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

By

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THESIS

Submitted in partial fulfilment of the requirement for the degree of

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DECLARATION

I hereby declare that the thesis entitled " **Soil Resource Inventory of the main campus, Kerala Agricultural University, Vellanikkara: Part II (West)** 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, associateship, fellowship or similar title, of any other University or Society.

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DEDICATED

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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 land use 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 land use 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 fertiliser 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 western 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 mean 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. According to Webster and Nye (1997), the assessment of the soil resources of any region includes an inventory of the kinds of soil and their distribution, and knowledge of the way each kind can be used and its performance under a range of circumstances. Soil varies substantially and intricately over short distances in most parts of the world. Inventories may be combined so that an individual nation state or region of similar size can know what kinds of soil it has, how much and where they are, how much each can produce, how to manage each property and the risks of degradation in use.

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 Table1.

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 light textured and low in organic matter. The level of available phosphorus was medium and that of potassium was medium to high in the soils.

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

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.

The important research institutions were focussed mainly on the studies on soil resource development, including management of soil fertility in newly formed terraces by using lime, phosphorus and FYM (ICAR, 1988).

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.

Kelsey and Hootman (1990) have briefly discussed methods for overcoming urban soil deficiencies following soil analysis (pH; P, K, Mg, Ca and Na concentrations; electrolytic conductivity; cation exchange capacity; and base saturation) of samples from 17 planter vaults situated in the central business district in Geneva, Illinois, USA. In addition to high Na concentrations and soil pH (range 7.3 to 9.9, mean 8.5), soil structure and drainage in the planter vaults were poor.

The objectives of soil surveys in Tanzania can be summarized as the identification, characterization and mapping of the country's land resources at a scale usable for land use planning at national level, provision of soil survey and land evaluation services to farm, district and regional land use planning bodies, and the development of methods and procedures for soil mapping and the assessment of the suitability of land for relevant production systems (Msanya and Magoggo, 1993).

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 and phosphorus, 58% low in potassium. But the soils were having enough quantity of 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 characteristics, 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.

Tamagadge *et al.* (1999a) conducted an investigation regarding soil resource inventory of Madhya Pradesh and they established soil-physiographic relationship of the area. Tamagadge *et al.* (1999b) also investigated 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 indicates the extent of kinds of soils having typical characteristics and groups of soils having different 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.

LRRC (1988) summarized the work carried out by the Soil Resource Inventory and Mapping Section on mapping, interpretation and correlation studies, temperature and regional monitoring studies, soil conservation, soil information.

NBSS & LUP (1990) reviewed the progress made in preparing soil resource maps at 1:250 000 for the different states of India. They made soil resource inventory of Bihar, Orissa, Andaman and Nicobar islands. Future research and recommendations on the results already received are also discussed.

The procedure of Soil resource mapping was demonstrated with the example of Chitradurga district of Karnataka. Soil map data was input to GIS through manual digitization and associated land and soil characteristics, in tabular form, through keyboard entry. From the digital data set thematic maps depicting various land characteristics, land suitability for specific purposes and ultimately a potential land use map were generated. The use of these outputs in devising sustainable land use plans also was discussed (Nair *et al.*, 1996).

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.

Pandey *et al.* (1998) have undertaken an investigation to classify the soils of Rehar Basin Irrigation Project Area, district Surguja, Madhya Pradesh according to soil taxonomy, land capability, soil irrigability and land irrigability classes for their well suited management for optimum and sustainable crop production. Interpretative groupings like land capability, soil irrigability and land irrigability showed that the soils are suitable for crop cultivation but need proper management. The control measures to reduce erosion can improve the agricultural practices.

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. 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 potentialities 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 (Klingebiel and Montgomery, 1966).

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 was 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 to 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 regions. 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.

Several national and international institutions are updating the soil classification systems they use in their soil resource inventory programs. Wambeke (1989) reviewed recent trends in the classification of soils of the tropics as they appear in taxonomic updates, particularly the "Keys to Soil Taxonomy" by the Soil Survey Staff, and the revised legend of the FAO-UNESCO Soil Map of the World. He also discussed about the soil classification systems that emphasizes their international dimensions and their contributions to agricultural sciences.

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 intention 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, gravelliness etc. which have direct relevance to plant growth.

The objective of the Fertility Capability Classification System (FCC) is to generate soil groupings within which similar responses to agronomic soil management practices can be expected (McQuaid *et al.* 1995). Fertility limitations identified by the FCC system are those, which may require additional inputs and management over and above inputs and management normally employed in profitable, crop production. The ECC system was used in the Soil Survey Report of Granville County, North Carolina (USA) and suggestions were made about how the FCC could be incorporated into the soil survey report.

Mathan (1990) applied soil fertility capability classification to acid soil of district of Nilgiri for the assessment of fertility level. Among the several approaches 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.

The 'Fertility Capability Soil Classification' (F. C. C.) system was discussed and described as an objective way to quantify land quality as expressed by its physical and agronomic parameters. It was successfully applied to study the mountain and hill soils of the Comparia Lucania Appennines, Italy (Castriagnano and Lopez, 1990).

Soil fertility capability classification at a site near Kandy, Sri Lanka was applied, with particular reference to suitability for coffee and *Piper nigrum.* Recommendations for the area include increasing humus content, liming and agro-forestry or alley cropping (Botschek *et al.*, 1993)

In the attempt made by Mathan *et al.* (1994), twenty one soils, belonging to subgroups Typic Chromusterts, Typic Ustropepts, Udic Haplustalfs, Typic Haplustalfs, Vertic Haplustalfs and Typic Ustorthents were grouped in 8 FCC (Fertility Capability Classification) units based on type, substrata type and condition modifiers. The FCC units will serve as the basis for conducting fertility related experiments and extrapolation of such experimental results. The condition modifiers that decide the soil and fertility interactions in the study are 'd' (dry condition), 'b' (basic reaction), 'v' (vertic characters), 'm' (magnesium deficiency), 'n' (natric), 'k' (potassium deficiency), 'i' (Fe-P fixation) and 'e' (low CEC).

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 Regional Agricultural Research Station Campus, Pattambi (Deepa, 1995) have also been grouped under fertility classes.

The Fertility Capability Classification (FCC) system was used to group soils with similar limitations for fertility management in the title area, India. Thirty six mapping units at the level of series associations were converted into eleven FCC units. The meaning and interpretation of FCC units was discussed using the prepared FCC maps (Bhattacharyya, 1995).

Based on a soil survey carried out by Dazzi *et al.* (1996) on an area of 5000 hectares, representative of the various land elements (pedology, morphology, land use, etc.) of the Ragusa Plateau, Italy, the FCC system was applied. This demonstrated how, depending on the different physical, chemical, hydrological characteristics, the soils exhibit different natural fertility levels and, in particular, what the principal limitations of fertility are. Under the guidance of the results of the study, some agronomic suggestions were made, arising from soil characteristics analysis, aimed at overcoming the present limitations and at preserving, and/or increasing the natural fertility of the soil surveyed.

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.

McAlister *et al.* (1998) utilized the Fertility Capability Soil Classification System (FCC) as a means for determining the impact of landuse change (forest clearance) on fertility status of soils from the Sao Francisco area of Niteroi, Brazil.

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 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 size was generally high for laterite soil. Correlation between clay content and water holding capacity was positive in all soils except in 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 capacity for fixation. The result 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 fractions 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 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 the content of 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}, 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.

The content and distribution of organic C and available P and K were studied in a large number of soil samples collected from the Indian Punjab. Soils were grouped into 10 fertility classes based on their low, medium and high supplying capacity. Based on the analytical results a soil fertility map was also prepared (Brar and Chiibba, 1994).

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 potassium 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 to 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 found 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 will 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 were 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 it varied from 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 0-30, 30-60 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 and it is found that total Zn, Mn, Cu and Fe in surface soils varied from 72 to 284, 642 to 1698, 64 to 264 and 2.36 to 8.32 ppm respectively. Available Zn, Fe, Mn and Cu were in the range of 0.28-4.4, 6.62-28.6, 13.2-65.2 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 western part of the campus (12 blocks from 26th block to 37th), covering 166 ha of cultivated land (Fig. 2).

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 3324mm and temperature ranging from 20.8 to 36 $^{\circ}$C. Weather data of Vellanikkara (monthly average) was 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.

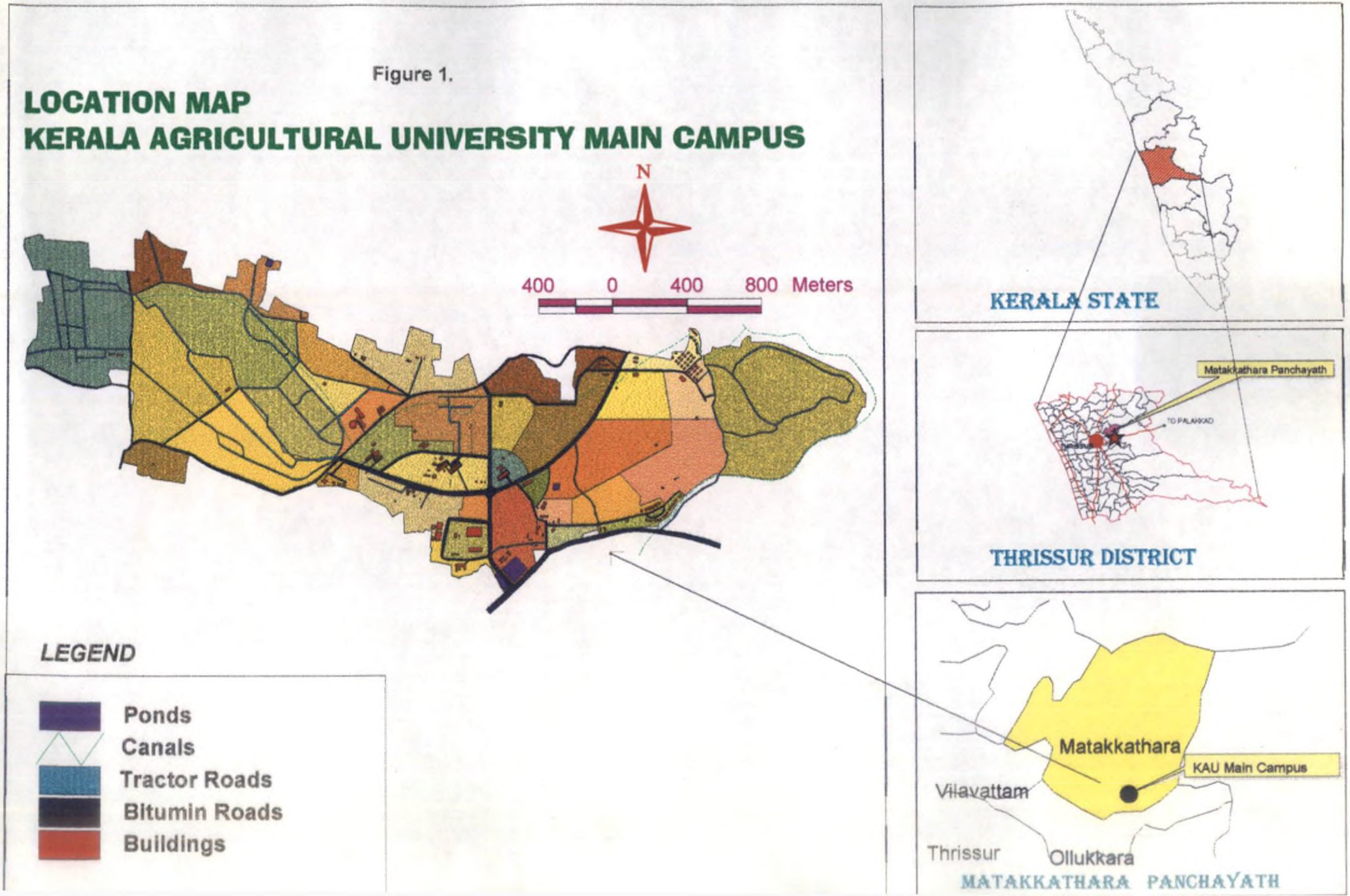
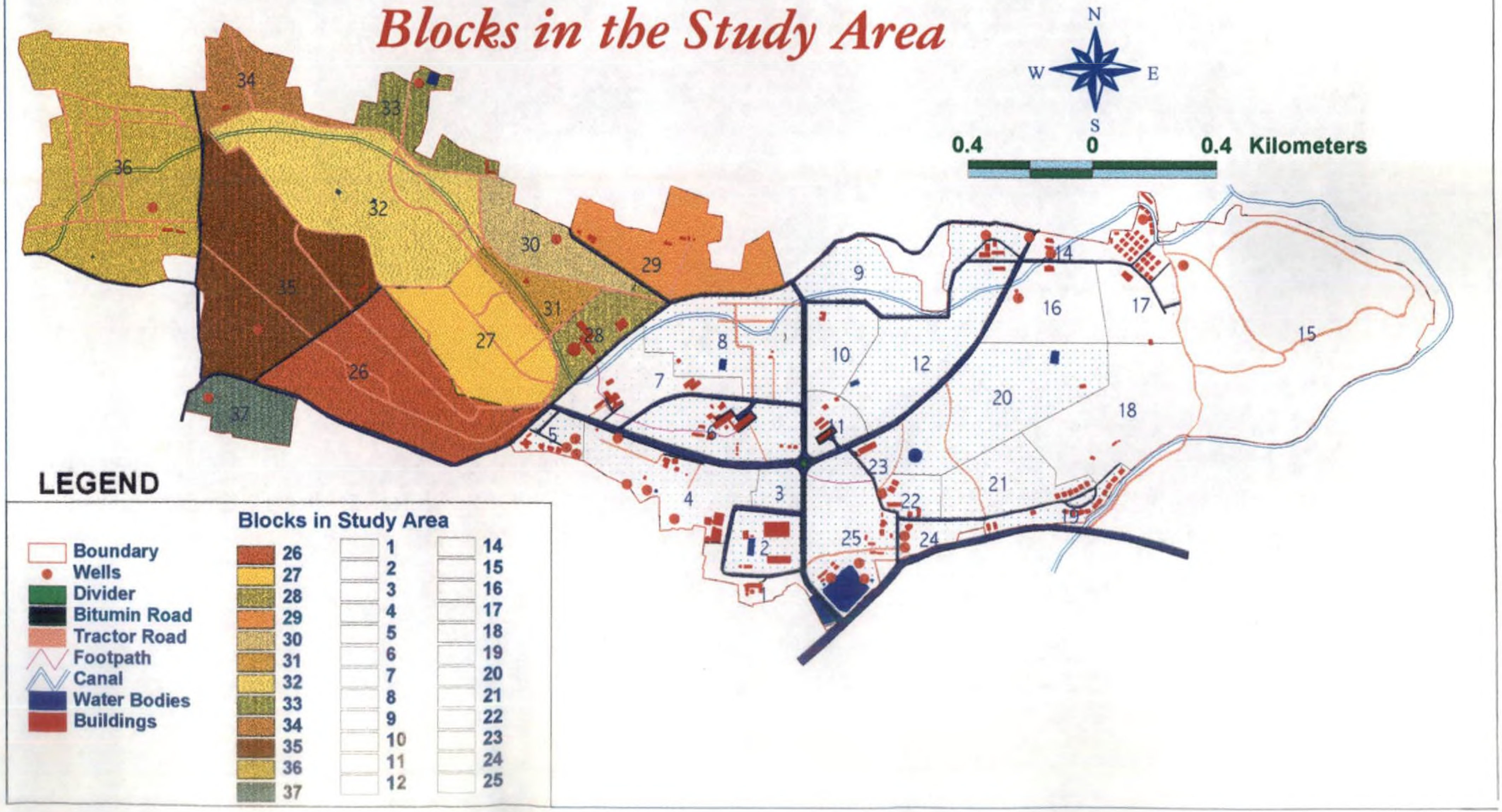

LOCATION MAP
KERALA AGRICULTURAL UNIVERSITY MAIN CAMPUS
N
400 0 400 800 Meters
LEGEND
Ponds
Canals
Tractor Roads
Bitumin Roads
Buildings
KERALA STATE
Matakkathara Panchayath
TO PALAKKAD
THRISSUR DISTRICT
Matakkathara
KAU Main Campus
Vilavattam
Thrissur
Ollukkara
MATAKKATHARA PANCHAYATH

Figure 2.

KERALA AGRICULTURAL UNIVERSITY - MAIN CAMPUS

Blocks in the Study Area



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 Instructional Farm of the College of Horticulture, Cashew Research Station, Pineapple Research Station, Pepper Research Schemes and Nursery, Cadbury Cocoa Project, NBPGR Experimental Plots 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	26	Rubber plantation
2	27	Mango, Cashew, Guava, Minor fruits
3	28	Rubber, Coconut
4	29	Pine apple, Banana, Rubber
5	30	Coconut, NBPGR Germplasm collection
6	31	Cashew, Rubber
7	32	Cocoa, Rubber, Coconut
8	33	Pepper, Coconut
9	34	Cocoa, Rubber, Cashew
10	35	Rubber, Cashew, Coconut
11	36	Cashew, Coconut
12	37	Coconut, Mango, Vegetables

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 staff, 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 Appendix II. 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	Occur rence	Phase No	Soil phase	Occur rence	Phase No	Soil phase	Occur rence
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	1	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	1
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 80 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.	26	22.88	24	48
2.	27	14.80	24	48
3.	28	7.30	07	14
4.	29	13.18	18	36
5.	30	8.14	12	24
6.	31	4.77	06	12
7.	32	12.81	43	86
8.	33	14.02	08	16
9.	34		10	20
10.	35	27.26	43	86
11.	36	35.56	56	112
12.	37	5.28	08	16
Total				518

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 and 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 colorimetrically 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-normal 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 (Jackson, 1973).

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). 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. Five ml of distilled water was added to it 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 0, 25, 50, 75, 100, 125, 250, 375 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 (Ghosh *et al.*, 1983).

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 tabulated and organised for information generation. Out of the 38 soil phases identified in the base map, 24 are covered in the present study (Fig. 3). But one phase is too small and coming under non-cultivating area (included cocoa nursery and green houses in block 34), so no sample was taken from that phase. Since only one sample was obtained from phase 31, the data from that phase was not included in the phase wise data analysis. Phase level mean tables of various soil physical and chemical parameters are provided in the ensuing text. Original data generated are provided in Appendix III.

Multiple regression analyses were carried out to study interaction of plant nutrients in the soil, using MSTAT software in a personal computer.

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, 89 polygons covering 24 phases occur in the Western 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.

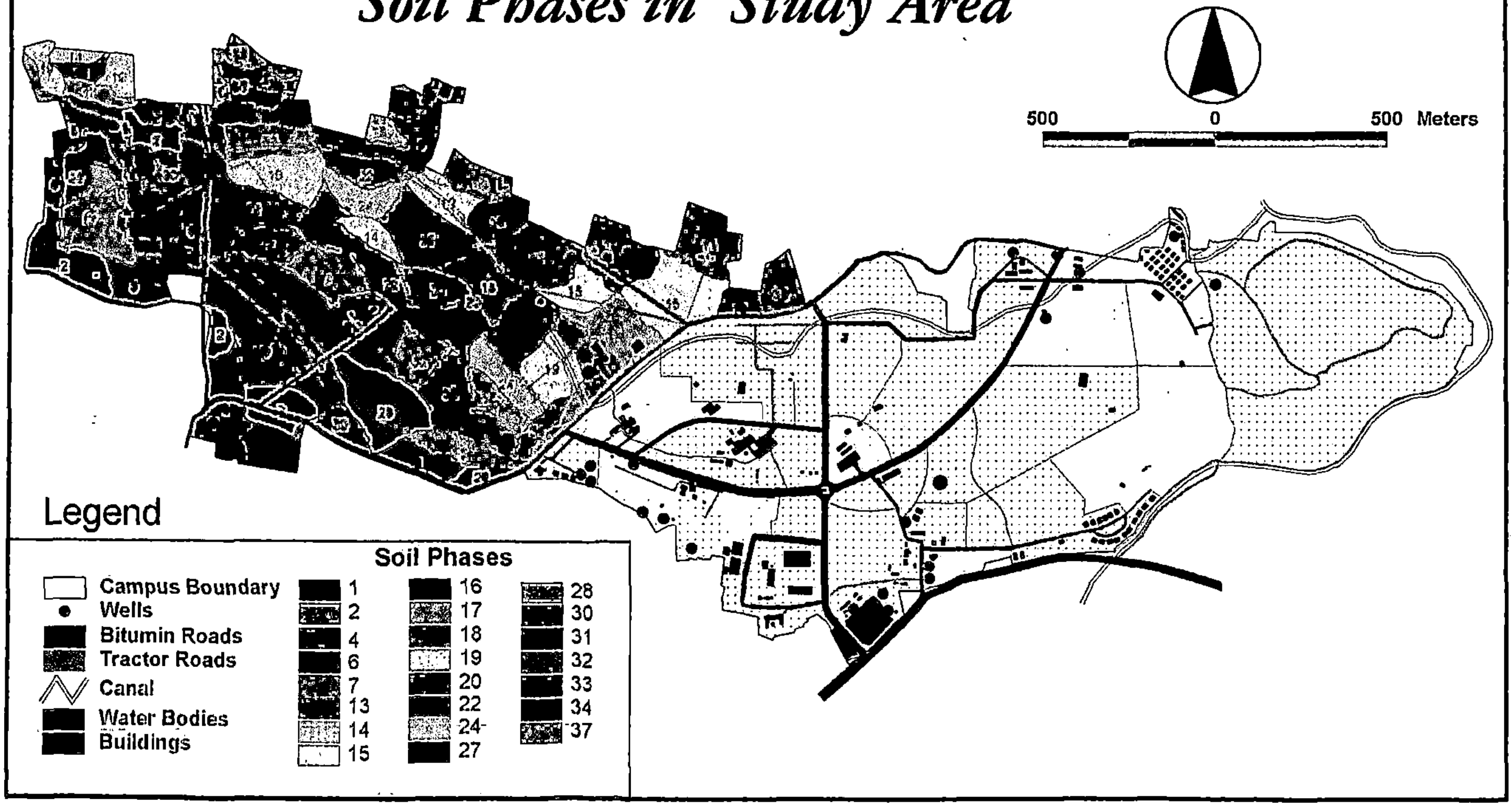
Phase level mode data on various soil characteristics generated during the study were attached to respective polygons in the PC ARC INFO coverages. Thematic maps were generated using GIS techniques.

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

Figure 3.

Kerala Agricultural University - Main Campus
Soil Phases in Study Area



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 Western 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

Updating of data on the soil fertility components of the Western part of the main campus, Kerala Agricultural University was accomplished through generation of information on various parameters. The data generated are presented in Appendix III. Mean, Mode and Range values for both surface (0-20 cm) and subsurface (20-40cm) of the 23 soil phases of the three soil series present in the study area are provided in different tables that follow. Altogether 518 samples were analysed for each parameter except for mechanical analysis and P fixing capacity where analysis was done selectively.

4.1. Gravelliness of soil samples

The coarse fragments (> 2 mm) of surface and subsurface soils were recorded by finding the percentage content on dry weight basis in the samples. The mean, range and most frequently occurring values of both surface and subsurface samples are presented in the Table 6.

In surface soils, the gravel content was higher than the fine earth. In most of the phases, the average gravel content was more than 55% in surface layer. A wide range of 25 - 73% was observed in a few soil phases such as 1, 2 and 6. The highest gravel content in the sample was recorded as 83% in phase 27 and lowest value was 24.66% in phase 1. While considering the phase wise mean values, the highest mean value of gravel for surface content was 66% (phase34) and lowest of the same was in phase 1 (41.81%).

In the case of fine earth content in surface soils, the most of the phase wise mean values were in the range of 35 – 45 %. The minimum fine earth content was obtained in phase 27 (17%) and maximum of 75.34% in phase 1. But in phase wise average fine earth percentage, the maximum was in Phase 1 (58.19%) and minimum was in Phase 34 (34%).

In subsurface soil, percentage of gravel was less than the surface level. The frequently observed values were in the range of 35-45%. But in phase 2, it went even up to 76%. The minimum value was recorded as 21.2% in phase 13. Among the phase averages of gravel, the maximum was in Phase 7 (52.48%) and minimum in Phase 14 (34.25%).

Table 6. Gravelliness of soil samples in the Western Part of KAU Main Campus

Sl. No	Phase No		Surface samples Gravel (%)	Surface samples Fine earth (%)	Subsurface samples Gravel (%)	Subsurface samples Fine earth (%)
1	1	Mean	41.81	58.19	42.60	57.40
		Range	24.66 - 51.66	48.34 - 75.34	29.33 - 69.3	30.70 - 70.67
		Mode	38.00	62.00	41.30	58.70
2	2	Mean	47.81	52.19	41.25	58.75
		Range	32.73 - 63.00	38.00 - 67.00	26.60 - 76.00	24.00 - 73.40
		Mode	47.81	52.19	32.00	68.00
3	4	Mean	60.00	40.00	48.51	51.49
		Range	52.00 - 69.00	31.00 - 48.00	37.30 - 65.33	34.67 - 62.70
		Mode	60.00	40.00	37.30	62.70
4	6	Mean	48.64	51.36	47.46	52.54
		Range	25.33 - 73.00	27.00 - 74.67	26.66 - 71.66	28.34 - 73.34
		Mode	50.00	50.00	64.00	36.00
5	7	Mean	64.26	35.74	52.48	47.52
		Range	47.30 - 79.00	21.00 - 52.70	45.30 - 66.60	33.40 - 54.70
		Mode	60.00	40.00	64.00	36.00
6	13	Mean	55.76	44.24	44.40	55.60
		Range	35.33 - 77.00	23.00 - 64.67	21.20 - 60.66	39.34 - 78.80
		Mode	59.00	41.00	46.00	54.00
7	14	Mean	50.58	49.43	34.25	65.75
		Range	40.00 - 61.30	38.70 - 60.00	30.00 - 42.66	57.34 - 70.00
		Mode	40.00	60.00	34.25	65.75
8	15	Mean	65.07	34.93	42.22	57.78
		Range	53.00 - 77.00	23.00 - 47.00	22.00 - 55.60	44.40 - 78.00
		Mode	66.00	34.00	55.60	44.40
9	16	Mean	52.90	47.10	46.07	53.94
		Range	35.40 - 70.00	30.00 - 64.60	26.00 - 68.00	32.00 - 74.00
		Mode	50.00	50.00	46.07	53.94
10	17	Mean	51.06	48.94	45.16	54.84
		Range	34.13 - 64.00	36.00 - 65.87	32.00 - 64.00	36.00 - 68.00
		Mode	50.00	50.00	45.16	54.84
11	18	Mean	54.53	45.47	36.66	63.34
		Range	41.00 - 62.60	37.40 - 59.00	30.66 - 40.00	60.00 - 69.34
		Mode	54.53	45.47	36.66	63.34

(Continued.......)

