46.60		3.4
320	1.54	50	30	52.0	32.9	94.2	0.8	8.87	40.80		3.1
321	1.58	72	37	59.5	32.7	69.2	1.0	7.20	43.70		3.2
322	2.96	70	35	47.0	32.5	59.9	0.7	5.12	34.00		3.3
323	2.83	70	39	63.0	33.8	73.1	1.0	5.17	30.10		3.1
324	1.75	85	67	85.5	34.7	71.1	0.8	6.60	33.80		3.4
325	1.71	54	43	30.2	34.6	44.3	1.3	18.94	51.00		2.8
326	1.88	43	40	59.0	33.4	49.7	0.8	7.50	23.90		3.3
327	2.04	47	60	69.5	35.0	78.2	1.1	9.73	36.20		3.1
328	4.67	38	47	58.0	35.8	70.3	1.1	6.84	34.10		2.9
329	3.96	141	46	166.5	37.1	65.5	0.8	9.14	15.30		2.9
330	2.04	114	43	128.5	31.1	23.7	0.6	3.29	31.70		2.8

*Sample code: Block No./ Sample site No. Surface (A) or Subsurface (B)

Appendix - III
Raw Data Generated by Physico-Chemical Analysis

Sample No.	Ex.Mn (ppm)	Ex.Ca (ppm)	Ex.Mg (ppm)	Ex.Na (ppm)	Ex.K (ppm)	Ex.Al (ppm)	CEC cmol(+)/kg	Na sat. %	BSP %	Al sat. %
298	76.00	339.4	18.60	116	78	33.25	3.21	15.73	79.60	11.53
299	129.20	591.9	88.30	136	108	36.13	5.43	10.89	83.80	7.40
300	48.00	301.7	88.50	124	104	23.38	3.49	15.47	87.25	7.46
301	106.80	421.7	76.70	124	92	33.25	4.28	12.59	82.05	8.63
302	126.80	421.7	46.90	120	78	36.75	4.10	12.74	78.51	9.98
303	128.30	149.4	23.60	108	70	17.63	2.26	20.76	70.27	8.67
304	148.00	131.3	24.70	98	72	37.63	2.44	17.49	60.33	17.18
305	92.60	494.9	65.10	120	82	35.25	4.48	11.65	83.51	8.75
306	118.50	135.1	38.20	94	86	34.00	2.44	16.77	66.40	15.51
307	77.40	401.8	69.60	112	82	38.13	3.99	12.20	82.08	10.62
308	70.00	199.5	53.60	106	84	36.38	2.78	16.56	75.94	14.53
309	133.30	145.8	52.40	100	76	34.88	2.67	16.27	66.95	14.52
310	99.00	136.4	51.10	100	72	24.63	2.37	18.38	72.75	11.58
311	94.00	296.1	60.60	108	72	21.13	3.22	14.59	81.76	7.30
312	102.60	417.1	67.20	110	68	36.63	4.08	11.72	80.63	9.98
313	106.70	474.7	80.50	116	80	44.88	4.64	10.86	80.63	10.75
314	95.60	317.1	73.20	114	82	13.63	3.40	14.57	85.02	4.45
315	76.30	387.5	66.30	106	80	36.25	3.84	12.01	82.00	10.50
316	80.70	685.7	79.60	118	96	50.00	5.70	9.00	84.89	9.75
317	144.00	728.8	98.20	146	74	48.63	6.35	10.00	83.05	8.51
318	133.20	759.3	98.70	138	68	59.00	6.53	9.19	82.37	10.04
319	155.70	624.6	87.30	126	78	53.88	5.77	9.50	79.57	10.39
320	160.60	415.1	68.20	116	82	38.75	4.38	11.53	76.55	9.85
321	173.00	471.7	74.00	112	80	48.63	4.84	10.06	75.58	11.17
322	187.10	356.8	69.80	102	72	16.13	3.86	11.50	77.39	4.65
323	169.20	380.8	67.10	106	84	38.75	4.19	11.00	74.75	10.29
324	177.60	421.7	75.70	118	82	16.25	4.29	11.95	80.45	4.21
325	163.70	545.6	81.30	120	76	36.13	5.12	10.19	80.32	7.85
326	129.40	512.9	74.14	120	70	15.50	4.53	11.52	85.54	3.81
327	154.00	500.7	78.20	118	64	31.63	4.75	10.81	80.55	7.41
328	147.20	586.2	81.20	116	60	16.38	4.99	10.12	85.39	3.65
329	107.40	518.5	75.40	114	110	16.38	4.57	10.84	87.24	3.98
330	106.20	606.9	77.50	118	104	16.25	5.03	10.21	88.52	3.59