Table 6. Gravelliness of soil samples in the Western Part of KAU Main Campus (......Continued)

Sl. No.	Phase		Surface samples		Subsurface samples	
	No		Gravel (%)	Fine earth (%)	Gravel (%)	Fine earth (%)
12	19	Mean	53.52	46.48	45.44	54.56
		Range	31.93 - 71.00	29.00 - 68.07	31.00 - 56.00	44.00 - 69.00
		Mode	50.00	50.00	45.44	54.56
13	20	Mean	57.10	42.90	43.16	56.85
		Range	42.40 - 70.00	30.00 - 57.60	25.93 - 66.00	34.00 - 74.07
		Mode	70.00	30.00	43.16	56.85
14	22	Mean	57.48	42.52	45.22	54.78
		Range	42.00 - 71.00	29.00 - 58.00	28.60 - 63.73	36.27 - 71.40
		Mode	60.00	40.00	54.00	46.00
15	24	Mean	54.63	45.38	43.33	56.67
		Range	33.00 - 70.00	30.00 - 67.00	31.46 - 59.60	40.40 - 68.54
		Mode	60.00	40.00	43.33	56.67
16	27	Mean	60.05	39.95	41.59	58.41
		Range	48.60 - 83.00	17.00 - 51.40	32.67 - 51.30	48.70 - 67.33
		Mode	60.05	39.95	41.59	58.41
17	28	Mean	53.20	46.80	40.88	59.12
		Range	39.00 - 68.00	32.00 - 61.00	34.00 - 48.00	52.00 - 66.00
		Mode	53.20	46.80	40.88	59.12
18	30	Mean	58.24	41.76	45.46	54.54
		Range	39.20 - 69.00	31.00 - 60.80	34.60 - 71.60	28.40 - 65.40
		Mode	62.00	38.00	45.46	54.54
19	31	Mean	62.00	38.00	47.40	52.60
20	32	Mean	61.47	38.53	50.02	49.98
		Range	50.00 - 74.00	26.00 - 50.00	40.00 - 61.00	39.00 - 60.00
		Mode	69.00	31.00	50.02	49.98
21	33	Mean	64.10	35.90	42.69	57.31
		Range	51.00 - 71.00	29.00 - 49.00	33.60 - 52.60	47.40 - 66.40
		Mode	63.00	37.00	42.69	57.31
22	34	Mean	66.00	34.00	41.33	58.67
		Range	60.00 - 72.00	28.00 - 40.00	38.66 - 44.00	56.00 - 61.34
		Mode	66.00	34.00	41.33	58.67
23	37	Mean	64.00	36.00	38.83	61.17
		Range	57.00 - 71.00	29.00 - 43.00	35.00 - 42.66	57.34 - 65.00
		Mode	64.00	36.00	38.83	61.17

The fine earth content was more than gravel percentage in all the phases except in phases 7 and 32. It was in range of 40 – 60% in most of the soils. The most frequently occurring values were in between 55 and 58 %. The highest content was recorded as 78.8% in phase 13 and the lowest percentage was 24% in phase 2. The highest mean value of fine earth for fine earth content was 65.75% (phase14) and lowest of the same was in phase 7 (47.52%).

4.2. Textural Variations

Particle size analysis of the fine earth fraction of soil samples was carried out to know the measure of size distribution of individual particles in the samples. Using Textural triangle, the samples were grouped into textural classes according to the percentage of the sand, silt, and clay content in them (Miller and Donahue, 1997). The percentage of the three components and the corresponding textural classes for surface as well as subsurface samples are given in Table 7.

In the surface samples, highest sand percentage was observed in the phase 2 (68.43%) where as the minimum was noted in phase 22 (33.03%). Silt percentage was varying from a minimum of 8.76% in phase 33 to a maximum of 38.99% in phase 22. The lowest clay content was recorded in the phase 15 (14.53%) and the highest clay percentage was in phase 33 (44.89%). Lowest percentage of sand and highest percentage of silt were recorded in the same phase (phase 22). Similarly, maximum content of clay and minimum content of silt were also obtained in the same phase (phase 33).

The results of particle size analysis of subsurface soils showed that there was decrease in sand content and increase in silt and clay content. But only marginal changes were observed. In phase 24, there was a drastic increase in the mean value of clay content from 23.74 to 33.84%. With respect to subsurface soils, the sand content was maximum in phase 2 (60.85%) and the same was lowest in phase 22 (30.21%). The silt content varied from 10.15% (phase 16) to 33.76% (phase13). The range of clay content was maximum in phase 13 (46.98%) and the same was minimum in phase 15 with a value of 20.47%.

Table 7. Textural Variations of the soils in the Western Part of the Main Campus, KAU

Sl. No.	Phase No.	-	Surface samples Sand (%)	Surface samples Silt (%)	Surface samples Clay (%)	Surface samples Textural Class	Subsurface samples Sand (%)	Subsurface samples Silt (%)	Subsurface samples Clay (%)	Subsurface samples Textural Class
1	1	Mean	57.09	20.34	22.57		51.16	21.32	27.52	
		Range	55.26 - 60.15	14.4 - 24.42	19.16 - 25.45	Sandy Clay Loam	48.49 - 55.10	16.16 - 25.24	25.17 - 29.91	Sandy Clay Loam
		Mode	57.09	20.34	22.57		51.16	21.32	27.52	
2	2	Mean	63.28	12.17	24.55		53.00	17.25	29.75	
		Range	57.45 - 68.43	9.32 - 18.15	22.25 - 25.74	Sandy Clay Loam	50.21 -60.85	11.08 - 20.72	28.07 - 31.09	Sandy Clay Loam
		Mode	63.28	12.17	24.55		53.00	17.25	29.75	
3	4	Mean	45.06	24.11	30.83		41.20	26.26	32.55	
		Range	42.82 - 48.12	21.70 - 25.81	29.96 - 32.35	Clay Loam	38.84 - 43.25	23.65 - 31.38	27.12 - 37.42	Clay Loam
		Mode	45.06	24.11	30.83		41.20	26.26	32.55	
4	6	Mean	54.92	16.32	28.75		50.05	20.14	29.81	
		Range	50.10 - 67.16	13.18 - 21.14	19.59 - 36.07	Sandy Clay Loam	39.79 - 57.70	13.45 - 24.92	28.29 - 35.29	Sandy Clay Loam
		Mode	54.92	16.32	28.75		50.05	20.14	29.81	
5	7	Mean	56.61	14.99	28.40		51.45	16.37	32.18	
		Range	49.40 - 62.49	13.26 - 17.71	24.25 - 34.94	Clay Loam	45.69 - 60.55	13.58 - 19.49	25.88 - 39.52	Sandy Clay Loam
		Mode	56.61	14.99	28.40		51.45	16.37	32.18	
6	13	Mean	54.19	12.65	33.16		50.74	13.75	35.51	
		Range	47.95 - 60.45	9.60 - 16.06	24.78 - 41.94	Sandy Clay Loam	42.87 - 58.87	10.15 - 16.29	26.65 - 46.98	Sandy Clay
		Mode	54.19	12.65	33.16		50.74	13.75	35.51	
7	14	Mean	57.05	15.09	27.86		50.65	14.84	34.51	
		Range	56.32 - 57.54	13.11 - 17.61	26.07 - 29.59	Sandy Clay Loam	49.66 - 51.33	12.65 - 15.95	32.75 - 36.38	Sandy Clay Loam
		Mode	57.05	15.09	27.86		50.65	14.84	34.51	
8	15	Mean	56.43	20.17	23.41		51.50	20.55	27.96	
		Range	53.08 - 58.63	10.70 - 27.54	14.53 - 31.53	Sandy Clay Loam	50.10 - 55.16	11.16 - 29.03	20.47 - 33.68	Sandy Clay Loam
		Mode	56.43	20.17	23.41		51.50	20.55	27.96	
9	16	Mean	54.63	16.27	29.09		48.65	18.10	33.25	
		Range	47.94 - 57.52	11.43 - 33.15	18.91 - 31.79	Sandy Clay Loam	37.30 - 53.25	12.58 - 33.76	28.94 - 35.24	Sandy Clay Loam
		Mode	54.63	16.27	29.09		48.65	18.10	33.25	
10	17	Mean	55.45	15.80	28.75		49.30	17.57	33.12	
		Range	51.74 - 60.24	9.16 - 21.48	25.79 - 34.74	Sandy Clay Loam	46.40 - 51.40	11.35 - 23.04	30.27 - 37.25	Sandy Clay Loam
		Mode	55.45	15.80	28.75		49.30	17.57	33.12	
11	18	Mean	57.46	15.83	26.71		50.69	18.36	30.95	
		Range	56.65 - 58.38	13.87 - 17.53	25.11 - 29.48	Sandy Clay Loam	50.35 - 51.11	16.13 - 20.57	28.81 - 33.52	Sandy Clay Loam
		Mode	57.46	15.83	26.71		50.69	18.36	30.95	

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

Table 7. Textural Variations of the soils in the Western Part of the Main Campus, KAU (.........Continued)

Sl. No.	Phase No.		Surface samples Sand (%)	Silt (%)	Clay (%)	Textural Class	Subsurface samples Sand (%)	Silt (%)	Clay (%)	Textural Class
12	19	Mean	56.29	16.34	27.37		50.72	18.82	30.46	
		Range	51.17 - 60.54	10.43 - 21.84	17.62 - 36.21	Sandy Clay Loam	42.72 - 54.40	11.83 - 23.87	21.74 - 40.05	Sandy Clay Loam
		Mode	56.29	16.34	27.37		50.72	18.82	30.46	
13	20	Mean	55.18	16.92	27.90		50.08	15.18	34.74	
		Range	54.60 - 56.10	10.43 - 23.03	21.47 - 33.48	Sandy Clay Loam	49.66 - 50.36	12.10 - 16.44	33.49 - 37.79	Sandy Clay Loam
		Mode	55.18	16.92	27.90		50.08	15.18	34.74	
14	22	Mean	48.45	25.80	25.75		43.67	26.66	29.68	
		Range	33.03 - 59.01	12.65 - 38.99	21.07 - 28.34	Sandy Clay Loam	30.21 - 52.70	14.52 - 34.89	21.82 - 34.89	Sandy Clay Loam
		Mode	48.45	25.80	25.75		43.67	26.66	29.68	
15	24	Mean	56.43	19.82	23.74		49.73	16.43	33.84	
		Range	55.29 - 57.79	13.39 - 26.07	16.14 - 31.32	Sandy Clay Loam	46.98 - 52.89	15.18 - 18.45	28.66 - 37.84	Sandy Clay Loam
		Mode	56.43	19.82	23.74		49.73	16.43	33.84	
16	27	Mean	57.08	19.10	23.82		50.82	23.31	25.88	
		Range	54.36 - 59.33	17.92 - 20.31	22.75 - 25.33	Sandy Clay Loam	48.65 - 52.33	22.53 - 24.29	25.14 - 27.06	Sandy Clay Loam
		Mode	57.08	19.10	23.82		50.82	23.31	25.88	
17	28	Mean	57.96	18.69	23.35		52.35	20.11	27.54	
		Range	55.24 - 62.61	15.47 - 22.33	21.92 - 26.03	Sandy Clay Loam	48.3 - 56.50	16.19 - 22.46	26.03 - 29.86	Sandy Clay Loam
		Mode	57.96	18.69	23.35		52.35	20.11	27.54	
18	30	Mean	51.46	17.85	30.70		43.80	21.59	34.61	
		Range	45.42 - 57.49	10.27 - 25.43	29.15 - 32.24	Sandy Clay Loam	36.40 - 51.20	12.32 - 30.85	32.75 - 36.48	Clay Loam
		Mode	51.46	17.85	30.70		43.80	21.59	34.61	
19	31	Mean	52.77	18.56	28.67	Sandy Clay Loam	46.25	24.28	29.47	Sandy Clay Loam
20	32	Mean	54.59	19.49	25.93		51.39	20.89	27.73	
		Range	53.99 - 55.20	11.19 - 27.19	18.39 - 34.82	Sandy Clay Loam	50.91 - 52.20	12.72 - 28.11	20.69 - 35.08	Sandy Clay Loam
		Mode	54.59	19.49	25.93		51.39	20.89	27.73	
21	33	Mean	52.85	11.76	35.39		48.83	14.09	37.08	
		Range	45.36 - 61.38	8.76 - 17.68	27.00 - 44.89	Sandy Clay	44.55 - 55.10	10.67 - 20.76	29.12 - 44.48	Sandy Clay
		Mode	52.85	11.76	35.39		48.83	14.09	37.08	
22	34	Mean	47.54	19.30	33.16		41.52	23.56	34.93	
		Range	46.97 - 48.11	13.26 - 25.33	27.70 - 38.63	Sandy Clay Loam	38.83 - 44.20	15.20 - 31.92	29.26 - 40.60	Clay Loam
		Mode	47.54	19.30	33.16		41.52	23.56	34.93	
23	37	Mean	52.14	18.21	29.66		47.30	20.61	32.09	
		Range	45.75 - 58.52	17.06 - 19.36	22.12 - 37.19	Sandy Clay Loam	42.10 - 52.50	18.55 - 22.67	24.84 - 39.35	Sandy Clay Loam
		Mode	52.14	18.21	29.66		47.30	20.61	32.09	

For textural class identification, the mode class among the samples analysed in a phase was taken for that particular phase. In the study area, it was found that 20 phases out of 23 were sandy clay loam, two were clay loam and one was sandy clay in texture in the case of surface samples. There was no considerable variation in the texture of subsurface samples from surface samples. But in two phases (30 and 34), the texture of surface soil was sandy clay loam and the corresponding subsurface soil texture was clay loam.

4.3. Electrochemical Properties

The electrochemical properties of soil that will affect the availability of nutrients to plants were also analysed. These properties are fetching importance when we try to improve the nutrient supplying capacity of the soil. Soil reaction, Electrical Conductivity, Buffer pH and Lime Requirement of surface and subsurface soils of different phases are presented in the Table 8. The Lime Requirement was calculated from buffer pH as the actual $CaCO_3$ equivalent, in tonnes per hectare required to reach the soil pH to 7.

In general, soils were acidic with pH from 4.3 to 6.1, in 1:2.5 soil water suspension. In most of the soils, pH ranged from 4.6 - 5.6 in the surface layer. The maximum value was in phase 19 and minimum was in phase 13. When looking into the phase wise mean values, highest average was in phase 14 (5.4) and the lowest was in phase 27 (4.6).

There was not much variation in the pH of subsurface soils from surface level. The highest value in subsurface samples was recorded in the phase 32 (6.6) and lowest was in phase 4 (4.3). Among the phase wise average values, two phases (15 and 32) were having the minimum (4.7) and the maximum (5.3) values respectively.

The data on electrical conductivity (EC) showed that almost all soils had low conductivity. There was little variation in this parameter between surface and subsurface soil samples except in a few phases. The lowest conductivity was recorded in about

Table 8. Electrochemical Properties of the Soils in western part of the main campus, KAU

Sl. No	Soil Phase No		Surface samples PH	Surface samples EC (dS m^{-1})	Surface samples Buffer PH	Surface samples Lime R. (t ha^{-1})	Subsurface samples PH	Subsurface samples EC (dS m^{-1})	Subsurface samples Buffer PH	Subsurface samples Lime R. (t ha^{-1})
1	1	Mean	4.82	0.027	5.68	20.45	4.71	0.053	5.64	21.26
		Range	4.48 - 5.06	0.001 - 0.242	5.30 - 6.10	13.40 - 26.70	4.39 - 5.08	0.001 - 0.330	5.20 - 6.20	12.10 - 28.50
		Mode	4.84	0.018	5.80	18.60	4.71	0.001	5.60	21.80
2	2	Mean	4.72	0.049	5.65	21.12	4.81	0.026	5.54	22.85
		Range	4.36 - 5.00	0.004 - 0.185	5.10 - 6.80	2.40 - 30.20	4.37 - 5.10	0.001 - 0.102	5.10 - 6.60	5.30 - 30.20
		Mode	4.72	0.007	5.50	23.30	4.81	0.001	5.50	23.30
3	4	Mean	4.90	0.026	5.50	23.56	4.91	0.034	5.62	21.54
		Range	4.37 - 5.18	0.015 - 0.062	5.20 - 5.90	17.20 - 28.50	4.30 - 5.96	0.004 - 0.115	5.40 - 5.90	17.20 - 25.30
		Mode	4.90	0.030	5.50	23.56	4.91	0.001	5.50	23.30
4	6	Mean	4.99	0.018	5.68	20.52	4.90	0.027	5.69	20.41
		Range	4.41 - 5.82	0.001 - 0.128	5.20 - 6.50	7.00 - 28.50	4.37 - 5.41	0.001 - 0.144	5.10 - 6.60	5.30 - 30.20
		Mode	4.94	0.020	5.50	23.30	5.02	0.001	5.50	23.30
5	7	Mean	4.66	0.123	5.72	19.92	5.13	0.022	5.70	20.22
		Range	4.35 - 5.10	0.002 - 0.385	5.40 - 6.00	15.20 - 25.30	4.86 - 5.52	0.001 - 0.051	5.40 - 6.20	12.10 - 25.30
		Mode	4.66	0.120	5.72	19.92	5.02	0.001	5.50	23.30
6	13	Mean	4.88	0.034	5.52	23.22	4.82	0.048	5.59	22.01
		Range	4.31 - 5.54	0.001 - 0.185	5.10 - 6.70	4.10 - 30.20	4.34 - 5.45	0.001 - 0.451	5.20 - 6.70	4.10 - 28.50
		Mode	4.84	0.030	5.30	26.70	4.95	0.001	5.30	26.70
7	14	Mean	5.41	0.057	5.53	23.00	4.90	0.084	5.70	20.15
		Range	5.14 - 5.56	0.001 - 0.187	5.40 - 5.70	20.10 - 25.30	4.34 - 5.38	0.001 - 0.184	5.50 - 5.80	18.60 - 23.30
		Mode	5.41	0.060	5.50	23.30	4.90	0.084	5.80	18.60
8	15	Mean	4.93	0.017	5.53	22.90	4.69	0.043	5.60	21.79
		Range	4.61 - 5.02	0.005 - 0.038	5.30 - 6.00	15.20 - 26.70	4.35 - 5.08	0.001 - 0.147	5.20 - 6.50	7.00 - 28.50
		Mode	5.02	0.009	5.30	26.70	4.69	0.001	5.70	20.10
9	16	Mean	4.98	0.016	5.59	21.92	4.91	0.024	5.67	20.65
		Range	4.53 - 5.38	0.001 - 0.036	4.80 - 6.60	5.30 - 34.90	4.37 - 5.54	0.001 - 0.192	5.20 - 6.70	4.10 - 28.50
		Mode	4.88	0.021	5.60	21.80	5.16	0.001	5.70	20.10
10	17	Mean	4.90	0.040	5.59	22.04	4.98	0.026	5.63	21.36
		Range	4.43 - 5.18	0.004 - 0.18	5.10 - 6.60	5.30 - 30.20	4.40 - 5.36	0.001 - 0.152	5.00 - 6.30	10.50 - 31.80
		Mode	4.92	0.021	5.60	21.80	5.02	0.001	5.80	18.60
11	18	Mean	4.87	0.004	5.47	24.07	4.74	0.001	5.37	25.60
		Range	4.70 - 5.08	0.001 - 0.009	5.00 - 5.80	18.60 - 31.80	4.57 - 5.01	0.001 - 0.002	5.10 - 5.50	23.30 - 30.20
		Mode	4.87	0.004	5.47	24.07	4.74	0.001	5.50	23.30

(Continued........)

Table 8. Electrochemical Properties of the Soils in western part of main campus, KAU (.....Continued)

Sl. No.	Soil Phase No		Surface samples pH	EC (dS m^{-1})	Buffer PH	Lime R. (t ha^{-1})	Subsurface samples pH	EC dS m^{-1}	Buffer PH	Lime R. (t ha^{-1})
12	19	Mean	5.04	0.030	5.47	24.02	5.04	0.015	5.50	23.48
		Range	4.34 - 6.11	0.001 - 0.17	4.80 - 6.30	10.50 - 34.90	4.33 - 6.12	0.001 - 0.100	4.80 - 6.30	10.50 - 34.90
		Mode	5.06	0.001	5.50	23.30	5.11	0.001	5.80	18.60
13	20	Mean	5.05	0.044	5.70	20.20	4.97	0.011	5.54	22.78
		Range	4.59 - 5.43	0.003 - 0.085	5.40 - 6.00	15.20 - 25.30	4.49 - 5.23	0.001 - 0.034	5.30 - 5.90	17.20 - 26.70
		Mode	4.99	0.003	5.70	20.10	4.97	0.001	5.50	23.30
14	22	Mean	5.06	0.030	5.58	22.11	5.02	0.036	5.56	22.48
		Range	4.71 - 5.67	0.001 - 0.142	4.80 - 6.30	10.50 - 34.90	4.61 - 5.74	0.001 - 0.286	4.90 - 6.20	12.10 - 33.60
		Mode	4.75	0.025	5.70	20.10	5.13	0.008	5.70	20.10
15	24	Mean	5.25	0.059	5.78	19.05	5.17	0.023	5.71	20.03
		Range	4.86 - 5.69	0.006 - 0.200	5.10 - 6.40	9.00 - 30.20	4.83 - 5.89	0.001 - 0.080	5.10 - 6.40	9.00 - 30.20
		Mode	4.75	0.025	5.70	20.10	5.17	0.001	5.71	20.03
16	27	Mean	4.63	0.073	5.60	21.76	4.98	0.028	5.90	17.06
		Range	4.38 - 4.84	0.010 - 0.230	5.50 - 5.80	18.60 - 23.30	4.76 - 5.38	0.001 - 0.117	5.60 - 6.40	9.00 - 21.80
		Mode	4.64	0.073	5.50	23.30	4.89	0.009	5.90	17.20
17	28	Mean	5.09	0.014	5.95	16.16	5.00	0.040	5.58	21.45
		Range	4.59 - 5.41	0.001 - 0.030	5.20 - 6.80	2.40 - 28.50	4.41 - 5.34	0.001 - 0.286	4.40 - 6.80	2.40 - 34.90
		Mode	5.02	0.007	5.80	18.60	5.00	0.007	5.50	23.30
18	30	Mean	4.81	0.043	5.46	24.16	4.95	0.011	5.62	21.48
		Range	4.39 - 5.09	0.001 - 0.200	5.00 - 6.00	15.20 - 31.80	4.70 - 5.21	0.001 - 0.023	5.20 - 6.30	10.50 - 28.50
		Mode	4.81	0.004	5.60	21.80	4.95	0.023	5.50	23.30
19	31	Mean	5.25	0.032	5.20	28.50	4.93	0.003	4.90	33.60
20	32	Mean	5.12	0.033	5.53	23.01	5.27	0.052	5.47	23.38
		Range	4.34 - 5.61	0.002 - 0.182	4.80 - 6.80	2.40 - 34.00	4.80 - 6.55	0.001 - 0.363	4.40 - 6.20	12.10 - 32.60
		Mode	5.08	0.033	4.80	34.90	4.80	0.052	6.20	12.10
21	33	Mean	5.19	0.031	5.53	23.04	5.07	0.030	5.73	19.70
		Range	4.63 - 5.97	0.003 - 0.117	5.00 - 6.50	7.00 - 31.80	4.32 - 5.73	0.001 - 0.148	4.80 - 6.80	2.40 - 34.90
		Mode	5.19	0.003	5.20	28.50	5.07	0.001	5.50	23.30
22	34	Mean	4.95	0.021	5.60	21.80	5.09	0.013	5.20	28.45
		Range	4.63 - 5.27	0.007 - 0.035	5.10 - 6.10	13.40 - 30.20	5.06 - 5.11	0.008 - 0.017	5.10 - 5.30	26.70 - 30.20
		Mode	4.95	0.021	5.60	21.80	5.09	0.013	5.20	28.45
23	37	Mean	4.89	0.012	5.20	28.45	5.11	0.011	5.15	29.35
		Range	4.84 - 4.94	0.012 - 0.012	5.10 - 5.30	26.70 - 30.20	5.07 - 5.14	0.010 - 0.012	5.10 - 5.20	28.50 - 30.20
		Mode	4.89	0.012	5.20	28.45	5.11	0.011	5.15	29.35

ten phases as 0.001 dS m^{-1}. The maximum EC of the surface soils was in phase 7 (0.385dS m^{-1}). The minimum value of EC for subsurface was same as surface samples. But, the highest value obtained here was 0.451 dS m^{-1} in phase 13.

The soil buffer pH was determined by shaking the soil with Shoemaker, McLean 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 was calculated. 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 observed in phase 2 (6.8) and the lowest was in phase 22 (4.8). Buffer pH of the subsurface were also recorded and the highest value was noted in phases 28 and 33 (6.8) while the lowest was in phases 28 and 32 (4.4). Lime required to bring the soil pH to 7 was worked out accordingly and given in the Table 8. The lime requirement will be more as the buffer pH decreases.

The lime required to raise pH of the surface soil to neutrality was highest in phase 22 (34.9 t ha^{-1}). Some samples in phase 2 showed that only a minimum quantity of lime is needed. But the mean value of Phase 2 was 21.2 t ha^{-1}. The lime requirement of the subsurface soil was varied from 2.4t ha^{-1} in phase 28 to 34.9 t ha^{-1} in the soils of phases 19, 28 and 33.

As far as the phase wise average values of the surface samples were considered, the lowest mean was obtained in phase 28 with 16.16t ha^{-1} and the highest mean was recorded in phase 37 with a value of 28.5t ha^{-1}.

4.4. Major nutrients

The content of available major nutrients in the soil is an important parameter as far as productivity of soil is considered. Knowledge about the presently existing amount will help to decide the quantity and type of fertilizer to be applied. The data on organic carbon, available phosphorus and available potassium content in surface and subsurface soils are given in Table 9. The nutrients were classified according to the fertility ratings and presented in Tables 10 and 11.

4.4.1. Organic carbon

In most of the soils, organic carbon contents in sub surface samples were lower than surface samples. But in phases 7 and 32, it is observed that a slight increase in organic carbon in the subsurface samples than surface samples. The mean values of majority of samples were in the range of 0.8 to 1.2%. In surface layer, the highest organic carbon content was recorded in phase 19 with 1.98% whereas in phase 1, it was lowest with 0.13%. In the sub surface layer organic carbon ranges from 0.32 (phase 14) to 1.61% (phase 6). The most frequently occurring values in subsurface layer were in the range of 0.7 to 1 %.

With regard to phase wise mean values, in surface layer, the highest average was noted in phase 34 with a content of 1.3% and phase 7 recorded a minimum of 0.79%. The data on subsurface level showed a maximum average of 1.05% in phase 32 and minimum average of 0.56% in phase 14.

Considering the total number of surface samples (259) analysed, 93 % of the samples (240 nos.) were under medium nutrient class in the fertility rating (Table 10). Only one sample was in the low class while 18 samples (6.9%) were found to be in high class. In the case of subsurface layer, only 2 samples (0.8%) were under high and 11 (4.2%) were under low fertility classes. About 95% samples (246 nos.) were in the medium class.

When we adopted fertility class (0-9-class system) rating among the surface samples, it could be seen that 33.2% (86 nos.) and 34.4% (89 nos.) of samples were in class 4 and 5,respectively. Further, 47 samples (18%) were under class 6 and 20 samples (7.7%) were in class 7. But in the case of subsurface content, 42.5% of samples were included in class 4 and class 3 contained 34.7% (90 nos.) of samples. Class 6 and 7 got only 9 (3.5%) and 2 (0.77%) surface samples respectively. Neither the class 1 nor the class 2 had surface samples. Still there were 3.9% (10 nos.) of subsurface samples in the class 2 and one sample in class 1. No sample was included in either class 8 or class 9 (Table 11).

Table 9. Concentration of major nutrients in the soils of western part of the main campus, Kerala Agricultural University

Sl. No	Soil Phase No		Surface samples Org. C (%)	Surface samples Av. P ($\mu g\ g^{-1}$)	Surface samples Av. K ($\mu g\ g^{-1}$)	Subsurface samples Org. C (%)	Subsurface samples Av. P ($\mu g\ g^{-1}$)	Subsurface samples Av. K ($\mu g\ g^{-1}$)
1	1	Mean	0.90	3.47	44.38	0.74	1.02	36.88
		Range	0.13 - 1.29	0.33 - 13.00	20.00 - 83.00	0.53 - 1.24	0.04 - 4.42	14.00 - 104.00
		Mode	0.87	3.47	44.38	0.74	0.50	26.00
2	2	Mean	1.04	3.42	38.46	0.78	1.18	31.15
		Range	0.77 - 1.32	0.17 - 20.96	24.00 - 59.00	0.50 - 0.98	0.21 - 2.71	19.00 - 54.00
		Mode	1.26	3.42	31.00	0.78	1.75	20.00
3	4	Mean	0.98	1.96	52.00	0.78	1.02	42.80
		Range	0.62 - 1.27	0.17 - 6.00	40.00 - 67.00	0.62 - 1.06	0.08 - 4.21	31.00 - 52.00
		Mode	0.98	1.96	52.00	0.74	0.08	42.80
4	6	Mean	1.00	3.90	44.89	0.80	1.71	36.74
		Range	0.55 - 1.65	0.04 - 20.42	11.00 - 147.00	0.36 - 1.61	0.08 - 16.83	11.00 - 102.00
		Mode	1.01	1.71	27.00	0.74	0.58	28.00
5	7	Mean	0.79	1.54	33.80	0.81	1.60	26.00
		Range	0.57 - 0.99	0.29 - 2.83	24.00 - 48.00	0.56 - 1.33	0.21 - 3.17	19.00 - 36.00
		Mode	0.79	1.46	33.80	0.74	0.58	28.00
6	13	Mean	1.22	4.91	50.06	0.91	2.99	39.19
		Range	0.87 - 1.94	0.92 - 26.5	11.00 - 192.00	0.55 - 1.25	0.29 - 16.79	12.00 - 143.00
		Mode	1.41	1.92	66.00	0.98	0.38	30.00
7	14	Mean	0.97	2.16	48.25	0.56	1.24	55.50
		Range	0.63 - 1.35	0.94 - 3.25	26.00 - 78.00	0.32 - 0.79	1.06 - 1.42	18.00 - 97.00
		Mode	0.97	2.16	48.25	0.56	1.24	55.50
8	15	Mean	1.24	9.47	50.56	0.96	3.76	38.78
		Range	1.01 - 1.60	1.92 - 23.96	16.00 - 111.00	0.77 - 1.20	1.54 - 7.83	13.00 - 76.00
		Mode	1.13	9.47	50.56	0.96	3.76	28.00
9	16	Mean	1.16	5.25	44.33	0.82	1.65	44.56
		Range	0.79 - 1.40	0.75 - 21.41	14.00 - 93.00	0.45 - 1.07	0.17 - 4.17	14.00 - 178.00
		Mode	1.20	5.25	44.33	0.71	0.83	14.00
10	17	Mean	1.16	3.28	49.18	0.81	1.05	51.65
		Range	0.76 - 1.73	0.58 - 9.33	19.00 - 89.00	0.50- 1.33	0.08 - 2.79	17.00 - 129.00
		Mode	1.16	3.28	49.18	0.81	1.04	17.00
11	18	Mean	0.95	2.47	29.00	0.60	1.69	25.00
		Range	0.77 - 1.06	0.50 - 4.0	26.00 - 31.00	0.48 - 0.72	0.29 - 2.71	19.00 - 33.00
		Mode	0.95	2.47	29.00	0.60	1.69	25.00
12	19	Mean	1.22	2.72	65.94	0.89	1.80	56.12
		Range	0.75 - 1.98	0.29 - 6.38	23.00 - 134.00	0.61 - 1.59	0.17 - 7.44	20.00 - 117.00
		Mode	1.14	2.72	65.94	0.75	1.80	60.00
13	20	Mean	1.05	2.89	61.00	0.95	1.06	37.13
		Range	0.79 - 1.57	0.58 - 8.58	20.00 - 119.00	0.63 - 1.39	0.08 - 1.81	14.00 - 65.00
		Mode	1.05	2.89	61.00	0.95	1.06	37.13
14	22	Mean	1.07	3.38	61.35	0.79	2.43	59.78
		Range	0.65 - 1.64	0.21 - 12.3	20.00 - 132.00	0.41 - 1.26	0.06 - 21.55	15.00 - 132.00
		Mode	0.99	0.58	61.35	0.78	0.55	41.00
15	24	Mean	1.23	5.17	80.00	0.85	4.08	61.00
		Range	0.82 - 1.64	1.13 - 15.5	38.00 - 115.00	0.50 - 1.26	0.13 - 22.00	29.00 - 96.00
		Mode	0.99	5.17	61.00	0.50	4.08	48.00

(Continued........)

Table 9. Concentration of major nutrients in the soils of the western part of the main campus, Kerala Agricultural University

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

Sl. No	Soil Phase No		Surface samples Org. C (%)	Surface samples Av. P (µg g⁻¹)	Surface samples Av. K (µg g⁻¹)	Subsurface samples Org. Class (%)	Subsurface samples Av. P (µg g⁻¹)	Subsurface samples Av. K (µg g⁻¹)
16	27	Mean	0.94	1.30	45.00	0.87	1.39	56.80
		Range	0.70 - 1.20	0.17 - 1.88	30.00 - 63.00	0.62 - 1.25	0.12 - 3.21	27.00 - 137.00
		Mode	0.94	1.30	45.00	0.62	1.39	27.00
17	28	Mean	1.09	5.05	75.13	0.82	1.03	63.75
		Range	0.73 - 1.58	1.29 - 9.31	58.00 - 105.00	0.63 - 1.05	0.42 - 1.88	38.00 - 106.00
		Mode	1.09	5.05	75.13	0.84	1.13	68.00
18	30	Mean	1.05	1.28	56.20	0.75	1.45	46.20
		Range	0.93 - 1.26	0.17 - 3.60	36.00 - 89.00	0.62 - 0.88	0.13 - 3.46	26.00 - 79.00
		Mode	1.05	1.28	56.20	0.75	1.45	46.20
19	31	Mean	1.44	8.00	87.00	1.11	1.00	69.00
20	32	Mean	1.02	5.03	61.60	1.05	3.12	65.40
		Range	0.73 - 1.42	0.58 - 9.42	35.00 - 116.00	0.69 - 1.37	0.46 - 6.31	29.00 - 103.00
		Mode	0.73	5.03	53.00	1.29	3.12	65.40
21	33	Mean	1.16	2.77	66.70	0.80	1.05	69.20
		Range	0.77 - 1.65	0.21 - 6.83	27.00 - 138.00	0.54 - 1.02	0.14 - 3.50	20.00 - 138.00
		Mode	1.16	2.77	66.70	0.80	1.05	30.00
22	34	Mean	1.30	2.59	67.00	1.00	0.65	51.00
		Range	1.10 - 1.49	1.71 - 3.46	56.00 - 78.00	0.84 - 1.16	0.29 - 1.00	44.00 - 58.00
		Mode	1.30	2.59	67.00	1.00	0.65	51.00
23	37	Mean	0.87	1.77	24.50	0.78	0.11	33.50
		Range	0.81 - 0.92	1.75 - 1.79	15.10 - 89.00	0.77 - 0.78	0.08 - 0.13	28.00 - 39.00
		Mode	0.87	1.77	24.50	0.78	0.11	33.50

Table 10. Fertility rating of Soil Samples and Phases in the western part of the main campus, KAU

Sl. No.	Nutrients	Nutrient Status (%)	No. of Soil Samples Surface	No. of Soil Samples Subsurface	No. of phases Surface	No. of phases Subsurface
1	Org. C	Low (0.0 - 0.5)	1 (0.4)	11 (4.2)	0	0
		Medium (0.5 - 1.5)	240 (92.7)	246 (95.0)	23 (100)	23 (100)
		High (1.5 - 2.5)	18 (6.9)	2 (0.8)	0	0
2	Available P.	Low (0.0 - 0.5)	180 (69.5)	237 (91.5)	16 (69.6)	23 (100)
		Medium (0.5 - 1.5)	65 (25)	17 (6.5)	7 (30.4)	0
		High (1.5 - 2.5)	14 (5.5)	5 (2.0)	0	0
3	Available K.	Low (0.0 - 0.5)	146 (56.3)	172 (66.4)	12 (52.2)	13 (56.5)
		Medium (0.5 - 1.5)	106 (40.9)	80 (30.8)	11 (47.8)	10 (43.5)
		High (1.5 - 2.5)	7 (2.8)	7 (2.8)	0	0

Percentages are given in Parenthesis

Table 11. Fertility Rating of Soil Samples from the western part of the main campus, KAU

Sl. No	Class	Org. Class			Available P.			Available K.		
		Rating (%)	No. of Samples		Rating ($\mu g\ g^{-1}$)	No. of Samples		Rating ($\mu g\ g^{-1}$)	No. of Samples	
			Surface	Sub surface		Surface	Sub Surface		Surface	Sub Surface
1	0	0.00 - 0.16	1 (0.4)	0	0.00 - 1.34	64 (24.7)	151 (58.3)	0.00 - 15.63	8 (3)	13 (5)
2	1	0.17 - 0.33	0	1 (0.4)	1.35 - 2.90	84 (32.4)	64 (24.7)	16.07 - 33.48	70 (270	103 (39.7)
3	2	0.34 - 0.50	0	10 (3.9)	2.95 - 4.46	32 (12.4)	23 (8.9)	33.93 - 51.34	67 (25.8)	57 (22)
4	3	0.51 - 0.75	16 (6.2)	90 (34.7)	4.51 - 6.03	23 (8.8)	9 (3.5)	51.79 - 69.20	45 (17.4)	40 (15.4)
5	4	0.76 - 1.00	86 (33.2)	110 (42.5)	6.07 - 7.59	19 (7.3)	3 (1.1)	69.64 - 87.05	33 (12.7)	23 (8.8)
6	5	1.01 - 1.25	89 (34.4)	37 (14.3)	7.63 - 9.15	16 (6.2)	4 (1.5)	087.5 - 104.9	12 (4.6)	11 (4.2)
7	6	1.26 - 1.50	47 (18)	9 (3.5)	9.16 - 10.71	7 (2.7)	1 (0.4)	105.36 - 122.77	17 (6.6)	6 (2.3)
8	7	1.51 - 1.83	20 (7.7)	2 (0.8)	10.76 - 12.28	2 (0.8)	0	123.21 - 140.63	5 (1.9)	4 (1.5)
9	8	1.84 - 2.16	0	0	12.32 - 13.84	4 (1.5)	0	141.07 - 158.48	1 (0.4)	1 (0.4)
10	9	2.17 - 2.50	0	0	13.88 - 15.40	8 (3.2)	4 (1.5)	158.93 - 176.34	1 (0.4)	1 (0.4)

Percentages are given in Parenthesis

4.4.2. Available Phosphorus

In general, the available phosphorus present in the soils was found to be low in concentration (Table 9). It was observed that the available phosphorus content in the surface layer is higher than the subsurface layer in all the phases except in phase 7 and 30. The most frequently occurring values are in the range of 1 to 6$\mu g\ g^{-1}$. A wide range of 0.17$\mu g\ g^{-1}$ (phases 2, 4, 27 and 30) to 26.5 $\mu g\ g^{-1}$ (phase 13) was seen in surface layer. The highest average of 9.47$\mu g\ g^{-1}$ in phase 15 and the lowest average of 1.28 $\mu g\ g^{-1}$ in phase 30 were recorded. There was no relation observed between the phosphorus contents of surface and subsurface soils. In the subsurface layer, the quantity of available phosphorus varied from 0.04 $\mu g\ g^{-1}$ to 22.0 $\mu g\ g^{-1}$. Majority of the mean values of different phases occurred in the range of 0.5 - 3.0 $\mu g\ g^{-1}$. But the lowest value for available phosphorus was in phase 1 and highest value was in the phase 24.

When these data were used for the fertility rating, most of the surface and subsurface soils were coming under low class (Table 10). In the surface samples, 180 samples (69.5%) and in subsurface soils, 237 samples (91.5%) were under low category. Sixty five surface samples and 17 subsurface samples (25 and 6.5%respectively) were medium in fertility while 14 surface samples and 5 subsurface samples (5.5 and 2% respectively) were coming under high fertility class. Seven surface samples were having values above high fertility class.

While these samples were distributed according to 0 - 9 fertility class rating, all the classes were occupied by surface samples. In surface samples, 84 (32.4%) and 64 (24.7%) samples were included in class 1 and 0. Similarly, class 2, 3, 4, 5 and 6 were accommodated by 32 (12.4%), 23 (8.8%), 19 (7.3%), 16 (6.2%) and 7 (2.7%) samples respectively. The class 7, 8 and 9 were having 2, 4 and 8 samples respectively. With respect to subsurface samples, 58.3 % (151nos.) was in the class 0 and 24.7% (64nos.) was in class 1. However other classes except 7 and 8 were also occupied by a few samples (Table 11).

4.4.3. Available Potassium

When the average of available potassium content was considered, most of the phases showed a decrease in subsurface layer than in surface samples. The usual range observed was from 40 - 65μg g^{-1}in the surface layer and 25 - 50μg g^{-1} in the subsurface. A minimum value of 11μg g^{-1} in phases 6 and 11 and a maximum of 192μg g^{-1} in the phase 13 were obtained in surface samples. The contents of available potassium in the subsurface soil varied from 11μg g^{-1} in phase 6 and 178μg g^{-1} in phase 16. With regard to phase wise mean values, in surface samples, phase 28 and 37 had maximum (75.13μg g^{-1}) and minimum (24.5μg g^{-1}) values respectively. But with subsurface layer, the minimum (26μg g^{-1}) was obtained in phase 7 and maximum (69.2%) in phase 33.

As far as the fertility rating was applied among with these data, most of the samples were under low category both in surface and subsurface samples (Table 10). About 146 out of 259 surface samples (56.3%) were under low category, while 106 (40.9%) and 7 (2.8%) were under medium and high classes, respectively. In the case of subsurface samples, 172 samples (66.3%) and 80 (31%) were in the low and medium ranges, respectively. Seven samples (2.8%) were in the high category.

The data on available potassium were grouped according to fertility class (0 - 9 class) rating (Table 11). Then almost equal number of surface samples were occupied in class 1 (27%) and class 2 (25.8%). Likewise, 8 (3%), 42 (16.2%), 33 (12.7%), and 12 (4.6%) samples were distributed in class 1, 3, 4 and 5. When the subsurface samples were categorized accordingly, class 1 had 103(39.7%), class 2 had 57 (22%) and class 3 had 40 (15.4%) samples.

4.5. Secondary Nutrients

Available secondary nutrients namely calcium and magnesium were estimated using neutral normal ammonium acetate solution. The phase wise mean, average and most frequently occurring values were given in Table 12.

4.5.1. Available Calcium

In secondary nutrients, available calcium was found to be high in both surface and subsurface samples than magnesium. An increase in calcium content in the subsurface was observed in 7 out of 23 phases. There was a wide range among the samples from 12μgg^{-1} (phase 6) to 378 μg g^{-1} (phase 22) in the case of surface samples. The same trend was seen in the case of subsurface samples also. The minimum and maximum values were 8 (phase 1) and 356μg g^{-1} (phases 19 & 22) respectively.

The mean values of most of the phases were in the range of 50-150μg g^{-1}. While looking at the phase average values, it was realized that the highest value for both surface (308.8μg g^{-1}) and subsurface (288.9μg g^{-1}) were obtained in the same phase (phase 14). In a similar way, the same phase (phase 15) had the lowest average for surface (46.5μg g^{-1}) as well as subsurface (47.39μg g^{-1}).

Table 12. Concentration of secondary nutrients in the soils of the western part of the main campus, KAU

Sl. No	Soil Phase No		Surface samples Calcium ($\mu g\ g^{-1}$)	Surface samples Magnesium ($\mu g\ g^{-1}$)	Subsurface samples Calcium ($\mu g\ g^{-1}$)	Subsurface samples Magnesium ($\mu g\ g^{-1}$)
1	1	Mean	55.72	26.09	61.16	21.84
		Range	14.00 - 151.10	16.00 - 47.00	8.00 - 205.50	10.50 - 34.50
		Mode	55.72	28.00	61.61	22.50
2	2	Mean	57.62	23.68	52.42	22.83
		Range	15.00 - 139.00	16.00 - 32.00	12.50 - 95.50	15.00 - 33.00
		Mode	57.62	23.68	52.42	21.50
3	4	Mean	90.80	29.80	88.70	30.80
		Range	23.50 - 149.00	22.00 - 34.00	32.00 - 107.50	26.50 - 34.50
		Mode	90.80	29.80	88.70	30.80
4	6	Mean	72.50	26.37	74.95	25.35
		Range	12.00 - 194.50	14.00 - 51.90	11.00 - 182.00	10.50 - 37.50
		Mode	117.00	25.00	74.95	32.00
5	7	Mean	140.80	31.20	132.80	30.50
		Range	34.50 - 265.50	24.50 - 38.50	12.00 - 263.50	20.50 - 39.50
		Mode	140.80	31.20	132.80	32.00
6	13	Mean	99.11	26.34	77.56	23.86
		Range	15.50 - 254.00	7.50 - 40.00	19.00 - 203.00	6.50 - 37.50
		Mode	81.50	24.00	47.00	30.50
7	14	Mean	308.88	38.63	288.88	37.00
		Range	254.00 - 345.50	36.50 - 41.00	219.00 - 329.50	34.50 - 39.00
		Mode	308.88	38.63	288.88	37.00
8	15	Mean	46.50	18.72	47.39	15.94
		Range	22.50 - 82.50	12.50 - 27.00	17.50 - 94.00	8.50 - 26.50
		Mode	46.50	18.72	47.39	8.50
9	16	Mean	75.25	24.74	69.78	23.21
		Range	13.00 - 208.00	6.50 - 36.50	17.00 - 223.50	7.50 - 35.00
		Mode	75.25	35.00	69.78	33.50
10	17	Mean	100.76	29.18	104.94	27.24
		Range	50.50 - 249.50	17.50 - 45.50	38.50 - 244.50	13.00 - 35.50
		Mode	100.76	28.00	121.00	27.00
11	18	Mean	64.17	26.83	54.00	23.00
		Range	23.00 - 102.00	23.00 - 31.50	15.50 - 117.50	11.00 - 34.50
		Mode	64.17	26.83	54.00	23.00
12	19	Mean	119.24	31.44	108.88	27.76
		Range	37.00 - 340.50	21.50 - 40.50	27.00 - 356.00	6.50 - 34.50
		Mode	159.00	32.50	108.88	27.00
13	20	Mean	171.19	33.56	174.25	31.38
		Range	24.00 - 321.00	22.50 - 39.50	32.00 - 286.50	24.50 - 36.50
		Mode	171.19	36.50	174.25	31.38

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

Table 12. Concentration of secondary nutrients in the soils of the western part of the main campus, KAU

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

Sl. No	Soil Phase No		Surface samples Calcium ($\mu g\ g^{-1}$)	Surface samples Magnesium ($\mu g\ g^{-1}$)	Subsurface samples Calcium ($\mu g\ g^{-1}$)	Subsurface samples Magnesium ($\mu g\ g^{-1}$)
14	22	Mean	182.83	32.74	177.48	31.91
		Range	56.00 - 378.00	14.00 - 41.00	45.00 - 356.00	15.00 - 41.50
		Mode	182.83	35.00	113.50	28.00
15	24	Mean	239.94	35.19	169.30	30.75
		Range	155.50 - 345.00	31.00 - 39.00	23.00 - 321.90	22.50 - 40.00
		Mode	239.94	35.00	169.30	32.50
16	27	Mean	78.10	25.70	96.50	25.90
		Range	41.00 - 105.00	20.50 - 30.00	38.50 - 246.50	17.50 - 36.50
		Mode	78.10	25.70	96.50	25.90
17	28	Mean	98.81	29.53	83.25	27.78
		Range	58.00 - 126.50	25.35 - 32.95	59.00 - 151.00	22.45 - 31.20
		Mode	98.81	29.53	59.00	27.78
18	30	Mean	100.10	27.15	139.80	27.12
		Range	34.00 - 195.50	16.00 - 35.50	67.00 - 199.50	21.00 - 35.00
		Mode	100.10	27.15	139.80	27.12
19	31	Mean	188.50	31.90	61.50	25.70
20	32	Mean	159.30	29.15	158.68	29.56
		Range	26.00 - 343.00	17.05 - 33.00	29.50 - 259.25	19.05 - 36.00
		Mode	159.30	33.00	158.68	29.56
21	33	Mean	147.95	30.80	170.15	27.88
		Range	15.00 - 312.00	12.50 - 37.50	41.50 - 304.00	13.00 - 42.40
		Mode	147.95	30.80	170.15	36.00
22	34	Mean	126.75	32.93	113.00	30.68
		Range	95.00 - 158.50	30.50 - 35.35	101.00 - 125.00	30.00 - 31.35
		Mode	126.75	32.93	113.00	30.68
23	37	Mean	143.25	29.75	240.00	34.25
		Range	134.50 - 152.00	28.00 - 31.50	227.50 - 252.50	33.50 - 35.00
		Mode	143.25	29.75	240.00	34.25

4.5.2. Available Magnesium

For magnesium, the most frequently occurring value was in the range of 25 - 40 $\mu g\ g^{-1}$. The highest value was 51.9$\mu g\ g^{-1}$ in phase 6 and lowest was in phase 16 with 6.5$\mu g\ g^{-1}$ in the surface samples. Among the subsurface samples, the maximum value (42.4$\mu g\ g^{-1}$) was in phase 33 and minimum value (6.5$\mu g\ g^{-1}$) was in phase 13 and 19. In subsurface layer highest value of Ca and lowest value of Mg were in the same phase (phase 19).

With regard to phase wise average values, it was observed that the highest value for both surface (38.63$\mu g\ g^{-1}$) and subsurface (37$\mu g\ g^{-1}$) were obtained in the same phase (phase 14). In a similar way, the phase 15 had the lowest average for surface (18.72$\mu g\ g^{-1}$) as well as subsurface (15.94$\mu g\ g^{-1}$). Both the maximum and minimum phase wise averages in two layers for the secondary nutrients were obtained in the same phases (phases 14 and 15).

4.6. Available Micronutrients

Available micronutrients such as manganese, zinc, copper and iron were determined by using 0.1M HCl extract. The mean, range and most frequently occurring value for each phase are listed in the Table 13. By considering the critical range of micronutrients, samples were classified as below critical range, critical range and above critical range. Number of surface and subsurface samples coming under these groups are found out and presented in the Table 14. By taking mean value of the phases, they were also graded under the above three groups.

4.6.1. Available Manganese

Among micronutrients, manganese is present in larger quantity in the soil. In the surface samples, manganese is found to be in the range of 4.5 - 116$\mu g\ g^{-1}$. Here the maximum and minimum values were obtained in the phase 18 and 1, respectively. The most probable mean value was in the range of 50 -60 $\mu g\ g^{-1}$. In subsurface level, the lowest value (3.1 $\mu g\ g^{-1}$) was observed in the phase 1 as in the surface samples and the highest content was recorded in phases 4 and 6 with 120.3 $\mu g\ g^{-1}$.

With regard to phase wise mean values, the highest value for surface (73.65$\mu g\ g^{-1}$) and subsurface (72.59$\mu g\ g^{-1}$) samples were recorded in the same phase (phase 28). Similarly, phase 37 was having the least average for both surface (32.15$\mu g\ g^{-1}$) and subsurface(27.45$\mu g\ g^{-1}$) samples.

The critical range for manganese in soil as given by Sims and Johnson (1991) is 1- 4$\mu g\ g^{-1}$. While taking the mean value of the contents for phases, all the phases were included in the above critical range group (Table 14).

Table 13. Concentration of micro nutrients in the soils of western part of the main campus, KAU ($\mu g\ g^{-1}$)

Sl. No	Phase No		Surface samples Mn	Zinc	Copper	Fe	Subsurface samples Mn	Zn	Cu	Fe
1	1	Mean	53.76	0.48	6.38	30.31	51.16	0.32	6.07	30.12
		Range	4.50-105.70	0.05-0.99	2.28-17.76	13.90 -101.30	3.10 - 99.70	0.09 -1.19	1.10 - 46.72	13.60 -72.00
		Mode	68.80	0.39	6.38	30.31	51.16	0.29	6.07	16.70
2	2	Mean	44.41	0.34	13.15	22.45	42.11	0.24	10.75	21.61
		Range	21.20-76.10	0.03 - 0.69	2.90-51.10	14.50-36.40	18.30-97.60	0.05-0.59	2.07-54.34	12.60-32.40
		Mode	44.41	0.49	13.15	22.45	18.30	0.29	10.75	21.61
3	4	Mean	62.22	0.59	8.99	25.56	69.14	0.43	4.86	21.70
		Range	24.40-103.10	0.42-0.80	3.27-13.01	22.80-29.90	39.00-120.30	0.32-0.56	2.90-9.89	18.00-26.30
		Mode	62.22	0.59	8.99	25.56	18.30	0.29	4.86	21.70
4	6	Mean	59.19	0.66	8.46	26.81	62.14	0.52	6.16	27.13
		Range	34.10-100.40	0.09-3.99	0.04-18.05	12.90-99.30	17.80-120.30	0.03-3.79	1.93-17.40	10.30-85.00
		Mode	57.60	0.49	8.46	25.00	62.14	0.39	2.13	19.40
5	7	Mean	58.12	0.56	8.54	26.88	57.66	0.60	9.76	25.42
		Range	45.50-70.80	0.16-1.19	3.69-16.43	14.50-55.00	19.60-84.20	0.14-0.99	1.80-16.71	16.60-35.61
		Mode	58.12	0.56	8.54	26.88	57.66	0.49	2.13	26.10
6	13	Mean	55.16	0.72	9.01	24.71	54.57	0.54	5.40	24.19
		Range	15.1-99	0.19-2.49	2.28-33.82	13.30-44.60	4.80-111.40	0.09-1.79	1.35-26.15	11.30-65.50
		Mode	55.16	0.39	9.01	15.50	54.57	0.29	5.40	21.80
7	14	Mean	36.33	0.59	7.30	16.50	38.25	0.42	4.78	12.45
		Range	26.30-54.90	0.39-0.79	3.99-12.00	14.10-21.30	23.00-54.80	0.29-0.69	2.81-9.96	4.50-20.80
		Mode	36.33	0.59	7.30	16.50	38.25	0.42	4.78	12.45
8	15	Mean	59.79	0.46	5.30	21.44	59.32	0.27	4.20	20.23
		Range	28.00-89.70	0.19-0.79	3.03-9.40	12.60-35.10	30.70-78.20	0.09-0.49	1.53-8.56	14.30-29.30
		Mode	59.79	0.46	5.30	21.44	59.32	0.29	4.20	20.23
9	16	Mean	57.84	0.62	7.57	22.42	57.84	0.45	5.10	21.08
		Range	32.00-101.00	0.19-1.49	2.65-19.52	13.50-52.00	25.00-97.10	0.09-1.19	0.89-25.79	11.00-41.20
		Mode	57.84	0.29	7.57	22.42	36.00	0.29	5.10	21.08
10	17	Mean	55.98	0.51	11.66	20.65	49.95	0.35	4.89	20.60
		Range	24.30-100.80	0.29-0.89	1.91-40.66	12.40-29.10	30.50-82.90	0.13-0.99	1.15-25.88	10.20-31.20
		Mode	55.98	0.29	5.54	26.30	49.95	0.29	4.89	13.10
11	18	Mean	64.40	0.26	6.02	24.70	52.67	0.16	3.05	30.13
		Range	28.70-116.00	0.20-0.34	4.23-8.72	21.50-30.30	17.90-94.50	0.06-0.23	2.24-4.60	22.00-34.60
		Mode	64.40	0.26	6.02	24.70	52.67	0.16	3.05	30.13

(Continued……………)

Table 13. Concentration of micro nutrients in the soil of western part of the main campus, KAU ($\mu g\ g^{-1}$) (..........Continued)