Appendix - III
Raw Data Generated by Physico-Chemical Analysis

Sample No.	Type	Code	Phase	Gravel %	Fine earth %	sand %	silt %	clay %	Textural class	pH	EC dS/ m	Buffer pH	Org.C (%)
331	s	16 / 31A	16	69.00	31.00	39.84	27.49	32.67	Clay Loam	5.15	0.03	6.30	1.12
332	ss	16 / 31B	16	46.93	53.07	37.65	26.20	36.15	Clay Loam	5.34	0.01	6.30	1.22
333	s	16 / 32A	22	87.00	13.00					4.50	0.11	6.30	1.21
334	ss	16 / 32B	22	53.53	46.47					5.27	0.01	6.40	0.76
335	s	16 / 33A	22	50.00	50.00					5.14	0.03	6.20	0.60
336	ss	16 / 33B	22	63.40	36.60					5.23	0.03	6.30	0.96
337	s	16 / 34A	22	50.00	50.00					5.02	0.01	6.40	0.61
338	ss	16 / 34B	22	54.80	45.20					4.81	0.04	5.90	0.69
339	s	16 / 36A	22	48.00	52.00					5.27	0.03	6.20	1.28
340	ss	16 / 36B	22	41.80	58.20					5.35	0.01	6.30	1.58
341	s	16 / 36A	22	49.00	51.00					5.00	0.01	6.00	1.61
342	ss	16 / 36B	22	42.46	57.54					5.22	0.02	6.30	1.38
343	s	16 / 37A	25	48.00	52.00					5.06	0.01	6.20	1.37
344	ss	16 / 37B	25	63.86	36.14					4.72	0.11	5.60	1.25
345	s	16 / 38A	25	50.00	50.00					5.36	0.02	6.20	1.21
346	ss	16 / 38B	25	56.53	43.47					5.22	0.01	6.10	1.48
347	s	16 / 39A	25	48.00	52.00					4.78	0.07	6.40	0.51
348	ss	16 / 39B	25	42.40	57.60					5.01	0.08	6.30	1.18
349	s	16 / 40A	25	50.00	50.00	30.51	30.40	39.09	Clay Loam	4.61	0.03	6.40	1.03
350	ss	16 / 40B	25	22.20	77.80	31.20	29.81	38.99	Clay Loam	5.22	0.04	6.20	0.87
351	s	16 / 41A	25	50.00	50.00					5.50	0.02	5.90	1.81
352	ss	16 / 41B	25	57.73	42.27					4.99	0.07	5.80	1.27
353	s	16 / 42A	26	56.00	44.00					5.18	0.01	6.00	0.81
354	ss	16 / 42B	26	66.00	34.00					4.88	0.04	5.90	1.16
355	s	16 / 43A	26	49.00	51.00					5.35	0.01	6.20	1.15
356	ss	16 / 43B	26	44.06	55.94					4.21	0.04	6.20	1.55
357	s	16 / 44A	26	80.00	20.00					5.31	0.01	6.10	1.37
358	ss	16 / 44B	26	62.13	37.87					5.23	0.02	6.10	1.01
359	s	16 / 45A	26	85.00	15.00					5.63	0.02	6.40	0.97
360	ss	16 / 45B	26	54.06	45.94					5.42	0.01	6.20	1.09
361	s	16 / 46A	26	71.00	29.00	46.95	25.34	27.71	Sandy Clay Loam	5.41	0.09	6.40	1.73
362	ss	16 / 46B	26	44.00	56.00	44.32	25.70	29.98	Clay Loam	5.22	0.01	6.30	1.58
363	s	19 / 1A	1	70.00	30.00					4.99	0.01	6.10	1.13

Appendix - III
Raw Data Generated by Physico-Chemical Analysis

Sample No.	Av.P (ppm)	Av.K (ppm)	Av.Na (ppm)	Ca (ppm)	Mg (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)	Fe (ppm)	P fix. %	Ex.Fe (ppm)
331	1.50	65	26	179.50	35.00	68.90	0.60	7.49	43.80	87.95	2.90
332	1.54	49	48	106.50	37.05	43.90	0.50	4.38	16.80	84.41	2.80
333	1.50	83	39	74.00	31.75	20.20	0.40	4.90	17.90		2.70
334	2.33	57	22	130.50	28.20	67.10	0.50	4.03	22.90		2.60
335	3.21	42	34	158.00	30.10	23.80	0.50	12.25	25.90		2.80
336	2.04	36	36	158.00	34.10	80.70	0.20	9.21	21.60		2.70
337	1.92	31	16	72.50	22.05	40.60	0.20	15.99	22.30		2.60
338	1.93	27	23	121.00	28.01	22.40	0.30	21.22	50.00		2.40
339	1.63	72	31	114.50	29.60	50.50	0.40	8.44	23.20		2.50
340	3.96	41	32	154.50	26.25	52.00	0.30	12.95	21.70		2.50
341	1.54	43	29	168.00	37.50	50.80	0.40	9.16	21.50		2.50
342	2.54	46	20	124.50	32.45	47.70	0.40	8.79	26.10		1.90
343	1.54	36	31	118.50	33.50	92.30	0.20	2.80	33.80		2.50
344	1.92	39	21	85.00	31.05	38.10	0.40	13.81	44.00		2.40
345	1.79	56	25	135.50	31.75	74.20	0.70	7.78	24.70		2.80
346	1.63	37	18	85.50	26.75	74.20	0.80	7.20	27.00		2.50
347	1.58	43	25	99.50	29.95	73.30	0.70	8.90	32.90		2.20
348	2.21	84	40	147.50	32.80	91.50	0.70	8.60	27.00		2.70
349	2.04	67	34	141.00	33.20	55.90	0.50	14.11	17.80	87.06	2.50
350	1.96	84	42	135.00	32.30	32.00	0.20	1.79	33.50	86.43	2.80
351	2.21	79	39	160.50	36.10	52.70	0.40	12.09	24.30		3.10
352	2.04	105	64	189.50	37.20	44.90	0.30	3.89	29.20		3.40
353	1.96	89	46	163.50	33.65	65.00	0.10	1.69	51.00		3.60
354	2.13	75	43	137.50	31.30	28.50	0.10	2.80	36.60		3.10
355	2.00	89	28	99.50	30.50	100.40	0.30	5.42	24.20		3.00
356	1.71	64	43	179.50	35.35	61.70	0.20	4.83	29.80		3.00
357	1.92	63	44	149.00	31.80	44.80	0.30	4.10	39.50		2.70
358	2.29	50	36	140.00	32.10	56.20	0.30	4.58	46.20		2.70
359	2.12	77	40	171.50	32.85	68.00	0.10	2.49	28.10		2.70
360	3.71	104	39	179.50	35.70	30.20	0.10	2.36	35.40		2.60
361	3.25	100	31	127.50	31.25	69.70	0.50	6.13	49.40	88.47	2.50
362	3.21	85	29	43.50	32.45	65.00	0.60	4.59	48.30	88.65	2.20
363	3.00	57	21	56.50	18.80	54.70	0.40	10.26	31.80		2.50