Sl. No	Phase No		Surface samples				Subsurface samples			
			Mn	Zn	Cu	Fe	Mn	Zn	Cu	Fe
12	19	Mean	52.79	0.63	12.18	25.02	48.39	0.43	7.44	21.77
		Range	33.30-106.10	0.29-1.39	4.13-23.97	10.10-65.60	26.30-93.40	0.13-1.39	1.52-33.00	11.50-44.90
		Mode	43.10	0.49	12.18	25.02	45.30	0.19	7.44	15.90
13	20	Mean	49.40	0.74	11.61	18.43	49.73	0.48	12.37	15.48
		Range	30.40-63.30	0.49-0.99	3.65-17.25	12.10-25.90	27.30-86.50	0.19-0.59	2.23-55.19	10.20-22.00
		Mode	49.40	0.99	11.61	18.43	49.73	0.59	12.37	14.60
14	22	Mean	46.00	0.66	7.66	18.68	40.23	0.57	4.09	21.39
		Range	6.20-88.50	0.29-1.49	1.73-17.22	9.70-59.90	8.80-74.60	0.19-1.59	0.98-8.87	10.50-48.00
		Mode	46.00	0.29	7.66	18.68	30.10	0.39	6.03	20.50
15	24	Mean	48.28	0.97	7.27	20.94	34.39	0.53	4.47	18.46
		Range	33.60-62.20	0.46-1.19	2.70-13.72	13.50-35.60	10.50-65.60	0.29-0.79	0.72-8.53	14.90-30.40
		Mode	33.60	0.29	7.27	16.60	34.39	0.49	4.47	18.46
16	27	Mean	66.30	0.42	10.03	19.56	56.06	0.46	8.20	20.76
		Range	30.80-83.40	0.33-0.49	4.27-17.62	11.80-27.70	45.90-72.00	0.29-0.90	2.84-24.40	12.80-27.60
		Mode	66.30	0.42	10.03	19.56	56.06	0.46	8.20	20.76
17	28	Mean	73.65	0.74	8.72	18.39	72.59	0.49	3.05	15.59
		Range	51.50-100.40	0.59-0.99	4.04-21.47	12.80-26.80	40.00-105.50	0.39-0.59	1.63-7.14	9.10-21.30
		Mode	73.65	0.69	8.72	18.39	72.59	0.49	3.05	15.59
18	30	Mean	65.62	0.75	10.82	33.76	52.26	0.49	6.22	23.48
		Range	41.40-96.90	0.39-1.19	7.12-15.68	14.10-51.90	34.30-84.40	0.29-0.79	1.94-14.05	15.50-32.20
		Mode	65.62	0.69	10.82	33.76	52.26	0.39	6.22	23.48
19	31	Mean	86.40	1.09	10.89	46.30	75.90	0.89	7.00	30.30
20	32	Mean	52.33	0.71	8.96	16.74	55.71	0.56	14.03	19.41
		Range	36.60-79.90	0.39-1.59	1.08-32.31	9.20-29.80	33.00-80.60	0.29-0.89	2.89-63.54	10.80-43.30
		Mode	52.33	0.39	8.96	13.30	55.71	0.49	14.03	19.41
21	33	Mean	37.95	0.61	6.01	21.27	35.01	0.51	4.01	18.48
		Range	25.10-50.70	0.19-1.09	1.28-15.73	10.10-47.40	17.40-53.60	0.39-0.79	1.80-8.16	9.10-39.90
		Mode	37.95	0.49	6.01	21.27	53.60	0.39	4.01	15.60
22	34	Mean	48.15	0.59	6.77	18.85	44.50	0.34	2.89	18.30
		Range	41.50-54.80	0.39-0.79	6.09-7.45	14.00-23.70	38.80-50.20	0.19-0.49	2.57-3.21	16.00-20.60
		Mode	48.15	0.59	6.77	18.85	44.50	0.34	2.89	18.30
23	37	Mean	32.15	0.59	2.28	24.25	27.45	0.49	5.67	15.05
		Range	29.20-35.10	0.59-0.59	2.00-2.56	13.00-35.50	24.30-30.60	0.49-0.49	5.67-5.67	13.40-16.70
		Mode	320.15	0.59	2.28	24.25	27.45	0.49	5.67	15.05

Table 14. Micronutrient Rating of Soil Samples from western part of the main campus, KAU

Sl. No.	0.1M HCl Extractable	Critical Range ($\mu g\ g^{-1}$)	Rating	No. of Samples		No. of Phases	
				Surface	Sub surface	Surface	Sub Surface
1	Fe	0.3 - 0.5	Below Critical Range	0	0	0	0
			Critical Range	0	0	0	0
			Above Critical Range	259 (100)	259 (100)	23 (100)	23 (100)
2	Mn	001 - 4	Below Critical Range	0	0	0	0
			Critical Range	0	1 (0.4)	0	0
			Above Critical Range	259 (100)	258 (99.6)	23 (100)	23 (100)
3	Zn	001 - 5	Below Critical Range	228 (88)	244 (94.2)	22 (95.7)	23 (100)
			Critical Range	31 (12)	15 (5.8)	1 (4.3)	0
			Above Critical Range	0	0	0	0
4	Cu	001 - 2	Below Critical Range	1 (0.4)	3 (1.1)	0	0
			Critical Range	9 (3.5)	34 (13.2)	0	0
			Above Critical Range	249 (96.1)	222 (85.7)	23 (100)	23 (100)

Percentages are given in parenthesis

4.6.2. Available Zinc

Compared to other micronutrients, zinc was found to be in minimum content in the soils. In the case of Zinc, the majority of samples were under low category (Table 13). In the surface layer, the highest value was observed in the phase 6 with 3.99 $\mu g\ g^{-1}$ and the minimum value was recorded as 0.03$\mu g\ g^{-1}$ in the phase 2. In the subsurface layer, the highest as well as the lowest contents were recorded in the same phase (phase 6). The maximum value was 3.79 $\mu g\ g^{-1}$ and the minimum value was 0.03 $\mu g\ g^{-1}$.

As far as average values for the phases were considered, the highest average for surface contents was obtained in phase 24 (0.97$\mu g\ g^{-1}$) and that for subsurface was in phase 7(0.6$\mu g\ g^{-1}$). The lowest average for both surface (0.26$\mu g\ g^{-1}$) and subsurface (0.16$\mu g\ g^{-1}$) samples were estimated in the same phase (phase18).

While categorizing according to the critical range (1-5µg g^{-1}), 88% of surface (228 nos.) and 94% of subsurface samples would come under below critical range. Only 31 (12%) surface and 15(5.8%) subsurface samples were included in the critical range. Out of 23 phases, mean values of 22 phases were in the below critical range group and that of one was in critical range group (Table 14).

4.6.3. Available Copper

Most of the samples showed a high content of copper. The range of copper was varying from 0.04 to 40.66µg g^{-1} in the case of surface samples. The lowest value was obtained in the phase 6 and the highest value was in phase 17. The frequently occurring values were in the range of 5-10 µg g^{-1} in the surface samples. The amount of available copper in the subsurface level was lower than surface level in all the phases except three phases (20, 32 and 37). Among the subsurface samples, maximum content was recorded as 63.54µg g^{-1} in phase 32 and minimum was in phase 24 with a value of 0.72 µg g^{-1}.

The highest and lowest mean values for surface layer were obtained in phase 2 (13.15µg g^{-1}) and phase 37 (2.28µg g^{-1}) respectively. In the same way, phase 32 was recorded the highest average (14.03µg g^{-1}) and the lowest (2.89µg g^{-1}) was in the phase 34 in subsurface samples (Table 13).

When these data were used for fertility rating, mean values of all the phases were in the above critical range (1-2µg g^{-1}), since the most of the phases were having a mean value in the range of 3-6µg g^{-1} (Table 14). Among 259 samples, 96% (249 nos.) surface as well as 85.7% (222 nos.) subsurface samples were categorized in as above critical range. In the critical range, only 9 (3.5%) surface and 34 subsurface (13.2%) samples were included.

4.6.4. Available Iron

The majority of samples were having a high content of available iron (Table 13). In the surface layer, the maximum content was recorded in the phase 1 (101.3µg g^{-1}) and the minimum content was in the phase 32 (9.2µg g^{-1}). While in the case of subsurface samples, in phase 14, it was recorded a minimum value of 4.5 $\mu g\ g^{-1}$ and in 6th phase a maximum value of 85 $\mu g\ g^{-1}$. Further, the highest phase average was recorded as 33.76$\mu g\ g^{-1}$ (phase 30) and the lowest as 16.5$\mu g\ g^{-1}$ (phase 14) in surface level. The phase 18 had the highest (30.13$\mu g\ g^{-1}$) and phase 14 had the lowest averages (12.45$\mu g\ g^{-1}$) in subsurface layer.

While classifying these samples by critical range evaluation, all of them in both surface and subsurface layer were under above critical range (Table 14). The critical level for iron is 0.3-0.5$\mu g g^{-1}$.

4.7. Phosphorus Fixing Capacity

The capacity of soil to fix phosphorus and make unavailable to plant was recorded as high. The phase wise distribution of P fixing capacity of surface and subsurface soil are given in Table 15. It was noticed that there is a little increase in the P fixing capacity from surface layer to subsurface samples. The range was from 36.26 % (phase 4) to 69.53% (phase 30) for surface samples. In he case of subsurface level, the recorded highest value was in phase 33 with 78.75% and the minimum value as 40.9% in phase 6.

The mean value of phases was seen in the range of 50-60% for surface layer and that for subsurface was 55-65%. The phase 2 and phase 15 were having maximum for surface (61.45%) and subsurface (70.13%) respectively. Among the subsurface samples, the minimum percentage for both surface (39.41%) and subsurface (51.95%) were recorded in the same phase (phase 4).

4.8. Exchangeable Cations

The content of exchangeable cations namely calcium, magnesium, sodium, potassium, iron and manganese were estimated using 0.1M $BaCl_2$ extract and presented in Table 16. The phase wise distribution of exchangeable cations in subsurface layer is presented in Table 17. The concentration of exchangeable cations (Ca, Mg, Na and K) extracted by 1N ammonium acetate was estimated and compared with that of 0.1M $BaCl_2$ (Table 18 & 19).

Table 15. P - Fixing Capacity of the soils in the western part of the main camp, KAU (%)

Sl. No.	Phase No		Surface samples	Subsurface samples	Sl. No.	Phase No		Surface samples	Subsurface samples
		Mean	53.53	57.11			Mean	60.48	68.49
1	1	Range	49.19 - 57.87	48.18 - 67.45	12	19	Range	56.74 - 66.93	66.04 - 71.23
		Mode	53.53	57.11			Mode	60.48	68.49
		Mean	61.45	61.88			Mean	58.11	65.20
2	2	Range	59.56 - 63.54	55.71 - 69.23	13	20	Range	53.71 - 62.5	61.99 - 68.41
		Mode	61.45	61.88			Mode	58.11	65.20
		Mean	39.41	51.95			Mean	59.50	63.15
3	4	Range	36.26 - 42.56	49.65 - 54.25	14	22	Range	52.58 - 65.94	56.7 - 70.43
		Mode	39.41	51.95			Mode	59.50	63.15
		Mean	52.47	54.36			Mean	49.00	58.38
4	6	Range	43.02 - 62.15	40.90 - 64.86	15	24	Range	41.35 - 55.95	57.28 - 60.45
		Mode	52.47	54.36			Mode	49.00	58.38
		Mean	55.46	67.36			Mean	54.87	61.33
5	7	Range	51.60 - 59.32	65.47 - 69.24	16	27	Range	52.37 - 57.37	61.07 - 61.58
		Mode	55.46	67.36			Mode	54.87	61.33
		Mean	56.66	65.28			Mean	53.03	60.40
6	13	Range	42.67 - 65.80	59.83 - 71.40	17	28	Range	51.87 - 54.88	58.49 - 62.47
		Mode	56.66	65.28			Mode	53.03	60.40
		Mean	58.95	58.38			Mean	60.85	60.98
7	14	Range	55.41 - 62.49	54.66 - 62.09	18	30	Range	47.53 - 69.53	52.06 - 68.30
		Mode	58.95	58.38			Mode	60.85	60.98
		Mean	57.49	70.13	19	31	Mean	61.50	65.87
8	15	Range	55.68 - 59.30	69.01 - 71.25			Mean	59.26	66.31
		Mode	57.49	70.13	20	32	Range	56.24 - 62.35	62.54 - 71.58
		Mean	55.23	61.64			Mode	59.26	66.31
9	16	Range	48.36 - 63.89	53.54 - 72.19			Mean	54.22	68.03
		Mode	55.23	61.64	21	33	Range	49.57 - 59.70	61.32 - 78.79
		Mean	56.75	52.50			Mode	54.22	68.03
10	17	Range	51.76 - 61.12	41.76 - 58.22			Mean	54.02	56.02
		Mode	56.75	52.50	22	34	Range	51.23 - 56.8	50.63 - 61.41
		Mean	57.64	57.80			Mode	54.02	56.02
11	18	Range	52.47 - 62.81	57.20 - 58.40			Mean	56.61	69.35
		Mode	57.64	57.80	23	37	Range	51.84 - 61.38	63.40- 75.30
							Mode	56.61	69.35

4.8.1. Exchangeable Calcium

Calcium is the divalent cation, which contributes the maximum amount in the total amount of exchangeable cations in the surface level. The highest content in the surface level was observed as 493μg g^{-1} and lowest as 12μg g^{-1} in phases 7 and 16, respectively. Among the subsurface samples, the highest value was recorded in the phase 27

Table 16. Concentration of Exchangeable Cations in Surface Soils of the western part of the main campus, KAU ($\mu g\ g^{-1}$)

Sl. No	Soil Phase No		Exch. Fe	Exch. Mn	Exch. Ca	Exch. Mg	Exch. Na	Exch. K	Exch. Al
1	1	Mean	2.51	112.57	166.81	51.07	110.75	71.00	58.25
		Range	1.40 - 4.90	21.10 - 221.10	61.00 - 328.00	18.30 - 79.80	66.00 - 144.00	46.00 - 92.00	34.25 - 96.38
		Mode	2.30	112.57	166.81	51.07	114.00	70.00	58.25
2	2	Mean	2.14	104.92	166.46	51.18	110.62	64.92	43.83
		Range	1.20 - 3.00	45.50 - 196.60	97.00 - 224.00	33.50 - 65.60	70.00 - 186.00	38.00 - 84.00	32.50 - 53.50
		Mode	2.10	104.92	166.46	51.18	116.00	64.00	43.83
3	4	Mean	1.88	151.20	285.00	74.82	115.20	81.60	38.25
		Range	1.70 - 2.30	62.70 - 279.90	162.00 - 393.00	44.60 - 99.30	104.00 - 130.00	72.00 - 90.00	13.13 - 64.75
		Mode	1.88	151.20	285.00	74.82	115.20	81.60	38.25
4	6	Mean	2.12	138.09	212.89	67.08	132.37	95.37	38.30
		Range	1.30 - 3.70	47.20 - 261.20	50.00 - 447.00	19.00 - 101.50	94.00 - 178.00	60.00 - 158.00	8.75 - 70.25
		Mode	2.10	191.90	228.00	61.40	116.00	78.00	38.38
5	7	Mean	1.94	185.68	387.60	88.18	169.60	93.60	24.35
		Range	1.70 - 2.40	137.00 - 235.80	269.00 - 493.00	65.60 - 114.00	114.00 - 234.00	70.00 - 110.00	15.50 - 36.50
		Mode	1.80	185.68	387.60	88.18	169..60	93.60	24.35
6	13	Mean	2.40	110.96	186.41	61.46	152.56	109.38	44.34
		Range	3.60 - 5.31	43.60 - 200.00	19.00 - 460.00	13.60 - 125.60	100.00 - 238.00	68.00 - 242.00	7.88 - 90.38
		Mode	2.30	110.96	186.41	72.00	172.00	98.00	44.34
7	14	Mean	2.40	63.65	319.75	93.45	153.00	83.00	8.53
		Range	2.20 - 2.60	45.40 - 97.60	281.00 - 345.00	84.40 - 102.50	134.00 - 164.00	72.00 - 98.00	5.50 - 14.00
		Mode	2.40	63.65	319.75	93.45	153.00	83.00	8.53
8	15	Mean	2.84	99.91	88.33	36.39	140.22	95.11	44.69
		Range	2.20 - 4.00	40.00 - 139.80	38.00 - 287.00	16.60 - 62.00	110.00 - 206.00	76.00 - 110.00	15.00 - 54.50
		Mode	2.84	99.91	88.33	36.39	166.00	110.00	44.69
9	16	Mean	2.76	120.47	188.28	61.88	131.11	91.00	36.08
		Range	1.50 - 9.80	65.00 - 182.70	12.00 - 420.00	10.80 - 96.50	112.00 - 150.00	60.00 - 146.00	1.25 - 72.38
		Mode	1.70	97.80	188.28	61.88	134.00	82.00	36.08
10	17	Mean	2.26	112.08	190.59	63.77	141.41	107.76	42.40
		Range	1.20 - 3.70	45.10 - 162.80	37.00 - 378.00	16.00 - 103.70	84.00 - 232.00	50.00 - 172.00	15.63 - 66.88
		Mode	1.60	112.08	154.00	66.70	176.00	100.00	15.63
11	18	Mean	1.80	135.63	291.33	65.30	107.33	74.67	41.08
		Range	1.60 - 2.20	60.50 - 248.00	154.00 - 367.00	54.60 - 83.70	86.00 - 150.00	56.00 - 108.00	38.88 - 44.75
		Mode	1.80	135.63	291.33	65.30	86.00	74.67	41.08

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

Table 16. Concentration of Exchangeable Cations in Surface Soils of western part of the main campus ($\mu g\ g^{-1}$) (....Continued)

Sl. No.	Soil Phase No.		Exch. Fe	Exch. Mn	Exch. Ca	Exch. Mg	Exch. Na	Exch. K	Exch. Al
12	19	Mean	2.39	116.06	213.53	74.40	149.18	111.29	32.99
		Range	1.50 - 3.70	71.10 - 204.50	98.00 - 286.00	52.60 - 105.40	110.00 - 200.00	64.00 - 156.00	5.75 - 52.25
		Mode	1.50	116.06	213.53	74.40	118.00	124.00	32.99
13	20	Mean	2.90	106.64	241.63	70.09	142.25	100.50	28.52
		Range	0.90 - 3.90	69.40 - 144.90	99.00 - 339.00	33.70 - 110.70	122.00 - 172.00	62.00 - 150.00	2.00 - 84.50
		Mode	2.90	106.64	241.63	70.09	150.00	100.50	28.52
14	22	Mean	2.78	91.89	235.35	82.02	160.17	114.78	28.14
		Range	1.80 - 5.60	9.20 - 181.70	85.00 - 350.00	48.00 - 124.80	96.00 - 206.00	60.00 - 216.00	6.00 - 69.63
		Mode	2.90	91.89	235.35	67.90	142.00	98.00	28.14
15	24	Mean	2.26	101.45	294.75	85.18	188.25	157.00	21.08
		Range	1.90 - 2.50	67.10 - 151.90	230.00 - 393.00	63.10 - 101.80	120.00 - 240.00	96.00 - 224.00	6.88 - 39.25
		Mode	2.90	101.45	298.00	67.90	142.00	98.00	10.63
16	27	Mean	2.08	208.78	251.00	62.42	137.60	95.20	49.03
		Range	1.50 - 2.40	82.10 - 283.30	108.00 - 396.00	42.60 - 84.80	114.00 - 154.00	80.00 - 126.00	27.63 - 70.13
		Mode	2.40	208.78	251.00	62.42	154.00	80.00	49.03
17	28	Mean	2.78	89.70	222.00	66.83	138.25	91.75	22.81
		Range	2.20 - 3.40	60.90 - 165.00	168.00 - 272.00	55.70 - 76.00	126.00 - 154.00	84.00 - 102.00	8.38 - 38.88
		Mode	2.78	89.70	222.00	66.83	138.00	84.00	22.81
18	30	Mean	3.54	104.98	304.80	72.48	133.20	106.40	27.65
		Range	1.70 - 9.90	73.60 - 144.50	190.00 - 440.00	30.50 - 113.00	102.00 - 156.00	78.00 - 132.00	7.50 - 47.63
		Mode	1.70	104.98	304.80	72.48	133.20	106.40	27.65
19	31	Mean	2.70	72.90	330.00	68.50	132.00	86.00	2.88
20	32	Mean	3.23	92.06	233.80	72.26	169.40	115.00	24.10
		Range	2.30 - 6.30	40.80 - 170.60	88.00 - 364.00	31.60 - 96.90	128.00 - 228.00	84.00 - 158.00	6.50 - 39.63
		Mode	2.70	92.06	233.80	72.26	169.40	122.00	29.50
21	33	Mean	2.21	68.58	276.30	78.00	159.80	120.20	22.66
		Range	1.40 - 3.40	36.00 - 124.20	105.00 - 454.00	36.50 - 108.70	108.00 - 196.00	76.00 - 176.00	6.13 - 40.50
		Mode	2.00	68.58	332.00	78.00	196.00	130.00	22.66
22	34	Mean	2.50	71.10	209.00	68.70	134.00	91.00	36.00
		Range	1.70 - 3.30	51.00 - 91.20	148.00 - 270.00	61.40 - 76.00	120.00 - 148.00	80.00 - 102.00	20.88 - 51.13
		Mode	2.50	71.10	209.00	68.70	134.00	91.00	36.00
23	37	Mean	2.30	69.40	209.00	66.85	188.00	133.00	45.94
		Range	2.20 - 2.40	67.60 - 71.20	203.00 - 215.00	65.60 - 68.10	180.00 - 196.00	120.00 - 146.00	41.38 - 50.50
		Mode	2.30	69.40	209.00	66.85	188.00	133.00	45.94

Table 17. Concentration of Exchangeable Cations in Subsurface Soil of the western part of the main campus, KAU ($\mu g\ g^{-1}$)

Sl. No	Soil Phase No.		Exch. Fe	Exch. Mn	Exch. Ca	Exch. Mg	Exch. Na	Exch. K	Exch. Al
1	1	Mean	3.04	111.56	145.63	50.31	117.25	66.75	57.02
		Range	1.40 - 7.10	17.90 - 247.00	37.00 - 354.00	10.80 - 74.40	68.00 - 216.00	44.00 - 94.00	20.50 - 113.75
		Mode	1.80	17.90	145.63	50.31	120.00	56.00	57.02
2	2	Mean	1.96	90.21	132.38	46.25	99.23	60.92	43.69
		Range	1.50 - 2.40	37.90 - 167.80	46.00 - 242.00	17.50 - 69.80	68.00 - 132.00	40.00 - 84.00	11.13 - 56.00
		Mode	2.40	90.21	132.38	46.25	96.00	76.00	43.69
3	4	Mean	3.04	191.50	307.40	76.14	118.00	75.60	37.83
		Range	1.90 - 5.10	112.20 - 324.80	164.00 - 361.00	49.80 - 88.80	112.00 - 130.00	70.00 - 78.00	14.00 - 66.50
		Mode	2.40	191.50	307.40	76.14	96.00	76.00	37.83
4	6	Mean	2.29	139.16	203.74	64.95	137.74	91.37	40.79
		Range	1.10 - 5.10	13.80 - 292.60	66.00 - 443.00	25.40 - 139.70	100.00 - 196.00	54.00 - 148.00	11.13 - 85.75
		Mode	2.10	155.70	120.00	69.00	138.00	66.00	37.63
5	7	Mean	2.02	168.60	359.80	88.40	153.20	87.60	25.65
		Range	1.80 - 2.20	53.20 - 252.60	129.00 - 488.00	75.70 - 121.80	122.00 - 184.00	72.00 - 96.00	12.38 - 41.25
		Mode	2.10	155.70	120.00	69.00	138.00	66.00	37.63
6	13	Mean	2.80	118.00	207.03	57.69	150.63	104.31	42.75
		Range	1.50 - 10.60	12.50 - 205.00	23.00 - 490.00	10.10 - 96.60	110.00 - 244.00	68.00 - 304.00	15.13 - 71.25
		Mode	2.00	115.60	207.03	62.50	198.00	70.00	48.50
7	14	Mean	2.98	71.28	299.50	90.05	151.50	84.00	7.84
		Range	2.20 - 4.30	38.40 - 105.20	258.00 - 322.00	79.30 - 99.10	138.00 - 166.00	72.00 - 104.00	4.88 - 12.63
		Mode	2.70	71.28	299.50	90.05	151.50	84.00	7.84
8	15	Mean	2.73	115.79	100.89	36.63	143.78	96.67	44.03
		Range	2.40 - 3.30	59.20 - 154.20	44.00 - 189.00	18.00 - 59.30	110.00 - 184.00	72.00 - 112.00	26.25 - 63.63
		Mode	2.40	115.79	100.89	36.63	143.78	102.00	44.03
9	16	Mean	2.45	116.40	154.50	58.03	143.11	104.33	41.59
		Range	1.50 - 3.70	57.40 - 242.00	12.00 - 388.00	10.90 - 137.90	98.00 - 244.00	70.00 - 190.00	2.88 - 79.63
		Mode	1.70	93.80	154.50	58.03	140.00	76.00	42.75
10	17	Mean	2.54	103.98	175.00	60.02	141.18	101.53	43.08
		Range	1.30 - 6.80	44.90 - 184.40	30.00 - 330.00	16.80 - 79.70	72.00 - 224.00	54.00 - 158.00	8.88 - 80.13
		Mode	2.70	103.98	175.00	60.02	174.00	142.00	43.08
11	18	Mean	1.67	95.03	229.33	59.83	121.33	80.67	46.46
		Range	1.60 - 1.70	41.30 - 124.70	135.00 - 391.00	19.10 - 90.00	86.00 - 150.00	54.00 - 106.00	36.38 - 64.38
		Mode	1.70	95.03	229.33	59.83	121.33	80.67	46.46

(Continued ....)

Table 17. Concentration of Exchangeable Cations in Subsurface Soil of the western part of the main campus ($\mu g\ g^{-1}$) (...Continued)

Sl. No	Soil Phase No.		Exch. Fe	Exch. Mn	Exch. Ca	Exch. Mg	Exch. Na	Exch. K	Exch. Al
12	19	Mean	2.53	116.13	203.06	68.39	143.53	103.41	35.60
		Range	1.80 - 3.40	61.30 - 181.90	117.00 - 383.00	43.70 - 97.70	104.00 - 188.00	60.00 - 160.00	14.38 - 53.63
		Mode	2.60	85.80	203.06	68.39	176.00	90.00	35.60
13	20	Mean	3.08	101.61	204.63	64.15	125.25	76.00	39.52
		Range	2.20 - 4.50	60.10 - 153.80	86.00 - 290.00	42.00 - 78.90	106.00 - 150.00	60.00 - 100.00	12.50 - 73.50
		Mode	3.40	101.61	204.63	64.15	125.25	62.00	39.52
14	22	Mean	2.55	95.67	236.83	77.44	163.13	112.78	30.29
		Range	1.80 - 3.70	16.80 - 203.90	70.00 - 333.00	32.00 - 127.90	104.00 - 322.00	62.00 - 188.00	2.00 - 63.38
		Mode	2.90	95.67	264.00	79.00	142.00	144.00	30.29
15	24	Mean	2.74	83.20	234.88	75.31	190.00	149.00	30.38
		Range	1.70 - 5.30	24.10 - 154.40	103.00 - 326.00	37.20 - 103.00	136.00 - 230.00	118.00 - 188.00	4.13 - 51.75
		Mode	2.80	83.20	234.88	75.31	182.00	149.00	30.38
16	27	Mean	2.20	173.60	288.60	66.72	138.80	101.20	34.75
		Range	1.60 - 2.80	120.60 - 240.30	119.00 - 492.00	37.20 - 109.40	106.00 - 172.00	66.00 - 164.00	4.00 - 51.63
		Mode	2.20	173.60	288.60	66.72	138.80	101.20	34.75
17	28	Mean	2.68	96.44	191.88	58.24	136.00	100.00	25.36
		Range	2.30 - 3.10	40.10 - 188.30	112.00 - 272.00	47.60 - 69.60	112.00 - 150.00	82.00 - 114.00	15.63 - 32.38
		Mode	2.90	96.44	191.88	58.24	132.00	108.00	25.36
18	30	Mean	2.08	84.14	290.20	83.00	145.20	103.20	30.98
		Range	1.60 - 2.70	45.60 - 147.20	194.00 - 379.00	47.40 - 121.40	132.00 - 152.00	82.00 - 126.00	22.75 - 40.75
		Mode	2.08	84.14	290.20	83.00	150.00	96.00	30.98
19	31	Mean	2.40	72.40	151.00	49.20	150.00	110.00	29.00
20	32	Mean	2.68	89.68	287.50	71.96	166.40	111.20	24.04
		Range	1.50 - 3.50	39.80 - 182.90	205.00 - 369.00	36.20 - 112.30	132.00 - 228.00	82.00 - 172.00	3.75 - 62.50
		Mode	2.68	89.68	290.00	71.96	160.00	100.00	24.04
21	33	Mean	2.65	64.17	274.10	72.98	155.20	116.60	30.36
		Range	2.00 - 4.30	38.00 - 107.90	84.00 - 443.00	54.10 - 98.40	96.00 - 172.00	68.00 - 162.00	7.38 - 46.75
		Mode	2.40	64.17	274.10	78.20	170.00	116.60	30.36
22	34	Mean	3.15	68.70	215.00	66.00	127.00	70.00	44.06
		Range	3.00 - 3.30	46.10 - 91.30	168.00 - 262.00	65.30 - 66.70	106.00 - 148.00	50.00 - 90.00	35.50 - 52.63
		Mode	3.15	68.70	215.00	66.00	127.00	70.00	44.06
23	37	Mean	2.30	63.50	229.50	78.40	198.00	111.00	37.75
		Range	2.10 - 2.50	54.60 - 72.40	206.00 - 253.00	75.60 - 81.20	174.00 - 222.00	94.00 - 128.00	24.75 - 50.75
		Mode	2.30	63.50	229.50	78.40	198.00	111.00	37.75

with 492 μg g^{-1} and the lowest value was in the phase 16 with 12μg g^{-1}(Table 17). The minimum content in both surface and subsurface layers was seen in the same phase (phase 6). With respect to phase wise mean values, the highest values for surface (387.6μg g^{-1}) and subsurface (359.8μg g^{-1}) were recorded in the same phase (phase 7). Similarly, phase 15 was included the lowest average for both surface (88.33μg g^{-1}) and subsurface (100.89μg g^{-1}) samples.