Appendix - III

Raw Data Generated by Physico-Chemical Analysis

Sample No.	Ex.Mn (ppm)	Ex.Ca (ppm)	Ex.Mg (ppm)	Ex.Na (ppm)	Ex.K (ppm)	Ex.Al (ppm)	CEC cmol(+)/kg	Na sat. %	BSP %	Al sat. %
331	85.10	436.9	71.30	108	84	17.50	3.97	11.83	87.03	4.90
332	108.80	689.2	69.00	130	66	12.50	5.29	10.68	89.70	2.63
333	61.70	432.7	61.50	136	92	16.13	3.91	15.13	89.42	4.59
334	79.00	243.8	52.00	112	78	12.38	2.77	17.60	84.30	4.97
335	82.50	529.1	57.00	114	70	17.25	4.29	11.55	88.30	4.47
336	115.20	538.6	77.60	132	74	11.13	4.65	12.35	88.11	2.66
337	114.50	215.1	52.30	132	78	17.13	2.90	19.82	78.71	6.58
338	52.10	443.1	51.00	134	78	16.13	3.80	15.36	90.05	4.73
339	178.10	519.8	84.90	152	122	13.63	5.08	13.02	84.08	2.98
340	43.40	619.5	75.60	152	84	16.25	4.94	13.37	92.97	3.66
341	99.60	417.4	73.50	136	88	36.13	4.28	13.82	81.94	9.39
342	111.50	331.2	80.30	130	82	16.38	3.69	15.34	83.86	4.94
343	133.20	480.7	69.90	126	86	17.63	4.44	12.35	84.45	4.42
344	115.70	599.7	68.70	140	82	18.50	5.02	12.14	87.33	4.10
345	106.30	570.2	68.40	140	90	17.50	4.84	12.57	87.79	4.02
346	95.00	350.1	55.50	130	82	21.13	3.57	15.83	83.49	6.58
347	177.20	332.8	64.80	122	78	15.38	3.75	14.15	78.03	4.56
348	74.70	558.1	72.00	140	102	12.50	4.67	13.03	91.00	2.98
349	140.70	695.8	77.70	154	106	18.63	5.79	11.57	87.42	3.58
350	114.10	552	95.80	148	108	48.63	5.43	11.85	82.22	9.95
351	142.90	402	85.90	138	114	52.50	4.72	12.71	76.39	12.36
352	172.70	449.3	75.60	142	106	48.88	4.94	12.50	76.03	11.00
353	71.40	532.2	83.70	154	102	54.13	5.16	12.99	83.03	11.68
354	71.50	585.2	74.50	162	118	41.25	5.28	13.36	86.16	8.70
355	108.60	573.9	89.50	144	96	53.63	5.48	11.43	81.71	10.88
356	152.60	758.9	89.10	180	126	40.13	6.65	11.78	84.76	6.72
357	75.20	477.1	68.50	136	82	52.25	4.62	12.82	81.27	12.59
358	84.60	485.2	66.90	140	82	39.75	4.56	13.37	83.32	9.71
359	40.40	543.2	78.90	144	88	24.13	4.64	13.49	90.84	5.78
360	58.30	367.2	74.70	128	110	24.13	3.78	14.73	87.03	7.10
361	72.90	413.6	76.10	140	100	40.13	4.28	14.23	83.16	10.43
362	141.50	540.1	75.20	142	100	36.13	5.12	12.07	81.93	7.85
363	76.50	127.4	35.90	110	84	36.63	2.32	20.62	70.06	17.56

APPENDIX - III

Raw data generated by physico-chemical analysis

Sample No.	Type	*Code	Phase	Gravel %	Fine earth %	sand %	silt %	clay %	Textural class	pH	EC dS/ m	Buffer pH	Org.C (%)
364	ss	19 / 1B	1	35.33	64.67					4.62	0.011	6.2	0.96
365	s	19 / 2A	1	69.00	31.00					4.80	0.022	6.3	1.15
366	ss	19 / 2B	1	55.33	44.67					4.81	0.011	6.4	0.52
367	s	19 / 3A	1	69.00	31.00					4.51	0.088	6.4	1.03
368	ss	19 / 3B	1	50.66	49.34					4.90	0.011	6.4	0.64
369	s	19 / 4A	1	63.00	37.00					4.69	0.011	6.3	0.54
370	ss	19 / 4B	1	39.30	60.70					5.13	0.005	6.2	0.49
371	s	19 / 5A	1	64.00	36.00	57.75	30.56	11.69	Sandy Loam	4.84	0.022	6.5	0.42
372	ss	19 / 5B	1	54.13	45.87	50.40	28.72	20.88	Sandy Clay Loam	4.72	0.011	6.5	0.43
373	s	24 / 1A	1	70.00	30.00					5.29	0.066	6.4	0.70
374	ss	24 / 1B	1	41.20	58.80					5.10	0.066	6.4	0.54
375	s	24 / 2A	1	69.00	31.00					4.84	0.110	5.8	0.54
376	ss	24 / 2B	1	60.86	39.14					5.24	0.022	6.4	0.57
377	s	24 / 3A	4	50.00	50.00					4.97	0.011	5.9	0.76
378	ss	24 / 3B	4	52.73	47.27					5.61	0.022	6.4	0.75
379	s	25 / 1A	1	49.00	51.00					5.22	0.010	6.3	0.69
380	ss	25 / 1B	1	36.30	63.70					5.34	0.088	6.3	0.91
381	s	25 / 2A	3	56.00	44.00					5.17	0.033	5.7	1.33
382	ss	25 / 2B	3	32.00	68.00					5.81	0.033	5.9	1.12
383	s	25 / 3A	3	45.00	55.00					5.08	0.077	5.7	0.75
384	ss	25 / 3B	3	62.00	38.00					5.13	0.033	5.5	0.72
385	s	25 / 4A	3	68.00	32.00					5.18	0.011	6.1	1.27
386	ss	25 / 4B	3	54.00	46.00					4.80	0.011	5.7	0.96
387	s	25 / 5A	3	59.00	41.00					5.03	0.022	5.7	0.97
388	ss	25 / 5B	3	44.00	56.00					5.11	0.011	5.6	0.99
389	s	25 / 6A	3	57.00	43.00	25.63	30.10	44.27	Loam	4.81	0.055	6.2	1.13
390	ss	25 / 6B	3	27.86	72.14	26.46	29.64	43.90	Loam	4.89	0.011	6.1	1.12
391	s	25 / 7A	4	51.00	49.00					4.92	0.110	5.7	0.61
392	ss	25 / 7B	4	45.30	54.70					5.25	0.110	5.8	0.91
393	s	25 / 8A	4	61.00	39.00					4.91	0.110	6.0	0.84
394	ss	25 / 8B	4	40.00	60.00					5.92	0.044	6.4	0.73
395	s	25 / 9A	4	65.00	35.00					5.26	0.044	6.1	0.79
396	ss	25 / 9B	4	50.60	49.40					5.87	0.033	6.0	0.76

*Sample code: Block No./ Sample site No. Surface (A) or Subsurface (B)

APPENDIX - III

Raw data generated by physico-chemical analysis

Sample No.	Av.P (ppm)	Av.K (ppm)	Av.Na (ppm)	Ca (ppm)	Mg (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)	Fe (ppm)	P fix. %	Ex.Fe (ppm)
364	1.63	52	23	64.0	18.9	42.6	0.3	11.02	24.20		2.5
365	2.04	62	26	128.5	30.1	68.3	0.3	15.27	38.30		2.5
366	1.96	47	34	82.0	32.2	62.0	0.5	23.66	21.50		2.7
367	2.25	72	46	124.5	29.5	42.0	0.5	11.33	29.20		3.1
368	1.58	58	31	77.5	29.5	62.9	0.6	7.79	36.60		2.8
369	1.70	41	35	89.5	28.1	75.8	0.1	3.29	29.20		2.9
370	1.54	36	30	165.0	24.9	77.2	0.2	6.17	40.20		2.8
371	15.83	69	24	102.5	24.6	87.9	0.3	12.18	29.50	88.05	2.8
372	10.83	66	25	93.0	20.7	83.9	1.8	15.02	23.20	86.81	2.9
373	12.49	60	32	174.0	30.9	73.7	1.7	14.60	21.80		3.0
374	11.66	52	41	207.0	32.8	50.0	0.6	20.30	20.20		2.8
375	10.83	79	24	65.5	24.1	24.0	0.5	8.41	22.00		2.8
376	8.33	73	18	53.0	19.3	28.5	0.3	3.31	29.50		2.9
377	12.49	83	31	198.0	33.7	70.1	0.6	14.68	29.80		3.2
378	7.49	91	36	206.0	35.3	60.1	0.7	12.94	23.30		2.7
379	9.99	84	34	192.0	33.1	56.7	0.7	13.58	23.80		2.7
380	10.08	80	36	176.0	33.2	40.8	0.6	10.30	18.70		2.8
381	6.66	86	27	113.0	28.9	61.1	0.6	9.83	21.10		2.9
382	5.83	40	22	88.0	24.0	42.4	0.2	3.03	24.30		3.0
383	13.33	60	23	133.5	30.3	41.8	0.4	5.03	26.60		3.0
384	7.75	42	21	119.0	28.7	46.9	0.4	4.47	17.00		3.2
385	10.65	122	29	140.5	31.7	32.0	0.1	1.84	22.90		5.3
386	3.33	98	34	114.5	23.4	32.1	0.1	4.56	23.10		4.1
387	2.33	106	46	99.0	27.5	44.4	0.2	11.09	16.10		4.3
388	1.67	82	23	57.0	17.8	55.3	0.2	12.98	18.40		4.6
389	4.58	86	34	196.0	34.1	49.9	0.1	2.94	38.80	90.09	6.6
390	4.12	91	31	185.0	33.3	63.9	0.1	3.31	42.10	88.40	0.6
391	4.62	63	43	183.0	31.5	67.9	0.1	7.62	31.70		5.8
392	3.95	76	64	318.5	32.3	63.4	0.5	12.67	30.00		0.8
393	5.83	35	26	74.0	17.2	66.5	0.5	13.91	36.40		7.7
394	5.42	88	50	250.5	34.2	81.8	0.7	12.23	35.50		3.5
395	6.66	57	30	190.5	34.0	42.3	0.8	12.34	32.40		3.6
396	5.83	62	41	138.5	37.5	35.8	0.2	4.72	30.10		3.3