Table 18. Comparison of cations (me) extracted by 1N Ammonium acetate & 0.1M $BaCl_2$ extracts (Surface samples)

Sl. No	Phase No.	Neutral Normal Ammonium acetate extract				0.1M $BaCl_2$ extract			
		Av. Ca	Av. Mg	Av. Na	Av. K	Ex. Ca	Ex. Mg	Ex. Na	Ex. K
1	1	0.28	0.21	0.10	0.11	0.83	0.42	0.48	0.18
2	2	0.29	0.19	0.10	0.10	0.83	0.42	0.48	0.17
3	4	0.45	0.25	0.13	0.13	1.42	0.62	0.50	0.21
4	6	0.36	0.22	0.10	0.11	1.06	0.55	0.58	0.24
5	7	0.70	0.26	0.79	0.09	1.93	0.73	0.74	0.24
6	13	0.50	0.22	0.09	0.13	0.93	0.51	0.66	0.28
7	14	1.54	0.32	0.21	0.12	1.60	0.77	0.67	0.21
8	15	0.23	0.15	0.06	0.22	0.44	0.30	0.61	0.24
9	16	0.38	0.20	0.08	0.11	0.94	0.51	0.57	0.23
10	17	0.50	0.24	0.10	0.13	0.95	0.52	0.62	0.28
11	18	0.32	0.22	0.22	0.07	1.45	0.54	0.47	0.19
12	19	0.60	0.26	0.11	0.17	1.07	0.61	0.65	0.28
13	20	0.86	0.28	0.13	0.16	1.21	0.58	0.62	0.26
14	22	0.91	0.27	0.11	0.16	1.17	0.68	0.70	0.29
15	24	1.20	0.29	0.13	0.20	1.47	0.70	0.82	0.40
16	27	0.39	0.21	0.14	0.12	1.25	0.51	0.60	0.24
17	28	0.49	0.24	0.09	0.19	-1.11	0.55	0.60	0.23
18	30	0.50	0.22	0.11	0.14	1.52	0.60	0.58	0.27
19	31	0.94	0.26	0.15	0.22	1.65	0.56	0.57	0.22
20	32	0.80	0.24	0.12	0.16	1.17	0.59	0.74	0.29
21	33	0.74	0.25	0.13	0.17	1.38	0.64	0.70	0.31
22	34	0.63	0.27	0.12	0.17	1.04	0.57	0.58	0.23
23	37	0.72	0.24	0.09	0.06	1.04	0.55	0.82	0.34

4.8.2. Exchangeable Magnesium

It was seen that exchangeable magnesium had a wide range of 10 – 125.6 μg g^{-1} in surface layer. The most of phases were having a mean value in the range of 50-70 μg g^{-1}. The maximum content was recorded in the phase 13 with 125.6 μg $g^{-1}$and the minimum content in the phase 16 with 10.8μg g^{-1} in the surface layer (Table16). Among the subsurface samples, the lowest content of 10.1μg g^{-1} and the highest content of 139.7μg g^{-1} were recorded in the phases 13 and 6 respectively (Table 17). While looked into the phase wise mean values, the highest values for surface (93.45μg g^{-1}) and subsurface (90.05μg g^{-1}) were recorded in the same phase (phase14). Likewise, phase 37 was having the lowest average for both surface (36.39μg g^{-1}) and subsurface (36.63μg g^{-1}) samples.

Table 19. Comparison of cations (me) extracted by 1N Ammonium acetate & 0.1M $BaCl_2$ extracts (Subsurface samples)

Sl. No	Phase No	1N Ammonium acetate extract				0.1M $BaCl_2$ extract			
		Av. Ca	Av. Mg	Av. Na	Av. K	Ex. Ca	Ex. Mg	Ex. Na	Ex. K
1	1	0.31	0.18	0.12	0.09	0.73	0.41	0.51	0.17
2	2	0.26	0.19	0.09	0.08	0.66	0.38	0.43	0.16
3	4	0.44	0.25	0.14	0.11	1.53	0.63	0.51	0.19
4	6	0.37	0.21	0.10	0.09	1.02	0.53	0.60	0.23
5	7	0.66	0.25	0.12	0.07	1.80	0.73	0.67	0.22
6	13	0.39	0.20	0.10	0.10	1.03	0.47	0.66	0.27
7	14	1.44	0.30	0.23	0.14	1.49	0.74	0.66	0.21
8	15	0.24	0.13	0.06	0.13	0.50	0.30	0.63	0.25
9	16	0.35	0.19	0.08	0.11	0.77	0.48	0.62	0.27
10	17	0.52	0.22	0.09	0.13	0.87	0.49	0.61	0.26
11	18	0.27	0.19	0.06	0.06	1.14	0.49	0.53	0.21
12	19	0.54	0.23	0.10	0.14	1.01	0.56	0.62	0.26
13	20	0.87	0.26	0.11	0.09	1.02	0.53	0.54	0.19
14	22	0.89	0.26	0.13	0.15	1.18	0.64	0.71	0.29
15	24	0.85	0.25	0.10	0.16	1.17	0.62	0.83	0.38
16	27	0.48	0.21	0.14	0.15	1.44	0.55	0.60	0.26
17	28	0.42	0.23	0.09	0.16	0.96	0.48	0.59	0.26
18	30	0.70	0.22	0.11	0.12	1.45	0.68	0.63	0.26
19	31	0.31	0.21	0.07	0.18	0.75	0.40	0.65	0.28
20	32	0.79	0.24	0.12	0.17	1.43	0.59	0.72	0.28
21	33	0.85	0.23	0.11	0.18	1.37	0.60	0.68	0.30
22	34	0.57	0.25	0.12	0.13	1.07	0.54	0.55	0.18
23	37	1.20	0.28	0.14	0.09	1.15	0.65	0.86	0.28

4.8.3. Exchangeable Sodium

Among the mean values of phases, most of them were in the range of 100-150 μg g^{-1}. When surface samples were analysed, the highest content of sodium as 240μg g^{-1} in phase 24 and the lowest level in phase 1 with a value of 66μg g^{-1} were recorded (Table

16). While examining the data of subsurface samples, there also a wide range and a high content of sodium were obtained. The lowest value of 68μg g^{-1} was recorded in both and phases 1 and 2. The highest quantity was obtained in phase 22 with a value of 322μg g^{-1}.

The lowest mean values for surface (107.33μg g^{-1}) and subsurface (99.23μg g^{-1}) layers, were recorded in phase 18 and phase 2,respectively. But, phase 37 was having the highest average for both surface (188μg g^{-1}) and subsurface (198μg g^{-1}) samples.

4.8.4. Exchangeable Potassium

The highest value for exchangeable potassium in the surface samples was obtained as 242 μg g^{-1} in the phase 13 and lowest value was in the phase 2 with 38μg g^{-1} (Table 16). In the case of subsurface layer, 40μg g^{-1} is the minimum and 304μg g^{-1} is the maximum of recorded values. In subsurface level, the lowest value for sodium and potassium was in the same phase (Table 17).

Among the mean values of different phases, it was seen that both the maximum and minimum values were recorded in the same phases in both layers. However, in the phase wise mean values, the highest values for surface (157μg g^{-1}) and subsurface (149μg g^{-1}) were obtained in the same phase(phase 24). In a similar manner, phase 2 had the lowest average for both surface (64.92μg g^{-1}) and subsurface(60.92μg g^{-1}).

4.8.5. Exchangeable Iron

The iron content in the surface level varies from 0.9μg g^{-1} to 9.9 μg g^{-1}. There was no significant variation in subsurface content from that of surface. The majority of mean values of phases were obtained in the range of 2-3.5μg g^{-1}. The highest value of surface level was in phase 30 and lowest value in phase 20 (Table 16). Among the obtained data on subsurface samples, the maximum and the minimum were 1.1μg g^{-1} in phase 6 and 10.6μg g^{-1}in phase 13 respectively (Table 17).

As far as the phase wise mean values are considered, the lowest values for surface (1.8μg g^{-1}) and subsurface (1.67μg g^{-1}) were noted in the same phase(phase18). The highest average for surface and subsurface were estimated in phase 30 (3.54μg g^{-1}) and phase 34 (3.15μg g^{-1}) respectively.

4.8.6. Exchangeable Manganese

The data on analysis of surface samples revealed that exchangeable manganese content were high. It would vary in surface layer from 9.2 μg g^{-1} in phase 22 to 283.3 μg g^{-1} in phase 27 (Table 16). In subsurface samples, the minimum content was in phase 13 with a value of 12.5 and maximum was in phase 4 with a value of 324.8 μg g^{-1} (Table 17).

Further, the highest phase average was recorded as 208.78μg g^{-1} (phase 27) and the lowest as 63.65μg g^{-1} (phase 14) in surface level. In subsurface layer, the maximum (191.5μg g^{-1}) and minimum (63.5μg g^{-1}) values were obtained in the phases 4 and 37 respectively.

4.8.7. Exchangeable Aluminium

The amount of exchangeable aluminium in the surface soil ranges from 1.25 μg g^{-1} to 96.38 μg g^{-1}. The highest content was recorded in the phase 1 and the lowest content was in phase 16 in surface layer (Table 16). The minimum quantity was obtained in the phase, which is having the lowest content of calcium and magnesium. Among the subsurface layer the range was still wider (Table 17). As in the surface level, phase 1 was having the maximum amount with a value of 113.75 μg g^{-1}. The lowest content was recorded with a value of 2 μg g^{-1} in phase 22 where the sodium content was highest.

The biggest and smallest mean values were recorded in same phases both in the case of surface and subsurface levels. The recorded smallest mean values for surface and subsurface were 8.53 and 7.84μg g^{-1} respectively in phase 14. The highest mean values were recorded as 58.25 and 57.02 μg g^{-1} in the phase 1 for surface and subsurface respectively.

4.9. Cation Exchange Capacity (CEC)

For determining cation exchange capacity of soil samples, 0.1M $BaCl_2$ extract was used. Seven cations were quantified from this extract and estimated the CEC for surface and subsurface separately. The phase wise distribution of CEC in both layers is presented in Table 20.

When the CEC of surface samples were estimated, majority of samples were in the range of 2.5 - 3.5 cmol(+) kg^{-1} of soil. The 50% of phase values show no significant variation in subsurface level than from surface level. But 20% showed an increase in the capacity. In surface layer, the highest value recorded was 5.59 cmol(+) kg^{-1} in phase 7 and lowest value was 1.67 cmol(+) kg^{-1} in the phase 16. While considering the mean value of phases, the largest mean was in phase 7 with 4.59 cmol(+) kg^{-1} and the smallest average in 15 with 2.47 cmol(+) kg^{-1}.

Among the subsurface samples, the minimum value was 1.64 cmol(+) kg^{-1} in phase 16 and maximum value in phase 27 with 5.22 cmol(+) kg^{-1}. Here also highest mean (4.32 cmol(+) kg^{-1}) was obtained in the same phase as in the surface layer. The lowest mean was in phase 2 with a value of 2.45 cmol(+) kg^{-1}.

4.10. Cation saturation

The data on exchangeable cations were used to calculate the cation saturation like sodium saturation, aluminium saturation and base saturation percentage and presented in Table 20.

4.10.1. Percentage Base Saturation

Base saturation percentage was estimated by calculating the percentage of total quantity of exchangeable calcium, magnesium, sodium and potassium to the Cation Exchange Capacity. The results of surface sample analysis revealed that the highest BSP was recorded in phase 33 with a value of 94.58% and lowest was 41.86% in phase 1. While looking into phase wise mean values, the minimum (63.19%) and maximum (90.66%) were obtained in phase 15 and 14 respectively. In subsurface layer, the highest

Table 20. Exchange Capacity and Cation Saturation of Soil of the western part of the main campus, KAU

Sl. No.	Soil Phase No.		Surface CEC Cmol(+) kg^{-1}	Surface Sodium sat. %	Surface PBS %	Surface Al sat. %	Subsurface CEC cmol(+) kg^{-1}	Subsurface Na sat. %	Subsurface PBS %	Subsurface Al sat. %
1	1	Mean	2.98	16.31	63.85	22.33	2.87	18.13	62.66	22.86
		Range	2.06 - 4.14	12.20 - 22.70	41.87 - 76.01	10.99 - 38.97	2.11 - 3.95	12.97 - 33.02	35.52 - 82.34	6.08 - 44.16
		Mode	2.98	16.00	68.00	18.00	2.87	14.00	69.00	24.00
2	2	Mean	2.78	17.34	68.12	17.92	2.45	18.28	66.23	20.19
		Range	2.01 - 3.29	12.98 - 29.38	53.77 - 77.46	11.80 - 24.85	1.65 - 3.27	12.42 - 27.46	55.89 - 79.51	7.51 - 32.76
		Mode	2.78	15.00	77.00	16.00	2.45	19.00	64.00	22.00
3	4	Mean	3.73	13.61	72.90	12.31	4.00	13.02	71.41	11.46
		Range	2.99 - 4.51	11.58 - 16.00	60.51 - 85.63	3.24 - 24.03	3.10 - 4.62	11.36 - 15.73	61.86 - 79.23	3.37 - 23.88
		Mode	3.73	12.00	72.90	12.31	4.00	13.00	71.41	11.46
4	6	Mean	3.37	17.43	71.30	13.31	3.35	18.17	70.12	14.21
		Range	1.79 - 5.20	12.80 - 34.42	51.01 - 89.47	2.43 - 23.98	2.25 - 5.19	14.60 - 28.48	51.78 - 88.98	3.52 - 28.76
		Mode	3.37	17.00	64.00	10.00	3.35	17.00	81.00	15.00
5	7	Mean	4.59	15.88	78.75	6.27	4.32	15.81	78.48	7.26
		Range	3.67 - 5.59	12.43 - 18.21	75.54 - 85.32	3.21 - 10.18	2.90 - 5.03	12.06 - 21.28	73.08 - 92.99	2.85 - 15.81
		Mode	4.59	18.00	76.00	5.00	4.32	15.81	78.48	7.26
6	13	Mean	3.29	21.11	70.96	16.12	3.35	20.53	71.10	15.44
		Range	2.09 - 5.38	14.72 - 34.10	51.33 - 88.63	2.52 - 30.65	2.04 - 5.19	11.90 - 33.00	50.31 - 90.65	3.81 - 31.45
		Mode	3.29	15.00	70.00	10.00	3.35	17.00	79.00	10.00
7	14	Mean	3.58	18.60	90.66	2.74	3.47	19.00	89.72	2.60
		Range	3.2 - 3.94	18.10 - 19.39	89.23 - 92.68	1.55 - 4.86	3.13 - 3.76	18.51 - 19.24	88.14 - 92.70	1.43 - 4.49
		Mode	3.58	19.00	90.66	2.00	3.47	19.00	88.00	2.60
8	15	Mean	2.47	24.99	63.19	21.62	2.60	24.12	63.76	19.39
		Range	1.69 - 3.79	21.92 - 30.94	53.06 - 82.20	4.39 - 27.90	2.03 - 3.16	18.96 - 30.68	53.12 - 77.52	9.23 - 28.69
		Mode	2.47	24.99	63.19	21.62	2.60	24.00	60.00	19.00
9	16	Mean	3.10	19.52	71.20	13.75	3.03	21.51	68.47	16.85
		Range	1.67 - 4.57	12.25 - 29.72	49.99 - 89.21	0.42 - 28.09	1.64 - 4.88	15.15 - 30.68	51.85 - 84.18	0.66 - 34.33
		Mode	3.10	18.00	76.00	11.00	3.03	23.00	53.00	7.00
10	17	Mean	3.26	19.02	72.02	15.08	3.11	19.92	71.50	15.82
		Range	2.55 - 4.18	12.33 - 29.51	57.09 - 89.78	4.16 - 28.67	2.47 - 4.14	10.96 - 28.60	55.55 - 92.23	3.30 - 31.20
		Mode	3.26	17.00	65.00	17.00	3.11	20.00	59.00	3.00
11	18	Mean	3.61	12.95	73.15	13.61	3.24	16.63	70.93	18.44
		Range	2.61 - 4.72	10.71 - 14.33	66.91 - 80.91	9.16 - 19.07	2.22 - 4.51	14.47 - 18.56	60.64 - 80.28	9.53 - 32.30
		Mode	3.61	14.00	73.15	13.61	3.24	16.63	70.93	18.44

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

Table 20. Exchange Capacity and Cation Saturation of Soil of the western part of the main campus (.............Continued)

Sl. No.	Soil Phase No.		Surface CEC Cmol(+) kg^{-1}	Surface Na sat. %	Surface PBS %	Surface Al sat. %	Sub - Surface CEC cmol(+) kg^{-1}	Sub - Surface Na sat. %	Sub - Surface PBS %	Sub - Surface Al sat. %
12	19	Mean	3.41	19.00	76.43	10.90	3.29	18.93	74.40	12.51
		Range	2.74 - 4.19	15.93 - 23.51	60.90 - 88.78	2.05 - 19.07	2.73 - 4.39	15.82 - 24.39	65.20 - 84.88	3.93 - 18.82
		Mode	3.41	17.00	76.00	12.00	3.29	18.00	73.00	18.00
13	20	Mean	3.38	18.49	77.63	10.24	3.11	17.68	72.88	14.77
		Range	2.33 - 3.97	15.95 - 22.75	58.44 - 90.60	0.67 - 28.47	2.32 - 3.63	15.42 - 19.84	60.25 - 88.32	4.16 - 23.08
		Mode	3.38	16.00	73.00	12.00	3.11	18.00	72.88	23.00
14	22	Mean	3.50	20.27	80.87	9.42	3.51	20.51	80.01	9.85
		Range	2.27 - 4.71	10.03 - 34.46	63.03 - 93.97	1.84 - 23.88	2.15 - 5.00	12.27 - 37.16	67.14 - 94.35	0.65 - 19.95
		Mode	3.50	19.00	79.00	14.00	3.51	18.00	76.00	4.00
15	24	Mean	4.01	20.40	84.54	5.95	3.65	22.68	81.41	10.03
		Range	3.52 - 4.47	13.56 - 24.07	78.28 - 91.75	1.97 - 10.34	2.46 - 4.35	20.49 - 24.05	67.59 - 96.09	1.25 - 22.95
		Mode	4.01	24.00	84.00	3.00	3.65	23.00	81.41	10.03
16	27	Mean	3.92	15.84	65.94	14.80	3.88	15.86	71.05	11.74
		Range	2.44 - 4.93	12.16 - 20.29	55.46 - 72.75	6.23 - 21.17	2.62 - 5.22	14.27 - 18.57	59.54 - 86.69	0.85 - 21.06
		Mode	3.92	15.84	65.94	17.00	3.88	14.00	71.05	11.74
17	28	Mean	3.09	19.52	80.86	8.26	2.93	20.27	77.98	9.63
		Range	2.89 - 3.26	17.60 - 21.84	71.85 - 86.17	2.99 - 14.10	2.63 - 3.38	17.58 - 22.51	61.95 - 86.53	5.99 - 12.99
		Mode	3.09	18.00	84.00	6.00	2.96	21.00	77.98	8.00
18	30	Mean	3.67	16.18	80.48	8.48	3.69	17.25	82.02	9.39
		Range	3.11 - 4.54	12.16 - 21.85	70.09 - 89.45	2.55 - 14.52	3.31 - 4.29	14.39 - 19.07	75.63 - 85.92	7.40 - 12.09
		Mode	3.67	13.00	89.00	10.00	3.69	18.00	82.02	10.00
19	31	Mean	3.31	17.32	90.74	0.96	2.69	24.27	77.88	12.00
20	32	Mean	3.41	21.97	81.30	8.84	3.64	19.83	83.27	7.61
		Range	2.15 - 4.37	17.72 - 26.33	70.45 - 89.74	1.66 - 20.53	2.94 - 4.56	16.95 - 22.35	72.73 - 94.54	1.152 - 20.53
		Mode	3.41	18.00	82.00	10.00	3.64	20.00	81.00	7.00
21	33	Mean	3.54	20.06	85.08	7.27	3.53	19.24	83.22	9.94
		Range	1.97 - 4.95	14.42 - 23.83	75.57 - 94.58	1.76 - 11.86	2.56 - 4.34	15.65 - 23.38	71.13 - 90.07	2.19 - 20.31
		Mode	3.54	20.00	83.00	8.00	3.53	16.00	83.00	6.00
22	34	Mean	3.09	18.79	77.76	13.39	3.10	17.70	75.28	16.08
		Range	2.88 - 3.31	18.13 - 19.45	68.50 - 87.02	7.02 - 19.76	2.90 - 3.31	15.93 - 19.46	67.93 - 82.63	11.94 - 20.22
		Mode	3.09	18.79	77.76	13.39	3.10	17.70	75.28	16.08
23	37	Mean	3.52	23.19	78.13	14.47	3.60	24.13	81.86	11.51
		Range	3.44 - 3.61	22.76 - 23.61	77.02 - 79.24	13.38 - 15.56	3.43 - 3.77	20.10 - 28.17	77.81 - 85.91	8.03 - 14.99
		Mode	3.52	23.19	78.13	14.47	3.60	24.13	81.86	11.51

value as 96.09% in phase 24 and the lowest value as 35.52% in phase 1 were recorded. In the case of phase wise mean values, the phases 14 and 1 showed the maximum (89.72%) and the minimum (62.66%) values,respectively. The highest mean values for surface and subsurface layers were obtained in the same phase (Table 20).

4.10.2. Percentage sodium saturation

By calculating the percentage of sodium in CEC, the sodium saturation percentage was obtained. Both the highest and lowest values were in the same phase (phase 22) and the values varied from 10.03 to 34.46% in the surface samples (Table 20). As far as subsurface layer is considered, the maximum was recorded in phase 22 with a value of 37.16% and minimum was 10.96% in phase 17.

While looking into phase wise mean values, the highest value was 24.99% in phase 15 and the lowest was 12.95% in phase 18 for surface samples. Similarly the minimum average (13.02%) and the maximum average (24.13%) were obtained for subsurface layer in phase 4 and 37 respectively.

4.10.3. Percentage Aluminium Saturation

Aluminium saturation percentage is the percentage of aluminium in total quantity of exchangeable ions for the estimation of cation exchange capacity. The results of surface sample analysis revealed that the highest value was recorded with a value of 38.97% in phase 1 and lowest was 0.42% in phase 16 (Table 20). While looking into phase wise mean values, the minimum (2.74%) and maximum (22.33%) were obtained in phase 14 and 1 respectively. In subsurface layer, the highest value (44.15%) in phase 1 and the lowest value (0.64%) in phase 22 were recorded. In the case of phase wise mean values, the phases 1 and 14 showed the maximum (22.86%) and the minimum (2.6%) values respectively.

The highest mean value for both surface (22.33%) and subsurface (22.86%) layers were obtained in the same phase (phase 1). Likewise, the phase 14 had the lowest value for both surface (2.74%) an subsurface (2.6%).

4.11. 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.

4.11.1.Correlation of exchangeable ions with soil parameters

4.11.1.1.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	pH	-0.122	-0.072	-0.131	0.077	0.078	-0.086	
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	0.38*	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	-0.35*	-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*	0.52*	0.468*	0.421*	-0.179	-0.299*	-0.645*

* significant correlation

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.

4.11.1.2.Subsurface samples

Unlike in the case of surface samples, exchangeable potassium of subsurface samples had significant correlation with pH (Table 22).

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	PH	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	0.12	-0.048
3	P-Fix. Cap	0.23*	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*	0.43*	0.04	0.39*	-0.191
7	Na -sat	-0.362*	-0.323*	0.274*	0.13	-0.196*	-0.274*	-0.133
8	Al- sat	-0.649*	-0.621*	-0.612*	-0.43*	0.163	0.195*	0.732*
9	BSP	0.609*	0.558*	0.544*	0.413*	-0.145	-0.228*	-0.616*

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. 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.

4.11.2. Correlation of 0.1M HCl extractable micronutrients and phosphorus fixing capacity with soil parameter

4.11.2.1.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	Iron	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	-0.08	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	0.15	0.034	-0.059	-0.009
10	Exch. Mn	0.41*	-0.024	0.04	0.121	0.021
11	Exch. Al	-0.075	-0.234*	-0.009	0.169	-0.015

4.11.2.2.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	Iron	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	0.04	0.213*
4	Silt (%)	0.158	0.111	0.064	0.2*	0.285*
5	Clay (%)	0.074	-0.02	-0.064	-0.044	0.165
6	Exch. Na	0.028	0.186	-0.097	-0.217*	0.12
7	Exch. K	0.009	0.152	-0.051	-0.169	0.156
8	Exch. Ca	0.137	0.3*	0.054	-0.052	0.23*
9	Exch. Mg	0.035	0.25*	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

4.11.3.Correlation of different ionic ratios with soil parameters

The ratios $K/(Ca+Mg)^{1/2}$, $K/((Mn)^{1/2}+(Al)^{1/3})$, $K/(Ca+Mn)^{1/2}$, $K/((Ca+Mn)^{1/2}+(Al)^{1/3})$ and $K/((Fe+Mn)^{1/2} + (Al)^{1/3})$ and $Na/(Ca+Mg)^{1/2}$, $Na/(Mn+Al)^{1/2}$, $Na/(Ca+Mn)^{1/2}$, $Na/((Ca+Mn)^{1/2} + (Al)^{1/3})$ and $Na/((Fe+Mn)^{1/2} + (Al)^{1/3})$ 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).

4.11.3.1.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:

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

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

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

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

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

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*	0.850*
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*

* significant correlation

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.

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*	.0.1	0.226*	0.555*

* significant correlation

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

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

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

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

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

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

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

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

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

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

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 $K/(Ca+Mg)^{1/2}$, $K/((Mn)^{1/2}+(Al)^{1/3})$ and $K/((Fe+Mn)^{1/2}+(Al)^{1/3})$ both in surface and subsurface soil of which $K/(Ca+Mg)^{1/2}$, 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 $K/((Mn)^{1/2}+(Al)^{1/3})$ and $K/((Fe+Mn)^{1/2}+(Al)^{1/3})$ in surface soil, but failed to get any significant correlation in subsurface soil .

Exchangeable aluminium was having significant negative correlation with $K/((Mn)^{1/2}+(Al)^{1/3})$ and $K/((Fe+Mn)^{1/2}+(Al)^{1/3})$, 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 $K/(Ca+Mg)^{1/2}$ 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.

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

In order to draw a general conclusion 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.

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	-0.290*	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*

- 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)

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*

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

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

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

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

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

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

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

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

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

And for the sub surface samples, the equations are,

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

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

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

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

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

Exchangeable Calcium and exchangeable magnesium gave significant correlation with $\text{Na}/(\text{Ca+Mg})^{1/2}$ (-ve), $\text{Na}/((\text{Mn})^{1/2} + (\text{Al})^{1/3})$ and $\text{Na}/((\text{Fe+Mn})^{1/2} + (\text{Al})^{1/3})$ 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 $Na/(Ca+Mn)^{1/2}$. In subsurface soil exchangeable manganese significantly and positively correlated with $Na/((Mn)^{1/2}+(Al)^{1/3})$ and negatively with $Na/((Fe+Mn)^{1/2}+(Al)^{1/3})$.

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

Exchangeable aluminium gave significant negative correlation with $Na/((Mn)^{1/2}+(Al)^{1/3})$ and $Na/((Fe+Mn)^{1/2}+(Al)^{1/3})$ 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 $Na/(Ca+Mn)^{1/2}$ (0.714 and 0.631,respectively).

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

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

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

The soil fertility maps generated have revealed that the content of different soil fertility parameters in the surface soils of the western part of the campus. From the map, it can be concluded that 165.5 ha, 6.8 ha and 5.3 ha areas are sandy clay loam, sandy clay and clay loam, respectively in the study area (Fig. 4). In the case of organic carbon 7.5, 47.6, 83.8 and 38.5 ha areas are in class 3, 4, 5 and 6 respectively in the area (Fig. 5). With respect to available P, 26.3, 83.9, 28.7, 29.8, 1.7 and 6.9 ha areas are in class 0, 1, 2, 3, 5 and 6 respectively (Fig. 6). In the case of available K, 33.8, 46.8, 88.5 and 8.3 ha are in class 1, 2, 3 and 4 respectively (Fig. 7).

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 29. The Western 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.

Surface texture of most of the phases was sandy clay loam as derived from mean values of data generated through mechanical analysis of grid samples. Clay soils were observed on the surface of phases 4 and 7. The substrata type (sub-soil texture) did not vary from type (surface soil texture) except in the case of phases 7, 13, 30 and 34.

Gravel content in both surface and subsurface for all the soil samples were above 35%. CEC was below 4 cmol(+) kg^{-1} in all the phases except phase number 7. Aluminium saturation was above 10% in 14 phases out of 23 studied. The phases where Al saturation

Figure 4.

KERALA AGRICULTURAL UNIVERSITY - MAIN CAMPUS

TEXTURE OF SOILS IN STUDY AREA

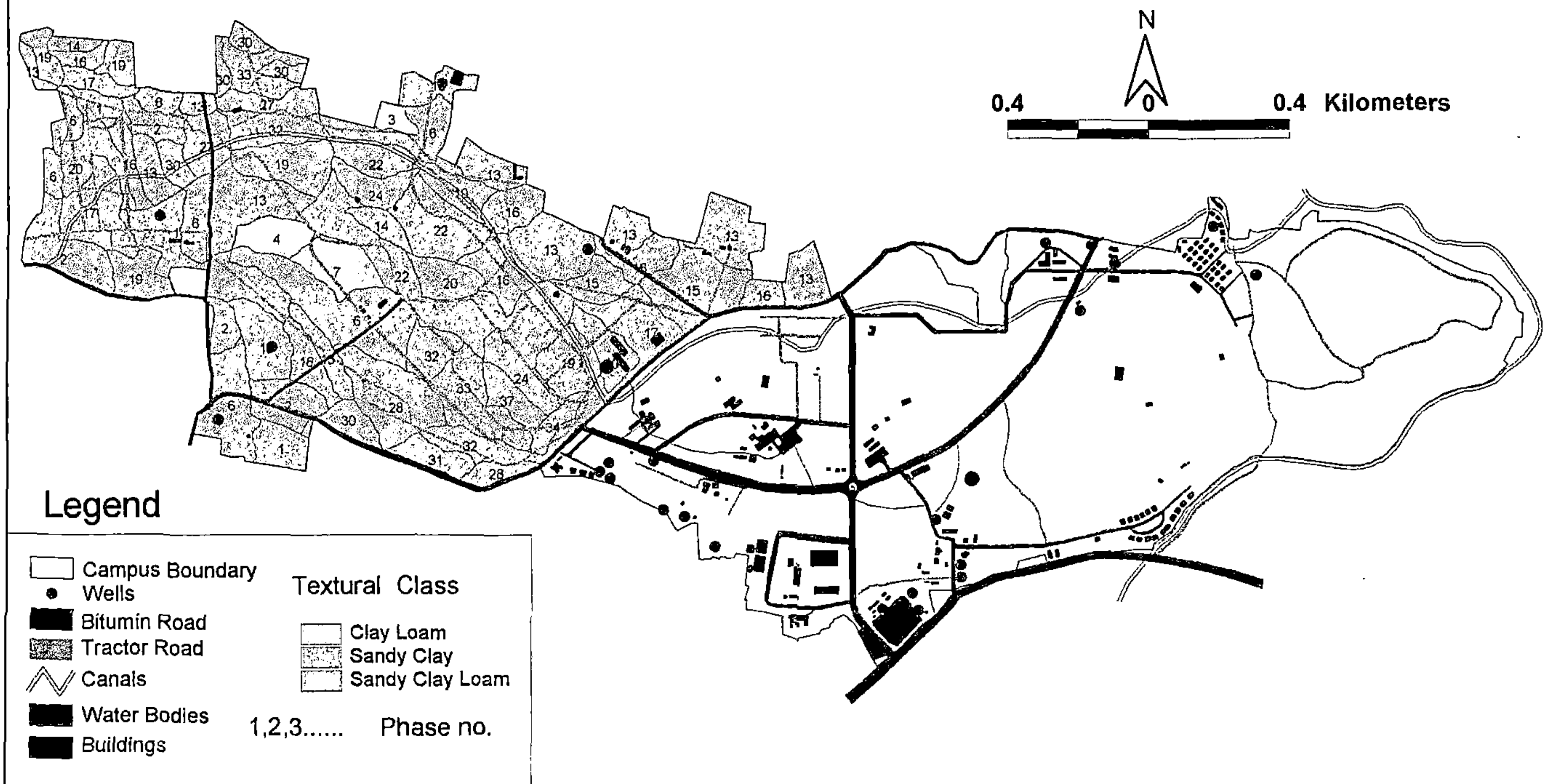


Figure 5.

KERALA AGRICULTURAL UNIVERSITY - MAIN CAMPUS

Organic Carbon Status of the Study Area

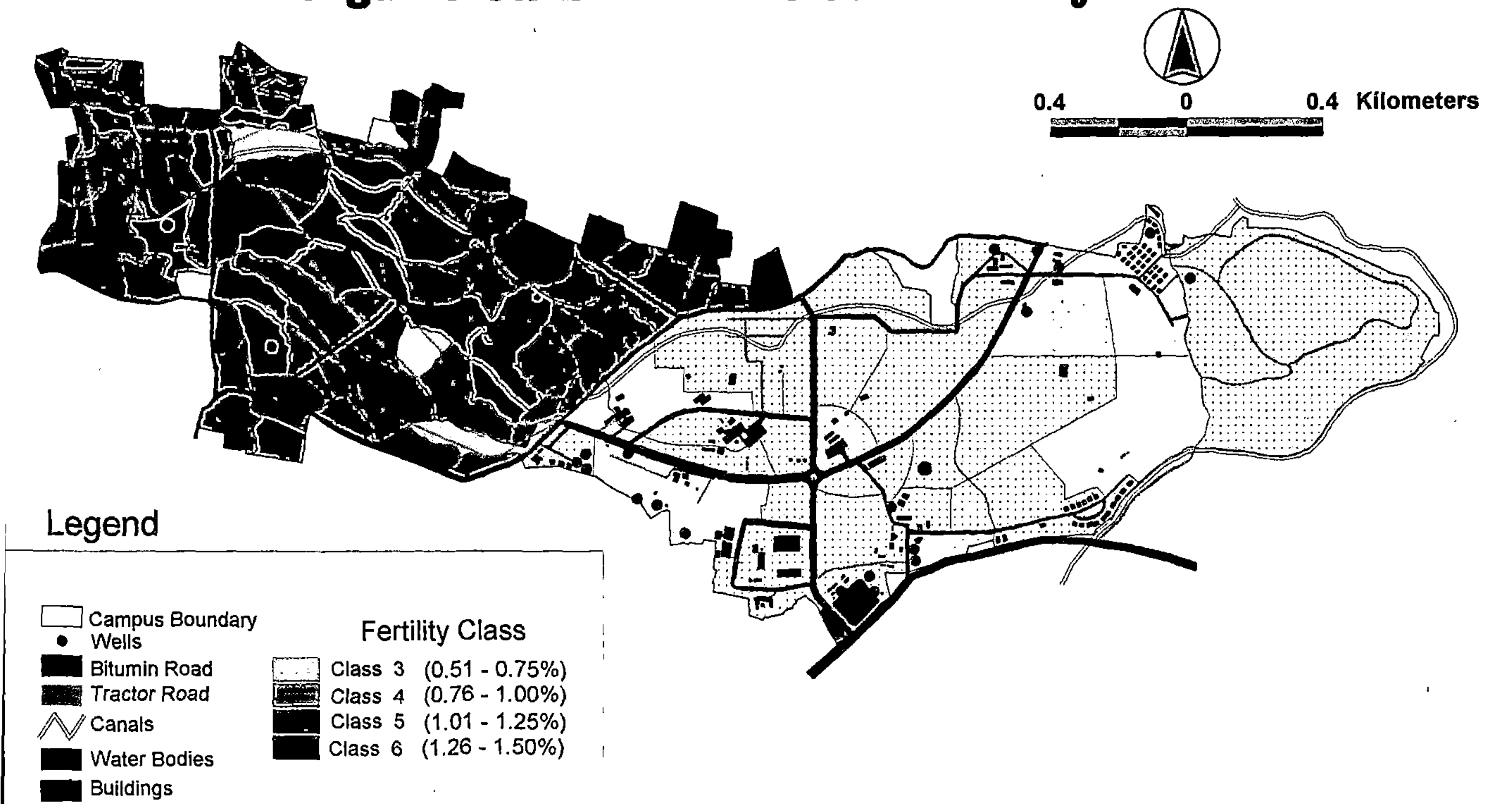


Figure 6.

KERALA AGRICULTURAL UNIVERSITY - MAIN CAMPUS

Available Phosphorus Status in Study Area

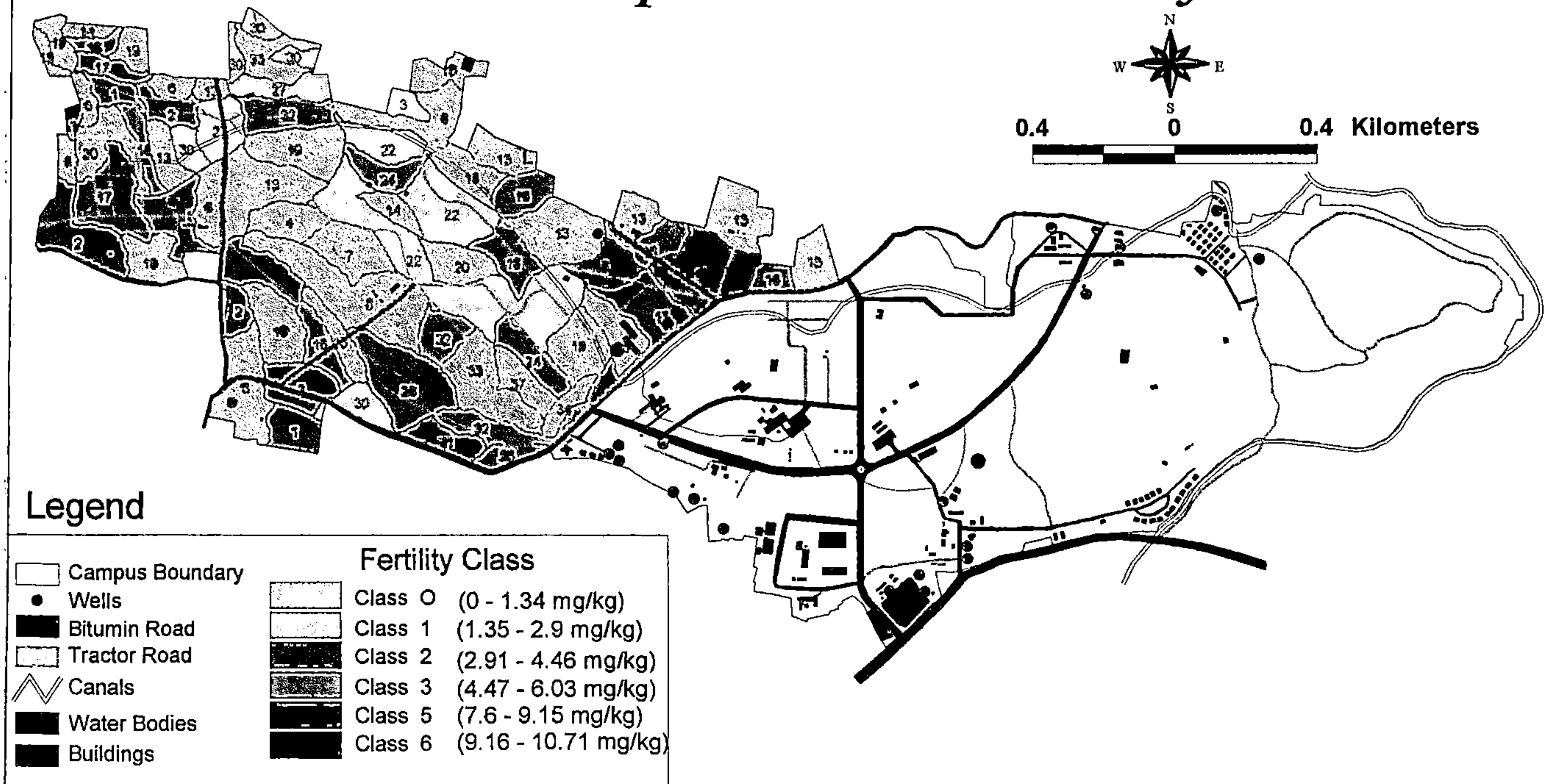
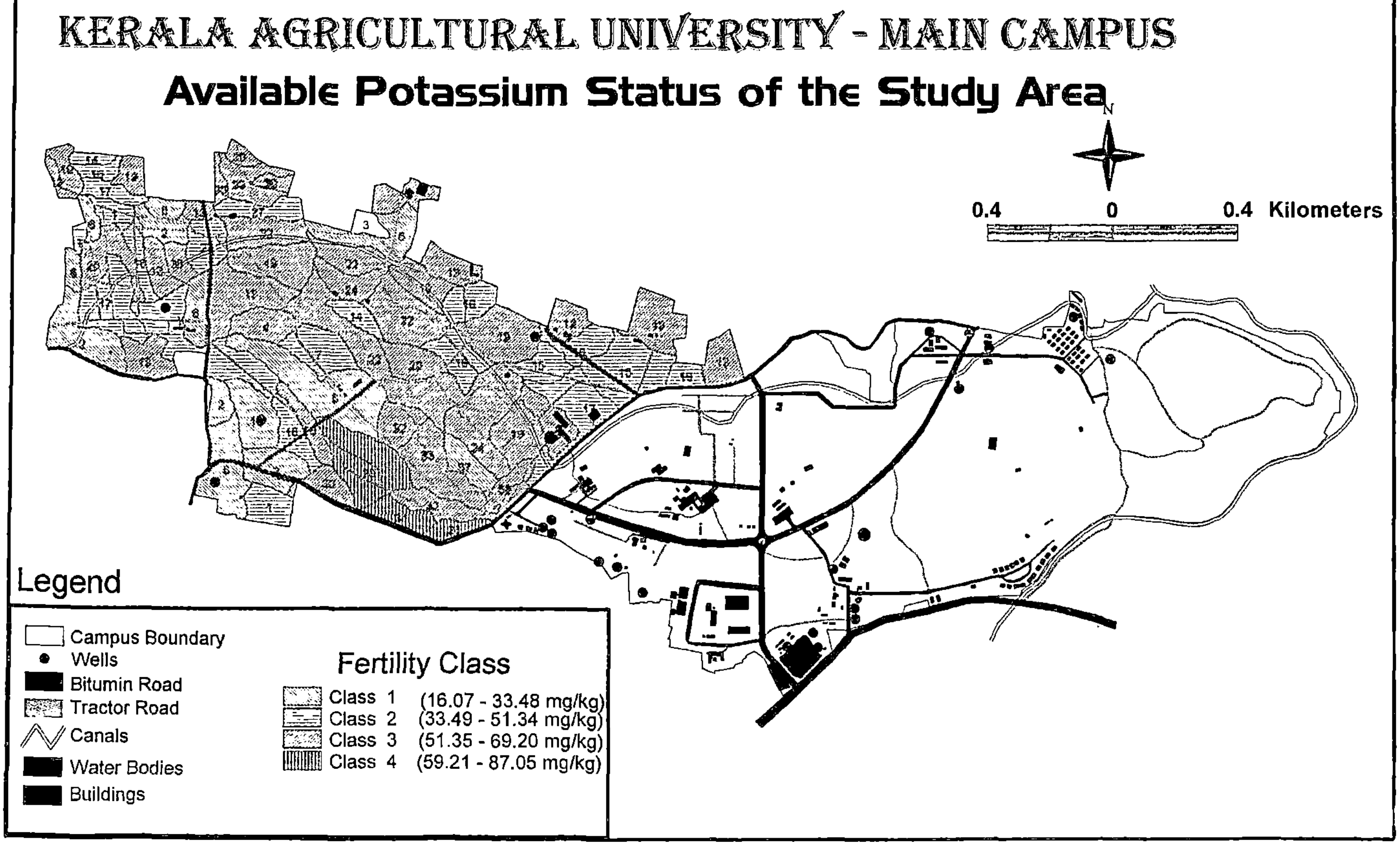


Figure 7.


KERALA AGRICULTURAL UNIVERSITY - MAIN CAMPUS
Available Potassium Status of the Study Area
N
0.4 0 0.4 Kilometers
Legend
Campus Boundary
Wells
Bitumin Road
Tractor Road
Canals
Water Bodies
Buildings
Fertility Class
Class 1 (16.07 - 33.48 mg/kg)
Class 2 (33.49 - 51.34 mg/kg)
Class 3 (51.35 - 69.20 mg/kg)
Class 4 (59.21 - 87.05 mg/kg)

was below 10% are 7, 14, 24, 28, 31 and 33. The mean values for P-fixing capacity were above 50% in most of the cases. K reserves in exchange complex were below 0.2 cmol(+) kg^{-1} in the phases 1, 2, 6, and 18. However the values exceeded the FCC limit of 0.2 cmol(+) kg^{-1} 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 4, 18 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° C. (Soil Survey Staff, 1992). Data on the climatic parameters of the study area are provided in Appendix I.

The slope percentage of the study area is class B (1-3%) to class G (>33%). The criteria for assigning slope limitations to field crop production (annuals and seasonal crops) 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. Working Table for Fertility Capability Classification

Sl. No	Soil Phase	Type	Sub strata Type	Gravel %		Moisture Regime	CEC me/100g		Al saturation (%)		P fixing Capacity (%)		Exch. K (me/100g)		Percentage Na saturation of CEC		Slope %
				Surface	Sub-surface		Surface	Sub-surface	Surface	Sub-surface	Surface	Sub-surface	Surface	Sub-surface	Surface	Sub-surface	
1	1	scl	scl	38.00	41.30	Ustic	2.98	2.87	18.00	24.00	53.53	57.11	0.179	0.143	16.00	14.00	B (1-3%)
2	2	scl	scl	47.81	32.00	Ustic	2.78	2.45	16.00	22.00	61.45	61.88	0.164	0.194	15.00	19.00	B (1-3%)
3	4	cl	cl	60.00	37.30	Ustic	3.73	4.00	12.31	11.46	39.41	51.95	0.209	0.194	12.00	13.00	C (3-8%)
4	6	scl	scl	50.00	64.00	Ustic	3.37	3.35	10.00	15.00	52.47	54.36	0.199	0.169	17.00	17.00	C (3-8%)
5	7	cl	scl	60.00	64.00	Ustic	4.59	4.32	5.00	7.26	55.46	67.36	0.239	0.169	18.00	15.81	D (8-15%)
6	13	scl	sc	59.00	46.00	Ustic	3.29	3.35	10.00	10.00	56.66	65.28	0.251	0.179	15.00	17.00	B (1-3%)
7	14	scl	scl	40.00	34.25	Ustic	3.58	3.47	2.00	2.60	58.95	58.38	0.212	0.215	19.00	19.00	B (1-3%)
8	15	scl	scl	66.00	55.60	Ustic	2.47	2.60	21.62	19.00	57.49	70.13	0.281	0.261	24.99	24.00	B (1-3%)
9	16	scl	scl	50.00	46.07	Ustic	3.10	3.03	11.00	7.00	55.23	61.64	0.210	0.194	18.00	23.00	C (3-8%)
10	17	scl	scl	50.00	45.16	Ustic	3.26	3.11	17.00	3.00	56.75	52.50	0.256	0.363	17.00	20.00	C (3-8%)
11	18	scl	scl	54.53	36.66	Ustic	3.61	3.24	13.61	18.44	57.64	57.80	0.191	0.206	14.00	16.63	C (3-8%)
12	19	scl	scl	50.00	45.44	Ustic	3.41	3.29	12.00	18.00	60.48	68.49	0.317	0.230	17.00	18.00	D (8-15%)
13	20	scl	scl	70.00	43.16	Ustic	3.38	3.11	12.00	23.00	58.11	65.20	0.257	0.159	16.00	18.00	D (8-15%)
14	22	scl	scl	60.00	54.00	Ustic	3.50	3.51	14.00	4.00	59.50	63.15	0.251	0.368	19.00	18.00	E (15-25%)
15	24	scl	scl	60.00	43.33	Ustic	4.01	3.65	3.00	10.03	49.00	58.38	0.251	0.381	24.00	23.00	F (25-33%)
16	27	scl	scl	60.05	41.59	Ustic	3.92	3.88	17.00	11.74	54.87	61.33	0.205	0.259	15.84	14.00	B (1-3%)
17	28	scl	scl	53.20	40.88	Ustic	3.09	2.96	6.00	8.00	53.03	60.40	0.215	0.276	18.00	21.00	B (1-3%)
18	30	scl	cl	62.00	45.46	Ustic	3.67	3.69	10.00	10.00	60.85	60.98	0.272	0.246	13.00	18.00	C (3-8%)
19	31	scl	scl	62.00	47.40	Ustic	3.31	2.69	0.96	12.00	61.50	65.87	0.220	0.281	17.32	24.27	C (3-8%)
20	32	scl	scl	69.00	50.02	Ustic	3.41	3.64	10.00	7.00	59.26	66.31	0.312	0.256	18.00	20.00	C (3-8%)
21	33	sc	sc	63.00	42.69	Ustic	3.54	3.53	8.00	6.00	54.22	68.03	0.332	0.298	20.00	16.00	D (8-15%)
22	34	scl	cl	66.00	41.33	Ustic	3.09	3.10	13.39	16.08	54.02	56.02	0.233	0.179	18.79	17.70	D (8-15%)
23	37	scl	scl	64.00	38.83	Ustic	3.52	3.60	14.47	11.51	56.61	69.35	0.340	0.284	23.19	24.13	E (15-25%)

DISCUSSION

DISCUSSION

The results of the study pertaining to different soil parameters of the study area were discussed. The soil samples taken for analysis were from different cropping areas of the campus. The analysis of surface and subsurface samples was undertaken to get an insight into the fertility status of the soils in a variety of cultivating fields and hence to design suitable management practices and modify the fertilizer recommendations in view of the existing resource potential. These data can be utilized for the preparation of soil fertility map of the campus using GIS, for better management of soils, which serve as the medium for several researches in the campus.

5.1. Gravelliness of soil samples

The fragments that range from 2 to 75 mm along their greatest diameter are termed as gravel. In the study area, it was found that all the surface soils were shown variations in gravel content among the phases, but it was higher than the corresponding subsurface layers. In most of the phases, the range was 50 –70 %. The highest content recorded was 83% (phase 27) and lowest value was 24.7% (phase 1). In the case of fine earth content, the minimum content was obtained in phase 27 (17%) and maximum of 74% in phase 6. While considering the phase wise mean values, the gravel content varied from 41 - 66% in surface and from 34 - 52% in the subsurface layer. Most of the areas are under plantation crops and not undergone intensive cultural practices. Some areas are still rocky in nature.

In subsurface samples, the gravel was in the range from 21% (phase 13) to 76% (phase 2). With regard to the fine earth content, the highest content obtained was 78.8 % in phase 13 and the lowest percentage was 28.34 in phase 6.

From Table 1, it can be concluded that the migration of fine earth also was more in soils with more gravel in surface soil. It is very clearly evident in the case of phase 34, where the average fine earth was almost double the quantity of that present in surface layer. The data would suggest that most of the samples analysed were gravelly in nature, which might enhance better infiltration rate as indicated by higher fine earth percentage of subsurface samples.

5. 2. Textural Variations

A particle size analysis gives a general picture of the physical properties of a soil. The analysis also is the basis for assigning each soil to a textural class. The textural class can convey an idea of the textural makeup of soils and to give an indication of their physical properties. Proportion of each sized particle in a given soil can't be easily altered, it is considered as a basic property of soil. Texture of the surface soil influences to a great extent the transmission and storage of water, flow of air in the soil and the capacity of soil to supply nutrients.

In the surface samples, highest sand percentage was observed in the phase 2 (68.43%) where as the minimum was noted in phase 22 (33.03%). Silt percentage was varying from a minimum of 8.76% in phase 33 to a maximum of 38.99% in phase 22. The lowest clay content was recorded in the phase 15 (14.53%) and the highest clay percentage was in phase 33 (44.89%). Lowest percentage of sand and highest percentage of silt were recorded in the same phase (phase 22). Similarly, maximum content of clay and minimum content of silt were also obtained in the same phase (phase 33).

In two phases, 30 and 34, the texture of surface soil was sandy clay loam and the corresponding subsurface soil texture was clay loam. Here a decrease of 9% gravel was observed and at the same time, an equal quantity increase both in silt and clay also was noted. The surface soils from most of the phases were sandy clay loam in texture.

With respect to subsurface soils, the sand content was maximum in phase 2 (60.85%) and the same was lowest in phase 22 (30.21%). The silt content was varied from 10.15% (phase 13) to 33.76% (phase16). The range of clay content was maximum in phase 13 (46.98%) and the same was minimum in phase 15 (20.47%). A trend of decrease in sand content and increase in silt and clay content was observed. In phase 24, there was a drastic increase in the mean value of clay content from 23.74 to 33.84%. While looked into the mean values of clay, majority of phases fell in the range of 27 – 34 %.

The increase in clay and silt content in the subsurface layers as compared to surface would be an indication of migration of finer particles from surface to subsurface layers. This might have even lead to the change of the texture at least in two phases (phases 30 and 34) from sandy clay loam to clay loam. This result is further established by higher gravel content and minimum fine earth content of phase 34. This gravelly light textured surface soil is well suited for tree crops which will feed from the subsurface layer but limits the possibility for growing seasonal crops.

5. 3. Electrochemical Properties

While planning for sustainable agriculture, the effective utilization of existing resource potential and the factors which favours the same should also be taken into consideration. The electrochemical properties of soil, such as Soil reaction, Electrical Conductivity, Buffer pH and Lime Requirement are fetching importance as they influence the nutrient supplying capacity of soils.

All the soil samples were acidic in nature with a pH range of 4.3 to 6.1. The most frequently occurring soil reaction was in the range of 4.9-5.1. The maximum value was in phase 19 and minimum was in phase 13. When looking into the phase wise mean values, highest average was in phase 14 (5.4) and the lowest was in phase 27 (4.6). There was no significant variation in pH between surface and subsurface samples (Table 8). With regard to subsurface layer, the highest value was in the phase 32 (6.55) and lowest was in phase 4 (4.3). It maybe due to high rainfall of Kerala, which is responsible for the intensive leaching of bases and consequent increase in acidity. Most of the samples from rubber and cocoa plantations show a low pH, since the soils are under humid conditions due to heavy surface coverage. Moreover the continuous fertilizer application to the perennial crops might have also led to low pH.

The recorded electrical conductivity (EC) of almost all the soils was low. There was little variation in this parameter between surface and subsurface soil samples except in a few phases. The predominant EC value in most of phases was 0.001 dS m^{-1}. The maximum EC of the surface soils was in phase 7 (0.385 dS m^{-1}). But in subsurface layer, the highest value obtained was 0.451 dS m^{-1} in phase 13.