*Sample code: Block No./ Sample site No. Surface (A) or Subsurface (B)

Appendix - III

Raw Data Generated by Physico-Chemical Analysis

Sample No.	Ex.Mn (ppm)	Ex.Ca (ppm)	Ex.Mg (ppm)	Ex.Na (ppm)	Ex.K (ppm)	Ex.Al (ppm)	CEC cmol(+)/kg	Na sat. %	BSP %	Al sat. %
364	67.20	146.6	30.90	114	84	31.25	2.30	21.57	73.85	15.12
365	137.70	272.4	52.80	112	82	35.00	3.39	14.36	73.49	11.47
366	110.00	159	63.60	120	78	39.75	2.89	18.05	70.53	15.29
367	139.80	247	60.30	130	90	51.25	3.62	15.63	69.86	15.76
368	70.40	242.1	64.90	124	84	49.13	3.31	16.29	75.46	16.50
369	179.20	147.9	52.80	116	76	59.88	3.20	15.76	58.50	20.80
370	73.20	306	55.60	126	78	36.13	3.41	16.06	80.13	11.77
371	263.00	229.6	51.70	122	102	51.25	3.90	13.60	60.60	14.61
372	198.00	168.4	35.80	116	94	28.75	2.93	17.21	64.16	10.90
373	136.60	321	66.30	124	86	16.38	3.60	14.98	80.83	5.06
374	110.60	383.1	72.30	124	94	30.00	4.04	13.36	81.51	8.27
375	108.50	227.4	51.10	118	76	17.50	2.86	17.92	79.07	6.79
376	160.70	306.4	63.10	122	114	33.75	3.84	13.80	74.75	9.77
377	105.00	430.5	74.40	146	112	26.25	4.37	14.53	84.32	6.68
378	116.80	556.7	79.00	144	110	53.75	5.37	11.66	80.78	11.13
379	202.00	537	81.30	140	122	36.25	5.42	11.23	78.83	7.43
380	173.80	479.8	81.30	140	.112	23.75	4.87	12.50	81.38	5.42
381	94.70	104.1	42.80	118	108	40.13	2.46	20.83	67.47	18.12
382	63.50	127.9	43.40	130	114	33.75	2.47	22.88	75.02	15.19
383	129.80	472	69.80	136	90	60.00	4.91	12.06	76.55	13.60
384	131.80	494.3	68.00	136	98	43.88	4.85	12.19	79.82	10.06
385	254.70	699.3	95.30	180	134	58.88	7.01	11.17	77.15	9.35
386	232.80	761.4	103.10	216	136	41.38	7.27	12.93	81.80	6.34
387	113.80	641.6	95.60	230	130	36.75	6.17	16.22	86.40	6.63
388	131.80	643.6	95.80	212	144	26.25	6.09	15.15	87.05	4.80
389	289.30	826	109.80	212	156	54.75	8.04	11.47	79.03	7.57
390	278.30	954.3	94.30	228	164	51.25	8.54	11.61	81.45	6.67
391	232.30	422	109.30	180	144	52.50	5.61	13.95	74.15	10.41
392	201.70	278.7	52.00	138	108	48.75	3.98	15.09	67.83	13.63
393	241.30	614.8	94.30	142	110	53.75	6.25	9.88	75.95	9.56
394	104.50	407.9	56.60	162	116	35.13	4.29	16.42	81.73	9.11
395	65.70	428.2	74.40	158	146	49.13	4.61	14.90	82.69	11.85
396	62.60	513.6	89.20	180	164	36.25	5.15	15.21	87.51	7.83

APPENDIX - IV

SOIL ANALYTICAL RESULTS OF THE MAIN CAMPUS OF
KERALA AGRICULTURAL UNIVERSITY
(By Soil Survey Wing)