The buffer pH of soil will include the total quantity of ions which favours acidity to a maximum extent. So the buffer pH was determined by using Shoemaker, McLean and Pratt (SMP) buffer solution. This single buffer method for the measurement of the lime requirement of acid soils has been widely adopted. This method is well suited for soils with the following properties: lime requirement >4 cmol(+) kg^{-1}, pH <5.8, organic matter <10% and appreciable quantities of soluble (extractable) aluminium (McLean *et al.*, 1966). In surface samples, the buffer pH was ranged from 4.7 - 6.9 and the same for the subsurface was 4.4- 6.8.

The value of liming material depends on the quantity of acid that a unit weight will neutralize, which, in turn, is related to the molecular composition and purity. Pure calcium carbonate is the standard against which other liming materials are measured, and its neutralizing value is considered to be 100%. The calcium carbonate equivalent is defined as the acid neutralizing capacity of a liming material expressed as a weight percentage of calcium carbonate.

The Lime Requirement was estimated to the quantity of lime in terms of pure $CaCO3$, required to bring the soil to neutral pH. The same was highest in phase 22 (34.9 t ha^{-1}) the least value was in phase 2. But the mean value of the Phase 2 was 21.2 t ha^{-1}. The lime requirement of the subsurface soils was varied from 2.4 t ha^{-1} (phase 28) to 34.9 t ha^{-1} (phases 28 & 33). The phase wise average values were also varied from 16.16t ha^{-1} (phase 28) to 28.45t ha^{-1}(phase 37) in surface layer and from 17.06t ha^{-1}(phase 27) to 29.35t ha^{-1}(phase 37) in subsurface layer.

Though the variation in pH in surface layer was mostly between one unit (4.6 to 5.6), the buffer pH varied from 4.7 to 6.9 indicating the lime requirement varying from 0 to 34.9 t ha^{-1}. This would mean that though the active acidity remained to be in similar range in most of the soils, the total acidity and hence the capacity factor vary widely among the soils. 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.

5.4. Major nutrients

In the present situation, information on natural sources of plant nutrients and the scope of their better use in different cropping systems will greatly facilitate their effective utilization. The knowledge about the amount of available major nutrients can be used for designing the fertilizer recommendation to a particular situation.

5.4.1. Organic carbon

The organic carbon content of predominant soil samples was high in surface layer than subsurface layer except in phases 7 and 32. The values of majority of samples were in the range of 0.8 to 1.2%. In surface layer, the range was 0.13% (phase 1) - 1.98% (phase 19) and that for subsurface was 0.32 (phase 14) - 1.61% (phase 6). In phase wise mean values, the range was 0.79% (phase 7) -1.3% (phase 34) for surface layer and 0.56 (phase 14)- 1.05% (phase 32) for subsurface layer.

When the individual samples were rated according to the fertility class, about 95% of samples were in medium class both in surface and subsurface layers. When we adopted fertility class (0-9) rating among the surface samples, it could be seen that 33.2% (86 nos.) and 34.4% (89 nos.) of samples were in class 4 and 5 respectively. But in the case of subsurface content, 42.5% of samples were included in class 4 and class 3 contained 34.7% (90 nos.) of samples.

The organic carbon percentage of soils was decreasing from surface to subsurface levels in most of the phases. Since the most of the area under study was under perennial tree crops, chances of deposition of organic matter in surface soil is more and hence higher organic matter in this layer when compared to subsurface layer. The samples taken from cocoa and rubber plantations showed high content of organic carbon. Poorly drained soils, because of their high moisture content and relatively poor aeration, are generally much higher in organic matter and nitrogen than their better drained equivalents. The results on fertility rating with respect to organic carbon indicated that a fairly good status is maintained which in turn would take care the N-supplying power of the soils.

5.4.2. Available Phosphorus

In surface layer, P content varied from 0.17 $\mu g\ g^{-1}$ (phases 2,4,27&30) to 26.5$\mu g\ g^{-1}$ (phase 13) and in the subsurface layer, the range is 0.04 (phase 1) – 22$\mu g\ g^{-1}$ (phase 24). Majority of the mean values of different phases occurred in the range of 0.5-3$\mu g\ g^{-1}$.

When these data were used for the fertility rating, in the surface samples, 180 samples (69.5%) and in subsurface soils, 237 samples (91.5%) were under low category. Only 65 surface samples and 17 subsurface samples (25 and 6.5%respectively) were medium in fertility.

While these samples were distributed according to fertility class (0 - 9) rating, all the classes were occupied by surface samples. In surface samples, 84 (32.4%) and 64 (24.7%) samples were included in class 1 and 0. With respect to subsurface samples, 58.3 % (151 nos.) was in the class 0 and 24.7% (64 nos.) was in class 1.

The available P was high in surface in phase 15 where the organic carbon also was high which would mean the increase in content might be due to the organically bound soluble complex. The higher content in surface layer in majority of phases might be due to relatively less finer fractions and particles in surface causing less fixation. This is further substantiated by lesser percentage of low P status of surface samples than subsurface. However the P fertility with respect to available P is alarming and would be due to high P fixation.

5.4.3. Available Potassium

The range observed was 11μg g^{-1}(phase 6&13)-147μg g^{-1} (phase 6) in surface samples and 11μg g^{-1} (phase 6) - 178μg g^{-1} (phase 16) in the subsurface soil. The phase wise mean values were varied from 24.5μg g^{-1}(phase 37) to 75.13μg g^{-1} (phase 28) in surface samples, and in subsurface layer, from 26μg g^{-1} (phase 7) to 69.2% (phase 33).

In the fertility rating, 56% surface samples and 66.3% subsurface samples were under low category, while 41% surface samples 31% subsurface samples were under medium class. Then almost equal number of surface samples were occupied in class 1(27%) and class 2 (25.8%). In the subsurface, class 1 had 103(39.7%), class 2 had 57(22%) samples.

About 30 to 50% of samples were rated as low, requiring for proper management with high input of K fertilizer. This especially attains significance under lateritic environment where the requirement of K is very high to manage the problems due to excess Fe and Mn.

While comparing the data on major nutrients 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 at least in 25% of the area. But the remaining 75% 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 fertilizer 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 types of soils. With respect to available K the study area was rated low in fertility, has now changed to medium in 40% of the area which indicate that area is under good management practices.

5.5. Secondary nutrients

The data on secondary nutrients of the soils under study, showed a wide range for both magnesium and calcium. Both these nutrients have a similar trend in their behavior in most of the samples.

5.5.1. Available Calcium

Calcium has an important role in the structure and permeability of cell membranes. It is essential for cell elongation and division. For calcium, there was a wide range among the samples from 12μg g^{-1}(phase 6) to 378μg g^{-1}(phase 22) in the case of surface samples and 8 (phase 22) to 356μg g^{-1} (phase 19) in subsurface samples. The mean values of both surface (308.88μg g^{-1}) and subsurface (288.88μg g^{-1}) were found to be high in phase 14.

While looked into the phase average value, it was realized that the highest value for both surface (308.8μg g^{-1}) and subsurface (288.9μg g^{-1}) were obtained in the same phase (phase 14). In a similar way, the phase had the lowest average for surface (46.5μg g^{-1}) as well as subsurface (47.39μg g^{-1}).

The Ca content was generally low, probably due to the process of laterisation where leaching losses of Ca was more, which in turn affect the aggregate stability and nutrient holding capacity of the soil.

5.5.2. Available Magnesium

Magnesium is a primary constituent of the chlorophyll molecule, and without chlorophyll, the autotrophic green plants would fail to carry on photosynthesis. It also serves as a structural component in ribosomes, stabilizing them in the configuration necessary for protein synthesis. The element is involved in a number of physiological and biochemical functions. It is essential with transfer reactions involving phosphate reactive groups.

The magnesium content varied from 6.5 $\mu g\ g^{-1}$ (phase 16) to 51.9$\mu g\ g^{-1}$ (phase 6) in the surface samples and 6.5$\mu g\ g^{-1}$(phase 13 and 19) to 42.4$\mu g\ g^{-1}$(phase 33) in subsurface samples. It was found that maximum value of Mg in surface and subsurface layers were in the same phase (22). In subsurface layer highest value of Ca and lowest value of Mg were in the same phase (phase 19). With regard to phase wise average values, it was observed that the highest value for both surface (38.63$\mu g\ g^{-1}$) and subsurface (37$\mu g\ g^{-1}$) were obtained in the same phase (phase 14). In a similar way, the same phase had the lowest average for surface (18.72$\mu g\ g^{-1}$) as well as subsurface (15.94$\mu g\ g^{-1}$).

The data on available magnesium also showed the same trend as that of calcium. Thus in general focuses to the need of amendments frequently to improve their individual status as well as to improve the conditions of the soil.

5.6. Available micronutrients

The trend towards high analysis fertilizers has reduced the use of impure salts, which formerly contained micronutrients. Increased knowledge of plant nutrition has helped in the diagnosis of trace element deficiencies that formerly might have gone unnoticed. Improved crop varieties and macronutrient fertilizer practical have greatly increased crop production and thereby the micronutrient removal. All micronutrients are required in very small quantities. In fact, they are harmful when present in the soil in larger amounts more than that can be tolerated by plants or by animals consuming the plants.

Cu and Fe are capable of acting as electron carriers in enzyme`system that bring about the oxidation-reduction reactions in plants. Apparently, such reactions, which are essential for plant development and reproduction, require the presence of these micronutrients. Zinc and manganese are also functioning in enzyme systems necessary for important reactions in plant metabolism.

Micronutrient cations are most soluble and available under acid conditions. In very acid soils, there is relative abundance of the ions, Mn, Zn and Cu. In acid condition, use of these micronutrients will be high to toxic level, so one of the primary reasons for liming acid soils to reduce the concentration of these ions. 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

Manganese is essential for nitrogen transformation, photosynthesis and respiration. In the surface samples, manganese was found to be in the range of 4.5 (phase 1) - 116$\mu g\ g^{-1}$ (phase 18). The subsurface content was varied from 3.1 $\mu g\ g^{-1}$ (phase 1) to 120.3 $\mu g\ g^{-1}$ (Phases 4 and 6). The highest phase wise mean values for surface (73.65$\mu g\ g^{-1}$) and subsurface (72.59$\mu g\ g^{-1}$) samples were in the same phase(phase28) as phase 37 was having the lowest average for both surface (32.15$\mu g\ g^{-1}$) and subsurface (27.45$\mu g\ g^{-1}$) samples.

All the sample contents and the phase wise mean values are included in the above critical range group. Manganese content is high and even toxicity could be anticipated. Further, this might lead to antagonistic interaction with other nutrients.

5.6.2. Available Zinc

Zinc plays an important role in protein synthesis in the formation of some growth hormones and in both photosynthesis and respiration and in the use of Fe. Cu also stimulates lignification of all plant cell walls. Fe is involved in chlorophyll formation and degradation and in the synthesis of protein contained in the chloroplast.

In the case of zinc, the majority of samples were under low category. In the surface layer, it ranges as 0.03μg g^{-1} (phase 2) - 3.99 μg g^{-1} (phase 6) in surface layer and 0.03 μg g^{-1} -3.79 μg g^{-1}(phase 6) in subsurface layer. The highest value were observed in the phase, where the copper content is the lowest. In the subsurface layer, the highest as well as the lowest contents were recorded in the same phase (phase 6). It was observed that the highest content of both zinc and iron were recorded in the phase 6.

As far as average values for the phases were considered, the highest average for surface contents was obtained in phase 24 (0.97μg g^{-1}) and that for subsurface was in phase 7 (0.6μg g^{-1}). The lowest average for both surface (0.26μg g^{-1}) and subsurface (0.16μg g^{-1}) samples were estimated in the same phase (phase18). While categorizing according to the critical range, 88% of surface (228 nos.) and 94% of subsurface samples would come under below critical range. Out of 23 phases, mean values of 22 phases were in the below critical range group and that of one was in critical range group.

Zinc deficiencies were reported under acidic lateritic environment due to the presence of excess of Mn and Fe (Sureshkumar, 1999). Application of zinc might not solve the problem, since it is not the total content but the availability that matters. Formation of insoluble zinc phosphate also could be expected.

5.6.3. Available Copper

Most of the samples showed a high content of copper. The range of copper was varying from 0.04 (phase 6) to 40.66μg g^{-1} (phase 17) in the case of surface samples. The amount of available copper in the subsurface level varies from 0.72 μg g^{-1}(phase 24) to 63.54μg g^{-1} (Phase 32). The highest and lowest mean values for surface layer, were obtained in phase 2 (13.15μg g^{-1}) and phase 37 (2.28μg g^{-1}), respectively. In the same way, phase 20 was recorded the highest average (14.03μg g^{-1}) and the lowest (2.89μg g^{-1}) in the phase 4 in subsurface samples.

When these data were used for fertility rating, 96% of surface samples, 85.7% of subsurface samples and mean values of all the phases were categorized as above critical range.

Copper availability might be related to organic carbon as well as due to high input of Cu in terms of copper containing fungicides especially by aerial spray to rubber plantation adopted in this area earlier.

5.6.4. Available Iron

The majority of samples were having a high content of available iron. In the surface layer, it is ranged from 9.2μg g^{-1}(phase 32) to 101.3μg g^{-1}(phase 1) but in subsurface samples, from 4.5 μg g^{-1} (phase 14) to 85 μg g^{-1}(phase 6). The lowest content of copper in the surface layer and the highest content of iron in the subsurface layer were in the same phase (phase 6).

Further, the highest phase averages were varied from 16.5μg g^{-1} (phase 14) to 33.76μg g^{-1} (phase 30) in surface level. The phase 18 had the highest (30.13μg g^{-1}) and lowest (12.45μg g^{-1}) averages in phase 14 in subsurface layer. All of them in both surface and subsurface layer were in above critical range class. The content of iron is the next to the highest quantity of Mn. Available iron also behaves in the same way as that of Manganese. Even toxic levels might be expected. It may also cause high P fixing nature of the soils.

5.7. Phosphorus Fixing Capacity

The capacity of soil to fix phosphorus and make unavailable to plant was recorded as high. The phase wise distribution of P fixing capacity of surface and subsurface soil were given in Table 15. It was noticed that there is a little increase in the P fixing capacity from surface layer to subsurface samples. The range was from 36.26 % (phase 4) to

69.53% (phase 30) for surface samples. In he case of subsurface level, the recorded highest value was in phase 33 with 78.75% and the minimum value as 40.9% in phase 6.

The mean value of phases was seen in the range of 50-60% for surface layer and that for subsurface was 55-65%. The phase 2 and phase 15 were having maximum for surface (61.45%) and subsurface (70.13%), respectively. Among the subsurface samples, the minimum percentage for both surface (39.41%) and subsurface (51.95%) were recorded in the same phase (phase 4).

This is related to the reverse trend in available P from surface to subsurface. It may be due to the presence of high contents of iron and aluminium in the soil. The management of P fixing nature of soil and improvement in nutrient supplying character should be taken in consideration.

5.8. Exchangeable Cations in the Soils

The contents of important monovalent (sodium and potassium), divalent (calcium, magnesium, iron and manganese) and trivalent (aluminium) cations were estimated in the both layers of soils. These data were used to compare the available and exchangeable quantity of four major cations in the soils (Table 18 & 19).

5.8.1. Exchangeable Calcium

When the data on Table 16 and 17 revealed that calcium had almost same range for surface and subsurface layers. In surface level range range was from 12μg g^{-1} (phase 16) to 493μg g^{-1} (phase 7) and in the subsurface samples, the range was from 12μg g^{-1} (phase 16) to 492 μg g^{-1} (phase 27). The minimum content of Ca in both surface and subsurface layers was seen in the same phase (phase 16). With respect to phase wise mean values, for both surface and subsurface samples the highest value was same phase (phase 7) and both the lowest values were in phase 15.

From this, it is clear that calcium is the predominant cation among the exchangeable ions extracted by 0.1 M $BaCl_2$. In comparison with the elemental content extracted by neutral normal ammonium acetate, it was seen that 0.1 M $BaCl_2$ could extract

25 -50% more calcium than the other (Table 18 and 19). This data revealed that barium, being divalent and with better replacing power as against the monovalent ammonium ion can extract more calcium from the exchange complex. Moreover 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 calcium is more strongly bound and the extracting ion (NH_4^+) is weak also.

CEC as well as the most dominant ions in exchange phases were very low, might be due to the dominance of 1:1 clay and leaching loss of these base saturation under high rainfall condition.

5.8.2. Exchangeable Magnesium

From Table 16 and 17, it was understood that exchangeable magnesium having a wide range of 10.8μg g^{-1} (phase 16) - 125.6 μg g^{-1} (Phase 13) in the surface layer. But in subsurface samples, it was from 10.1μg g^{-1} phase (13) to 139.7μg g^{-1} (phase 6). It was noticed that in surface layer, lowest amount of calcium and magnesium was in the same phase (phase 16).

The highest phase wise mean values for surface (93.45μg g^{-1}) and subsurface (90.05μg g^{-1}) were in the same phase (phase14). Likewise, the lowest average for both surface (36.39μg g^{-1}) and subsurface (36.63μg g^{-1}) were in phase 37.

The pattern of distribution of exchangeable Ca and Mg were found to follow the same trend. It is clear that exchangeable Mg content is very low. But compared to quantity obtained by ammonium acetate extract, the exchangeable Mg by $BaCl_2$ is 2-3 times higher quantity than that by the former extract.

5.8.3. Exchangeable Sodium

Most of the samples showed a high content of exchangeable sodium. Among the surface samples, it was varied from of 66μg g^{-1} (phase 1) to 240μg g^{-1} (phase 24) and in subsurface level, from 68µg g^{-1} (phases 1 and 2) to 322µg g^{-1} (phase 22). The phase 37 was having the highest average for both surface (188µg g^{-1}) and subsurface (198µg g^{-1}) samples.

The content of sodium in both surface and subsurface layers was more than that of potassium. Though divalent bases were leached easily, which in turn causes a trend for accumulation of Na. Further as the pH was lowered due to exchangeable aluminium, sodium was found to be replaced by Al.

Comparing to ammonium acetate extracted contents, in surface samples the range was 13.79 µg g^{-1} (phase 15) - 181.62µg g^{-1} (phase 7) and in subsurface samples from 13.79µg g^{-1} (phases 15 and 18) to 52.87 (Phase 14). From this comparison, it could be noted that the fraction of sodium extracted by $BaCl_2$ was 2 to 4 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). It is further supported by the comparison of data on exchangeable Na 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.

5.8.4. Exchangeable Potassium

The exchangeable potassium in the surface samples was obtained in the range of 38µg g^{-1} (phase 2) - 242 µg g^{-1} (phase 13). In the case of subsurface layer, it was from 40 µg g^{-1} to 304µg g^{-1}. The highest and lowest values for both surface and subsurface samples were in the same phases. The highest contents of magnesium and potassium were recorded in the same phase in surface layer. In subsurface level, the lowest value for sodium and potassium was in the same phase. The maximum and minimum phase wise average values, for surface and subsurface were recorded in the same phases (phases 24 and 2, respectively).

The data on ammonium acetate extract showed variation from that of $BaCl_2$ extract. In surface layer it is varied from 23.46 μg g^{-1} to 86μg g^{-1} and in subsurface layer it is from 23.46μg g^{-1} to 70.38μg g^{-1}. From this, it would mean that exchangeable potassium is held mainly by pH independent native surface charges.

5.8.5. Exchangeable Iron

From Tables 16 and 17, it was clear that the iron content in the surface level varied from 0.9μg g^{-1} (phase 20) to 9.9 μg g^{-1} (phase 30). There was no significant variation in subsurface content from that of surface. Among the subsurface samples, the range was 1.1μg g^{-1} (phase 6) - 10.6μg g^{-1} (phase 13). The relation between iron and magnesium was inversely proportional (phase 6 and 13). The lowest average values for surface and subsurface were noted in the same phase (phase18) but the highest average for surface and subsurface were estimated in phase 30 and phase 34, respectively.

Exchangeable iron was found to be very low as against its larger content in available pool extracted by 0.1M HCl. The available iron by 0.1M HCl in the surface layer varies from 9.2μg g^{-1} to 101.3μg g^{-1} and in the case of subsurface samples, from 4.5 μg g^{-1} to 85 μg g^{-1}(Table 13). Among the surface samples variation is 10 times and that in the subsurface layer is 4-8 times. This would mean that the available pool or availability governed by the insoluble iron oxides probably by the crystalline and amorphous ones - which was found to be in equilibrium with solution phase. This in turn might be due to the ferrous iron, if present will come to solution and under aerobic condition would get oxidised and thus could not occupy steadily the exchange phase (Sureshkumar, 1993).

5.8.6. Exchangeable Manganese

The exchangeable manganese content in the soil was high compared to other ions. It varied in surface layer from 9.2μg g^{-1} (phase 22) to 283.3μg g^{-1} (phase 27). In subsurface samples, the minimum content was 12.5 μg g^{-1} (phase 13) and the maximum was 324.8μg g^{-1}(phase 4). The highest phase wise surface average was 208.78μg g^{-1} (phase 27) and the lowest was 63.65μg g^{-1} (phase 14). The corresponding subsurface values were 191.5μg g^{-1} (phase 4) and 63.5μg g^{-1} (phase 37) (Table 16 & 17).

The minimum amounts of magnesium and manganese in the subsurface level were obtained in the same phase. In the case of Mn, Mn^{2+} exchange phase equilibrium was found to be more stable than that of iron and it was observed to occupy appreciably the exchange sites. Both available and exchangeable manganese were found to be high in the soils under study.

5.8.7. Exchangeable Aluminium

From Table 16, it was seen that the amount of exchangeable aluminium in the surface soil ranges from 1.25μg g^{-1} (phase 16) to 96.38μg g^{-1}(phase 1). In subsurface layer, it is from 2μg g^{-1} (phase 22) to 113.75 μg g^{-1} (phase 1) as shown in table 17. The minimum quantity in surface level was obtained in the phase, which is having the lowest content of calcium and magnesium. In subsurface layer, the lowest content was recorded in the phase where the sodium content was highest. In surface and subsurface layers, the minimum content of sodium and maximum content of aluminium were found in the same phase (phase 1).

The biggest and smallest mean values were recorded in same phases (phases 1 and 14, respectively) both in the case of surface and subsurface levels. The lowest mean in surface and subsurface levels was recorded in the phase 14 where, the highest magnesium was recorded.

The data revealed that the content of exchangeable aluminium is more than that of iron and less than manganese. So aluminium has a better role in the creation of soil acidity than iron.

9. Cation Exchange Capacity

The cation exchange capacity (CEC) of a given soil is determined by the relative amounts of different colloids in that soil and by the CEC of each of these colloids. Thus, sandy soils have lower CEC than clay and humus content. Likewise, a clay soil dominated by 1:1 type silicate clays and Fe, Al oxides will have a much lower CEC than one with similar humus content dominated by smectite clays (Brady, 1996).

When the CEC of surface samples were estimated, the samples were in the range of 1.67 cmol p(+) kg^{-1} (phase 16) - 5.59 cmol p(+) kg^{-1} (phase 7) as shown in Table 20. The 50% of phase values show no significant variation in subsurface level than from surface level. But 20% showed an increase in the capacity. For the subsurface samples, the range was 1.64 cmol p(+) kg^{-1} (phase 16) - 5.22 cmol p(+) kg^{-1} (phase 27).

The mean values of phases were varied from 2.47 cmol p(+) kg^{-1} (phase 15) to 4.59 cmol p(+) kg^{-1} (phase 7) in surface layer and from 2.45 cmol p(+) kg^{-1} (phase 2) to 4.32 cmol p(+) kg^{-1} (phase 7) in subsurface level. The highest mean values were obtained in the same phase in both layers.

The cation exchange capacity of both surface and sub surface soils was found to be low. Since the soil is dominated by 1:1 type kaolinitic clay minerals the CEC is expected to be low. The soils under study were having low pH. As the pH is raised, the negative charges on some 1:1 type silicate clays, allophane humus, and even Fe, Al oxides increases, thereby increasing the CEC. Similar results were reported by Deepa (1995).

10. Cation Saturation

10.1. Percentage Base Saturation

The percentage of the CEC that is satisfied by the base forming cations is termed percentage base saturation. A low percentage base saturation means acidity, whereas a percentage base saturation of 50-80 % will result in neutrality or alkalinity.

The data on Table 20 revealed that the PBS of surface samples were varied from 41.86% (phase 1) to 94.58% (phase 33). In subsurface layer, the range was 35.52% (phase 1) - 96.09% (phase 24). While looking into phase wise mean values of surface samples, the minimum (63.19%) and maximum (90.66%) were obtained in phase 15 and 14 respectively. In the case of subsurface layer, the phases 14 and 1 were showed the maximum (89.72%) and the minimum (62.66%) mean values, respectively. The highest mean values for surface and subsurface layers were obtained in the same phase.

The mode and mean values of this parameter would suggest that most of the samples analysed were found to get saturated by 70 - 75% or more of the CEC. The exchangeable calcium contributed 50% of this value 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.

10.2. Sodium Saturation Percentage

It is the percentage contribution of sodium in total cation concentration considered for calculation of cation exchange capacity. The data in Table 20 showed that the value was varied from 10.02 to 34.45% in the surface samples (phase 22). In the subsurface layer, the range was 10.96% (phase 22) – 37.16% (phase 1). Among the phase wise mean values, in subsurface level, the value was from 13.02% to 24.13% and in surface layer, it is from 12.95 to 24.99%.

In most of the phases, surface samples showed a higher sodium saturation than subsurface samples. Since exchangeable sodium percentage in majority of the cases well exceeds 15%, which is one of the criteria for existence of sodicity, we will expect sodicity in the field. But none of the location in the present study had shown any sign of sodicity. It is 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.

10.3. Aluminium Saturation Percentage

It is the percentage of aluminium in total quantity of exchangeable ions taken for the estimation of cation exchange capacity. In surface samples, it was varied from 0.42% (phase 16) to 38.96% (phase 1) and in subsurface layer, it is from 0.64% (phase 22) to 44.15% (phase 1). In phase wise means, the highest and lowest values were occupied in same phases in both surface and subsurface layers (Table 20).

The percentage saturation is in relation to the total CEC and hence it is not the indication of the actual quantity per unit weight of soil. This was also to be looked into in relation to the exchangeable calcium content. The relationship between base saturation percentage and aluminium saturation was in the inverse proportion (Table 20). 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. Soil Nutrient Interactions

In correlation studies, mainly interactions of soil parameters with different direct and derived parameters were used. Here, the discussion was mainly about the interaction of soil parameters with exchangeable ions, micronutrients and P fixing capacity. The derived equations of sodium and potassium were also correlated with important soil characteristics.

5.11.1. Studies on interaction of Exchangeable ions with soil parameters

5.11.1.1. Surface samples

The correlation coefficients given in Table 21 shows that the 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.

5.11.1.2. Subsurface samples

In the case of sub surface samples, exchangeable calcium was significantly correlated with phosphorus fixing capacity (Table 22). 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.

5.11.2. Micronutrient interactions with soil parameters

5.11.2.1. Surface samples

From the data shown in the Table 23, it was clear that 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. 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.

5.11.2.2. Subsurface samples

Available manganese and copper were having significant correlation with subsurface organic carbon, which was absent in surface soil (Table 24). This would indicate that fairly a good amounts of these elements were chelated to soluble organic complexes. But, 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.

5.11.3. 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 (Table 23 & 24). 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.

5.11.4. 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.

5.11.5. Correlation 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 to 13.5 would indicate that almost 86% of the variation in exchangeable potassium in surface soils could be explained by including K/(Ca + Mn + ^{3}Al) 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 reduced 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 wit 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.

5.11.6. 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 (Table 27 & 28). 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 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

5.12. Fertility Capability Classification

Fertility Capability Classification is one of the most popular methods of land resource evaluation that groups soils according to their fertility constraints in a quantitative manner. Boul *et al.* (1975) originally established this system which was later revised by Sanchez *et al.* (1982). This system was adopted by different workers adding local modifiers which suits specific localities. In a campus which comprise multiple micro variations in soil characteristics as well as topographic features, application of this system assumes importance in the context of soil fertility management. Analytical results of FCC parameters (Table 29) and their rating according to the criteria designed for current study (Table 5) have revealed that the western 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 with in 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 western 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 three cases out of 23 soil phases studied. Surface texture was sandy clay loam in 87% 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, the sandy clay loam is subjected to high infiltration and leaching of nutrients.