Series	Depth cm	pH	Av. P kg ha^{-1}	Av. K kg ha^{-1}	Gravel %	Coarse sand %	Fine sand %	Silt %	Clay %
Vellanikkara I	0-8	6.2	8.0	60	5.70	24.00	21.20	22.65	30.15
	8-23	6.5	3.0	17	7.50	21.00	20.20	24.26	33.24
	23-120	6.4	3.0	12	7.40	11.50	15.70	31.40	40.60
Vellanikkara II	0-15	6.3	7.0	62	18.00	27.20	18.50	20.00	31.45
	15-60	6.5	6.0	10	16.10	10.80	14.80	30.30	42.60
	60+	6.2	2.0	17	14.80	11.90	28.50	26.20	32.50
Vellanikkara III	0-18	6.0	7.0	45	12.15	13.50	22.20	25.40	35.40
	18-64	6.2	4.0	12	16.20	17.80	13.75	25.80	41.60
	64-100	5.9	1.0	10	24.01	9.50	15.00	30.40	45.30

SOIL RESOURCE INVENTORY OF THE MAIN CAMPUS KERALA AGRICULTURAL UNIVERSITY VELLANIKKARA : PART I - (EAST)

By

E. SEENA

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the degree of

Master of Science in Agriculture

Faculty of Agriculture

Kerala Agricultural University

Department of Soil Science and Agricultural Chemistry

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR - 680656

KERALA, INDIA

2000

ABSTRACT

ABSTRACT

The present study was conducted in the main campus of Kerala Agricultural University, Vellanikkara with the objective of preparation of a detailed soil resource inventory. The total area of the campus is 384.56 ha. The inventory under this report was carried out covering the eastern part of the campus comprising an area of 214 ha which is divided into 25 blocks. The study mainly concentrated on the resource potential of the campus with respect to soil resource. Here an attempt has been made to evaluate the physical, chemical and electrochemical properties of the soil. One hundred and ninety eight samples each from surface(0 – 20 cm) and sub surface(20 –40 cm) layers collected at a grid size of 80 m^2 were analysed for the above properties.

Soil samples collected from different parts of the campus were predominantly gravelly in nature both in the case of surface and subsurface samples. In the textural analysis majority of the phases were coming under clay loam. Irrespective of depth, in majority of the phases, surface and subsurface samples were coming under same textural classes.

In general almost all the soils were acidic in nature. This shall be due to the high rainfall and subsequent leaching. Electrical conductivity of the soil samples was found to be very low both in the case of surface and subsurface soils. Buffer pH was estimated to find out the lime requirement of the soils. It was found that buffer pH varied widely among the samples and so also the lime requirement .

An increase in organic carbon content with depth was observed in a few phases. Almost 91% of the surface and 90% of the sub surface samples analysed were medium in fertility, 7 per cent each of the surface and sub surface samples were coming under high fertility class and the remaining 2 and 3 per cent were low in organic carbon status. Available phosphorus content recorded low values in almost all the samples both in the case of surface and subsurface soils. 78% of surface and 84 %of sub surface samples were rated as low in fertility while 17 and 13 % were medium in fertility and only 5 and3 per cent of the samples from surface and sub surface were high in fertility. The results

revealed that about 63 to 65 % of soils were coming under medium fertility with respect to available potassium.

Available calcium and available magnesium content showed a wide variation depending on the degree of leaching.

Available micronutrients namely manganese, zinc, copper, and iron were extracted using 0.1M HCl and contents was in the order as Mn > Fe > Cu > Zn both in the case of surface and subsurface soil layers. Of these Mn, Fe and Cu in almost 98% of the samples showed values far above the critical ranges reported where as available zinc content was below critical range in 80 to 90 % of the samples. Only 8 to 14 % were coming within the critical range.

P fixing capacity of the soil was estimated and it was observed that all the soils of the study area were high in P fixing capacity. This is due to the high content of oxides of iron and aluminium under acidic 1:1 mineral dominated soil environment.

All the exchangeable ions present in the soil *viz.* calcium, magnesium, sodium, potassium, iron, manganese and aluminium were determined using 0.1M $BaCl_2$ and found that calcium formed the predominant cation both in the case of surface and subsurface soils. The exchangeable ions were in the order Ca > Na > Mn > K > Mg > Al >Fe. CEC of the soil ranged widely both in the case of surface and subsurface soils from about 1.5 to 8 cmol (P+) kg^{-1}.

Sodium saturation was observed very high in the case of both surface and subsurface soils; in many cases exceeding 15 % and yet not showing any sodicity due to low CEC and pH. Percentage base saturation of the soil varied widely from about 36 to 96 % and it was found that major part was contributed by exchangeable calcium.

The Eastern part of the campus poses 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.