Due to the above factors and 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 phase 7 and 24 when the CEC was marginally above the FCC unit of 4 cmol(+) kg^{-1}. 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

Table 30. Final Table of Fertility Capability Classification

Sl. No	Soil Phase No	Type	Sub strata Type	FCC MODIFIERS															FCC Unit
				Gravel "	Soil Moisture Regime	CEC	Al Toxicity	Acidity	P Fixation	K reserves	Natric	Salinity	Basic	Allo-Phane	Gley	Cat Clay	Verti-sol	Slope %	
1	1	S	S	"	D	e	*	h	I	k	N	*	*	Not studied	*	*	Not applicable	*	S dehikn"
2	2	S	S	"	D	e	*	h	I	k	N	*	*		*	*		*	S dehikn"
3	4	C	C	"	D	e	*	h	*	*	*	*	*		*	*		%	C deh"(3-8%)
4	6	S	S	"	D	e	*	h	i	k	n	*	*		*	*		%	S dehikn"(3-8%)
5	7	C	S	"	D	*	*	*	i	*	n	*	*		*	*		%	CS din"(8-15%)
6	13	S	S	"	D	e	*	h	i	*	n	*	*		*	*		*	S dehin"
7	14	S	S	"	D	e	*	*	i	*	n	*	*		*	*		*	S dein"
8	15	S	S	"	D	e	*	h	i	*	n	*	*		*	*		*	S dehin"
9	16	S	S	"	D	e	*	h	i	*	n	*	*		*	*		%	S dehin"(3-8%)
10	17	S	S	"	D	e	*	h	i	*	n	*	*		*	*		%	S dehin"(3-8%)
11	18	S	S	"	D	e	*	h	i	k	*	*	*		*	*		%	S dehik"(3-8%)
12	19	S	S	"	D	e	*	h	i	*	n	*	*		*	*		%	S dehin"(8-15%)
13	20	S	S	"	D	e	*	h	i	*	n	*	*		*	*		%	S dehin"(8-15%)
14	22	S	S	"	D	e	*	h	i	*	n	*	*		*	*		%	Sdehin"(15-25%)
15	24	S	S	"	D	*	*	*	*	*	n	*	*		*	*		%	S dn"(25-33%)
16	27	S	S	"	D	e	*	h	i	*	n	*	*		*	*		*	S dehin"
17	28	S	S	"	D	e	*	*	i	*	n	*	*		*	*		*	S dein"
18	30	S	C	"	D	e	*	h	i	*	*	*	*		*	*		%	SC dehi"(3-8%)
19	31	S	S	"	D	e	*	*	i	*	n	*	*		*	*		%	S dein"(3-8%)
20	32	S	S	"	D	e	*	h	i	*	n	*	*		*	*		%	S dehin"(3-8%)
21	33	S	S	"	D	e	*	*	i	*	n	*	*		*	*		%	S dein"(8-15%)
22	34	S	C	"	D	e	*	h	i	*	n	*	*		*	*		%	SC dehin"(8-15%)
23	37	S	S	"	D	e	*	h	i	*	n	*	*		*	*		%	S dehin"(15-25%)

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 4.5-5.5, 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 and therefore the modifier 'h' (acidic) is introduced in 17 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 subsoils were more than 50% except in surface soils of phase 4 (39.4%) and phase 24 (49%). 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 except 4 and 24 possess limitations leading to the modifier 'i' (high P fixation).

K reserves in the exchange complex in general showed low values (Table 29). But the FCC limit of 0.2 cmol(+) kg^{-1} was observed only in 4 cases. These phases 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 16 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 western 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.

SUMMARY

SUMMARY AND CONCLUSION

In the present investigation, an attempt has been made to evaluate the resource potential of the soils of western part of the main campus, Kerala Agricultural University, Thrissur. For identification of sample sites, a 1:2000 scale map of the campus was used. A grid size of 80 m x 80m was used to locate the sites. The study area constitutes 12 blocks out of 37 in the campus. The samples were taken from both surface (0-20cm) and subsurface (20-40cm) layer. Altogether 518 soil samples, collected from the 23 phases of the study area, were analysed by standard procedures to record their physical, chemical and electrochemical properties. The surface and subsurface samples were analysed for available nutrients and other fertility parameters. The salient results obtained in the present work are summarised below.

1. The soils contained a high amount of gravel in both surface and subsurface samples compared to fine earth content. An increase in amount of fine earth from surface to subsurface level was noted.

2. The mechanical analysis of the soil samples revealed that most of the samples were sandy clay loam in nature. In most of the soils, the texture was same for surface and subsurface samples. The data obtained on the soil components were used for their textural classification.

3. The soil reaction of the samples were shown that the soil is acidic in nature. It may be due to the considerable extend of leaching of cations because of high rainfall.

4. The electrical conductivity of almost all the samples was found to be very low in every phase. There was no significant difference in this parameter between surface and subsurface samples.

5. Buffer pH of the samples has a very wide range among the soil phases. The lime requirement also varies accordingly.

6. The organic carbon contents were medium in most of the soil samples. About 93% and 7% were in medium and high classes respectively. It is high in surface layer

6. The organic carbon contents were medium in most of the soil samples. About 93% and 7% were in medium and high classes respectively. It is high in surface layer than subsurface in majority of the phases. This trend was mainly seen in soils from rubber plantations. The data can be used for the estimation of available nitrogen in the soils.

7. Available phosphorus was generally low in content in 60 - 90% of sample. About 25% were in medium class. Only 5% were in high class. It is due to high P fixing nature of the soils.

8. The potassium content was rated as low in 56% of the surface samples and 66% of subsurface samples. In medium class, 30% surface and 40% subsurface samples were included.

9. Among the secondary nutrients, available calcium showed a wide range in the soil. There was slight variation in the content of surface and subsurface layers. Available magnesium was low in the samples. There was a decreasing trend in subsurface layer compared to surface layer. Both highest and lowest contents of these elements were recorded in the same phases.

10. Among the micronutrients, manganese was the highest content followed by iron. Only one subsurface sample was in critical range and all the other samples were above critical range for manganese. For iron, all of them are above critical range. In copper 96% of surface and 86% of subsurface contents were in above critical range. It may be due to fungicide spray in rubber plantations. But in general, zinc was low in concentration. About 88% of surface and 94% of subsurface samples were below critical range.

11. The P fixing capacity of the soil was found to be high and the same was reflected in the available content. This is due to the high content of oxides of iron and aluminium under acidic 1:1 mineral dominated soil environment.

12. In the exchangeable complex, calcium was in the predominant status followed by manganese. Sodium and potassium were also got a better contribution in the

complex. Aluminium was found to be higher than iron. The same trend was observed in the surface and subsurface samples.

13. The cation exchange capacity of the soil was low since a good amount of cations were leached off during the rainy season.

14. The percentage base saturation was high. It was from 60 - 90% in both the surfaces. It is mainly because of high calcium in the exchange complex.

15. Percentage sodium saturation was higher than 15% in most of samples in both surface and subsurface layers. But there was no sodicity, due to low CEC and low pH.

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 generated data were used to prepare a soil fertility map of the study area. From this, we can modify our recommendation based on the suitability of the crops for a better resource utilization.

18. The western part of the campus poses several limitations for the improvement in 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.

From the above results and the data generated, the present potential of the soil can be estimated by utilizing the resource capacity of the soil to the maximum extend, the management practices can be revised for improved crop production. The information regarding the properties of soils of the western part of the main campus, will play a significant role in planning and designing of new cropping area in that location, to achieve maximum returns. Soil information systems based on database through ground survey in combination with Geographic Information System have immense potential in planning, judicious management, conservation and sustainable use of soil, land and crop resources.

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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............)

APPENDIX - I (.........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 the analytical work on the soils of the western part of the main campus, KAU

No.	*Sample Code	Phase	Gravel %	Fine earth %	Sand %	Silt %	Clay %	Textural class	pH	EC dS/m	Buffer pH	Lime R. ($t\ ha^{-1}$)	Org. C (%)	Av. P ($\mu g\ g^{-1}$)	Av. K ($\mu g\ g^{-1}$)	Av. Na ($\mu g\ g^{-1}$)	Av. Ca ($\mu g\ g^{-1}$)	Av. Mg ($\mu g\ g^{-1}$)
1	26 / 1A	6	65.00	35.00	**N.A.				5.34	0.044	6.1	13.4	0.94	20.42	147	34	155.0	34.00
2	26 / 1B	6	40.60	59.40	N.A.				5.25	0.022	5.3	26.7	1.05	3.04	98	46	106.0	26.05
3	26 / 2A	6	50.00	50.00	N.A.				5.26	0.022	5.8	18.6	1.01	1.83	72	36	126.0	28.05
4	26 / 2B	6	51.30	48.70	N.A.				4.86	0.144	5.5	23.3	0.97	0.92	78	47	166.0	28.70
5	26 / 3A	32	69.00	31.00	N.A.				5.28	0.044	5.8	18.6	0.73	6.54	90	28	64.5	25.80
6	26 / 3B	32	40.00	60.00	N.A.				4.89	0.068	5.9	17.2	0.69	1.50	66	41	144.5	29.10
7	26 / 4A	32	54.00	46.00	N.A.				5.08	0.011	4.8	34.9	0.79	1.13	52	38	128.5	26.80
8	26 / 4B	32	55.30	44.70	N.A.				5.34	0.011	6.2	12.1	0.93	5.79	85	35	118.5	29.20
9	26 / 5A	33	63.00	37.00	N.A.				5.43	0.003	6.5	7.0	0.93	4.33	138	24	130.5	30.90
10	26 / 5B	33	52.60	47.40	N.A.				5.45	0.002	6.8	2.4	0.86	0.46	138	28	126.0	30.55
11	26 / 6A	32	74.00	26.00	54.92	26.69	18.39	Sandy Clay Loam	5.10	0.027	6.8	2.4	1.11	5.83	116	24	125.0	32.90
12	26 / 6B	32	46.40	53.60	51.20	28.11	20.69	Sandy Clay Loam	6.55	0.005	4.8	34.9	1.02	2.88	64	10	29.5	19.05
13	26 / 7A	33	62.00	38.00	49.33	10.86	39.81	Sandy Clay	4.87	0.117	5.8	18.6	1.10	1.55	98	35	139.5	31.60
14	26 / 7B	33	40.93	59.07	45.55	13.95	40.50	Sandy Clay	5.09	0.063	5.5	23.3	0.74	0.42	78	42	178.0	29.70
15	26 / 8A	32	57.00	43.00	N.A.				5.31	0.002	5.3	26.7	1.15	0.58	53	34	146.0	32.45
16	26 / 8B	32	47.40	52.60	N.A.				5.26	0.001	5.0	31.8	0.94	2.38	43	39	169.0	32.70
17	26 / 9A	34	72.00	28.00	48.11	13.26	38.63	Sandy Clay	5.27	0.007	6.1	13.4	1.10	3.46	78	33	158.5	35.35
18	26 / 9B	34	44.00	56.00	44.20	15.20	40.60	Sandy Clay	5.11	0.008	5.3	26.7	0.84	0.29	58	29	125.0	31.35
19	26 / 10A	28	66.60	33.40	62.61	15.47	21.92	Sandy Clay Loam	5.38	0.007	5.8	18.6	1.11	6.90	75	25	112.5	30.65
20	26 / 10B	28	40.26	59.74	56.50	16.19	27.31	Sandy Clay Loam	5.34	0.007	5.5	23.3	0.84	1.13	106	27	97.5	30.15
21	26 / 11A	28	53.00	47.00	N.A.				5.41	0.014	5.8	18.6	0.73	1.29	76	27	126.5	32.95
22	26 / 11B	28	34.06	65.94	N.A.				5.15	0.001	5.9	17.2	0.94	0.42	68	18	59.0	29.85
23	26 / 12A	32	55.00	45.00	55.20	12.88	31.92	Sandy Clay Loam	5.08	0.003	4.8	34.9	0.73	0.75	54	13	26.0	17.05
24	26 / 12B	32	53.00	47.00	51.24	15.04	33.72	Sandy Clay Loam	5.78	0.044	6.2	12.1	1.37	4.29	80	42	225.5	34.00
25	26 / 13A	28	49.00	51.00	55.24	18.73	26.03	Sandy Clay Loam	5.18	0.007	6.5	7.0	1.16	3.46	63	19	85.0	30.60
26	26 / 13B	28	38.66	61.34	48.30	21.84	29.86	Sandy Clay Loam	5.07	0.001	6.8	2.4	0.74	1.88	57	17	59.0	27.30
27	26 / 14A	28	44.00	56.00	N.A.				5.02	0.001	6.8	2.4	0.81	5.88	58	16	58.0	28.00
28	26 / 14B	28	47.46	52.54	N.A.				4.41	0.286	4.8	34.9	0.63	0.67	57	23	75.0	28.05
29	26 / 15A	13	59.00	41.00	N.A.				5.23	0.011	6.7	4.1	1.41	1.79	66	16	75.0	31.85

*Sample code:- Block No./ sample site No. and surface(A) or subsurface(B)

**N.A: Not analysed

Appendix III.

Raw Data generated by the analytical work on the soils of the western part of the main campus, KAU

No.	Av. Mn ($\mu g\ g^{-1}$)	Av. Zn ($\mu g\ g^{-1}$)	Av. Cu ($\mu g\ g^{-1}$)	Av. Fe ($\mu g\ g^{-1}$)	P- fix.cap. %	Exch. Fe ($\mu g\ g^{-1}$)	Exch. Mn ($\mu g\ g^{-1}$)	Exch. Ca ($\mu g\ g^{-1}$)	Exch. Mg ($\mu g\ g^{-1}$)	Exch. Na ($\mu g\ g^{-1}$)	Exch. K ($\mu g\ g^{-1}$)	Exch. Al ($\mu g\ g^{-1}$)	CEC cmol(+) kg^{-1}	Na sat. %	BSP %	Al sat. %
1	44.3	0.59	5.72	27.7	N.A.	2.90	86.4	332	94.3	174	154	8.75	4.0091	18.88	89.47	2.43
2	40.2	0.39	5.83	10.3	N.A.	2.80	66.2	308	64.2	160	114	17.50	3.5016	19.88	87.27	5.56
3	51.6	0.49	4.94	12.9	N.A.	2.90	78.2	295	62.7	150	98	21.25	3.4256	19.05	84.49	6.90
4	63.6	0.29	2.58	13.5	N.A.	2.90	73.8	151	69.0	162	100	21.25	2.7987	25.18	81.58	8.45
5	53.0	0.49	6.96	14.0	N.A.	2.70	75.5	262	55.4	138	112	29.00	3.2598	18.41	81.38	9.90
6	80.6	0.49	3.06	14.9	N.A.	2.80	114.5	255	67.4	150	94	19.88	3.3705	19.36	80.78	6.56
7	79.9	0.39	6.84	13.7	N.A.	3.90	111.4	224	62.9	144	84	29.50	3.2265	19.41	76.83	10.17
8	61.2	0.49	4.76	22.2	N.A.	2.90	67.3	205	65.4	140	100	23.00	2.9392	20.72	82.61	8.70
9	35.6	0.49	2.66	12.3	N.A.	2.80	36.0	239	67.8	146	130	23.75	3.1258	20.32	87.04	8.45
10	49.0	0.39	2.00	14.3	N.A.	3.10	49.5	244	67.2	150	136	32.50	3.3262	19.62	83.38	10.87
11	39.3	0.59	8.38	13.3	N.A.	3.10	40.8	88	71.5	146	122	24.88	2.4119	26.33	81.91	11.47
12	51.4	0.29	17.05	13.4	N.A.	3.30	59.5	267	36.2	132	100	62.50	3.3865	16.95	72.73	20.53
13	46.8	0.49	4.33	10.1	49.57	3.40	49.2	257	66.1	156	116	36.25	3.3988	19.96	82.51	11.86
14	33.9	0.39	1.80	9.1	61.32	3.30	38.0	305	75.6	170	104	17.75	3.5003	21.13	90.07	5.64
15	51.4	0.59	5.24	9.2	56.24	3.30	53.9	254	71.2	154	90	29.25	3.2894	20.36	83.78	9.89
16	56.2	0.39	2.89	10.8	62.54	3.50	58.0	290	71.4	154	82	23.13	3.3981	19.71	85.85	7.57
17	54.8	0.79	7.45	23.7	56.80	3.30	51.0	270	76.0	148	102	20.88	3.3098	19.45	87.02	7.02
18	50.2	0.49	2.57	20.6	61.41	3.30	46.1	262	66.7	148	90	35.50	3.3074	19.46	82.63	11.94
19	57.9	0.69	8.60	19.5	54.88	3.30	60.9	236	65.8	138	98	16.13	2.9853	20.11	86.17	6.01
20	40.0	0.49	2.75	9.1	62.47	3.00	40.1	199	64.6	138	114	19.75	2.7949	21.48	86.53	7.86
21	72.4	0.59	6.66	12.9	N.A.	2.90	78.4	258	74.4	130	84	17.50	3.1731	17.82	84.54	6.13
22	60.3	0.39	1.63	15.8	N.A.	2.90	74.7	160	62.5	136	96	17.50	2.6285	22.51	81.85	7.41
23	55.0	0.39	1.64	14.8	N.A.	6.30	47.0	92	31.6	128	92	39.63	2.1466	25.94	70.44	20.53
24	72.5	0.89	6.07	43.3	N.A.	3.10	39.8	369	76.3	160	100	3.75	3.6224	19.21	94.54	1.15
25	66.0	0.89	5.54	15.3	N.A.	3.00	63.4	264	66.1	140	102	25.38	3.2577	18.69	83.92	8.66
26	75.6	0.49	1.86	14.7	N.A.	3.10	101.1	169	48.5	148	102	31.50	2.8783	22.37	74.65	12.17
27	82.2	0.59	4.04	21.5	N.A.	3.40	95.6	171	61.5	150	102	38.88	3.0671	21.27	74.16	14.10
28	97.2	0.49	1.80	13.4	N.A.	2.90	112.5	220	69.6	150	108	32.13	3.3788	19.31	77.00	10.58
29	86.2	0.49	7.95	15.5	N.A.	2.80	72.3	182	68.0	150	98	27.00	2.9463	22.14	80.53	10.19

*Sample code:- Block No./ sample site No. and surface(A) or subsurface(B)

**N.A: Not analysed

Appendix III.

Raw Data generated by the analytical work on the soils of the western part of the main campus, KAU

No.	*Sample Code	Phase	Gravel %	Fine earth %	Sand %	Silt %	Clay %	Textural class	pH	EC dS/m	Buffer pH	Lime R. (t ha^{-1})	Org. C (%)	Av. P (µg g^{-1})	Av. K (µg g^{-1})	Av. Na (µg g^{-1})	Av. Ca (µg g^{-1})	Av. Mg (µg g^{-1})
30	26 / 15B	13	40.53	59.47	N.A.				4.34	0.451	6.7	4.1	0.83	0.38	58	47	102.5	19.95
31	26 / 16A	28	39.00	61.00	58.36	18.22	23.42	Sandy Clay Loam	4.59	0.034	6.8	2.4	1.10	9.31	105	18	93.5	28.90
32	26 / 16B	28	44.60	55.40	53.10	19.95	26.95	Sandy Clay Loam	4.95	0.011	6.1	13.4	0.81	1.13	38	16	64.5	22.45
33	26 / 17A	28	56.00	44.00	N.A.				5.03	0.002	5.5	23.3	0.92	2.96	66	18	75.0	25.35
34	26 / 17B	28	34.00	66.00	N.A.				5.12	0.003	5.5	23.3	0.71	0.58	68	17	151.0	31.20
35	26 / 18A	16	55.00	45.00	55.63	12.73	31.64	Sandy Clay Loam	5.24	0.013	4.8	34.9	1.40	6.96	58	18	89.0	30.25
36	26 / 18B	16	40.60	59.40	50.23	15.40	34.37	Sandy Clay Loam	5.16	0.005	5.4	25.3	0.90	1.50	57	18	64.0	26.80
37	26 / 19A	28	68.00	32.00	55.64	22.33	22.03	Sandy Clay Loam	5.02	0.024	5.2	28.5	1.32	3.75	80	24	117.0	29.30
38	26 / 19B	28	40.00	60.00	51.51	22.46	26.03	Sandy Clay Loam	4.93	0.007	5.4	25.3	0.84	1.13	54	20	98.0	26.40
39	26 / 20A	31	62.00	38.00	52.77	18.56	28.67	Sandy Clay Loam	5.25	0.032	5.2	28.5	1.44	8.00	87	34	188.5	31.90
40	26 / 20B	31	47.40	52.60	46.25	24.28	29.47	Sandy Clay Loam	4.93	0.003	4.9	33.6	1.11	1.00	69	16	61.5	25.70
41	26 / 21A	30	62.00	38.00	N.A.				4.39	0.198	5.0	31.8	1.26	3.60	51	46	195.5	17.75
42	26 / 21B	30	41.20	58.80	N.A.				5.11	0.023	5.2	28.5	0.84	3.46	48	27	155.0	23.60
43	26 / 22A	2	60.00	40.00	68.43	9.32	22.25	Sandy Clay Loam	4.93	0.017	5.1	30.2	1.20	3.92	46	13	59.5	24.40
44	26 / 22B	2	38.60	61.40	60.85	11.08	28.07	Sandy Clay Loam	4.90	0.005	5.1	30.2	0.83	1.75	43	10	27.5	15.90
45	26 / 23A	2	62.00	38.00	N.A.				4.80	0.084	5.2	28.5	1.26	20.96	55	35	139.0	22.45
46	26 / 23B	2	36.60	63.40	N.A.				5.10	0.017	5.2	28.5	0.75	1.75	54	18	87.0	25.45
47	26 / 24A	28	50.00	50.00	N.A.				5.12	0.023	5.2	28.5	1.58	6.81	78	23	123.0	30.45
48	26 / 24B	28	48.00	52.00	N.A.				5.01	0.007	5.0	31.8	1.05	1.29	62	18	62.0	26.85
49	27 / 1A	34	60.00	40.00	46.97	25.33	27.70	Sandy Clay Loam	4.63	0.035	5.1	30.2	1.49	1.71	56	20	95.0	30.50
50	27 / 1B	34	38.66	61.34	38.83	31.91	29.26	Clay Loam	5.06	0.017	5.1	30.2	1.16	1.00	44	26	101.0	30.00
51	27 / 2A	19	66.60	33.40	N.A.				5.11	0.030	5.0	31.8	1.95	0.75	118	30	138.5	37.00
52	27 / 2B	19	52.00	48.00	N.A.				5.01	0.008	4.8	34.9	1.23	0.38	117	20	87.5	34.50
53	27 / 3A	19	53.00	47.00	N.A.				5.06	0.038	4.8	34.9	1.98	4.29	66	20	96.5	32.50
54	27 / 3B	19	45.33	54.67	N.A.				5.12	0.019	4.8	34.9	1.59	1.00	59	21	123.0	30.00
55	27 / 4A	19	66.00	34.00	51.17	12.62	36.21	Sandy Clay	5.38	0.023	5.1	30.2	1.17	1.25	111	53	183.5	40.50
56	27 / 4B	19	38.00	62.00	42.72	17.23	40.05	Clay Loam	5.08	0.006	4.9	33.6	0.87	0.83	76	15	83.0	6.50
57	27 / 5A	22	60.00	40.00	N.A.				4.75	0.025	4.8	34.9	1.34	2.63	20	17	67.0	24.00
58	27 / 5B	22	28.60	71.40	N.A.				4.90	0.016	5.2	28.5	1.23	1.96	15	15	88.5	21.00

*Sample code:- Block No./ sample site No. and surface(A) or subsurface(B)
**N.A: Not analysed

Appendix III.

Raw Data generated by the analytical work on the soils of the western part of the main campus, KAU

No.	Av. Mn ($\mu g\ g^{-1}$)	Av. Zn ($\mu g\ g^{-1}$)	Av. Cu ($\mu g\ g^{-1}$)	Av. Fe ($\mu g\ g^{-1}$)	P- fix.cap. %	Exch. Fe ($\mu g\ g^{-1}$)	Exch. Mn ($\mu g\ g^{-1}$)	Exch. Ca ($\mu g\ g^{-1}$)	Exch. Mg ($\mu g\ g^{-1}$)	Exch. Na ($\mu g\ g^{-1}$)	Exch. K ($\mu g\ g^{-1}$)	Exch. Al ($\mu g\ g^{-1}$)	CEC cmol(+) kg^{-1}	Na sat. %	BSP %	Al sat. %
30	67.0	0.39	2.42	11.7	N.A.	2.60	79.9	207	59.9	142	106	29.63	3.0465	20.27	79.33	10.82
31	64.8	0.99	9.24	19.0	52.34	2.50	75.6	227	65.6	154	92	18.25	3.0672	21.84	84.12	6.62
32	54.1	0.59	3.34	21.3	58.49	2.40	68.9	196	47.6	132	108	31.13	2.8278	20.30	78.58	12.24
33	51.5	0.69	5.72	12.8	N.A.	2.30	63.2	168	76.0	138	84	33.38	2.8902	20.77	78.91	12.85
34	54.3	0.49	1.74	13.2	N.A.	2.30	73.5	272	67.1	132	90	22.88	3.2469	17.68	83.67	7.84
35	101.0	0.89	7.71	18.7	N.A.	2.10	91.6	202	58.5	142	82	9.50	2.7655	22.33	83.85	3.82
36	94.3	0.69	3.53	16.8	N.A.	2.30	81.9	155	52.4	134	96	15.63	2.5148	23.18	80.91	6.91
37	94.0	0.79	21.47	26.8	51.87	2.60	115.5	272	55.7	126	88	8.38	3.1145	17.60	83.21	2.99
38	105.5	0.59	7.14	18.7	60.25	2.30	112.4	207	50.1	140	100	15.63	2.9033	20.97	79.64	5.99
39	86.4	1.09	10.89	46.3	61.50	2.70	72.9	330	68.5	132	86	2.88	3.3149	17.32	90.74	0.96
40	75.9	0.89	7.00	30.3	65.87	2.40	72.4	151	49.2	150	110	29.00	2.6885	24.27	77.88	12.00
41	96.9	0.79	9.50	44.7	65.50	2.60	111.5	405	30.5	116	84	35.75	3.8083	13.25	78.66	10.44
42	43.8	0.39	3.70	15.5	68.30	2.70	45.6	372	47.4	152	82	40.75	3.7500	17.63	83.23	12.09
43	52.6	0.49	10.69	19.7	N.A.	2.80	50.8	196	43.6	144	84	39.50	2.8144	22.26	77.46	15.61
44	46.5	0.29	2.88	19.8	N.A.	2.40	92.9	46	27.6	116	76	36.50	1.9089	26.43	60.56	21.27
45	40.0	0.69	2.90	36.4	N.A.	3.00	196.6	221	44.1	116	78	34.88	3.2864	15.35	66.09	11.80
46	97.6	0.49	13.62	19.5	N.A.	2.10	167.8	146	45.3	132	84	39.13	2.9454	19.49	64.23	14.78
47	100.4	0.69	8.50	19.3	N.A.	2.20	165.0	180	69.5	130	84	24.63	3.1348	18.04	71.85	8.74
48	93.7	0.39	4.15	18.5	N.A.	2.50	188.3	112	55.9	112	82	32.38	2.7715	17.58	61.95	12.99
49	41.5	0.39	6.09	14.0	51.23	1.70	91.2	148	61.4	120	80	51.13	2.8787	18.13	68.50	19.76
50	38.8	0.19	3.21	16.0	50.63	3.00	91.3	168	65.3	106	50	52.63	2.8949	15.93	67.93	20.22
51	43.1	0.49	7.76	20.0	N.A.	1.50	119.7	231	85.5	142	108	36.00	3.5941	17.19	76.59	11.14
52	33.7	0.19	4.51	17.4	N.A.	3.20	101.7	178	51.7	122	92	48.00	2.9971	17.71	69.45	17.81
53	43.1	0.39	7.51	22.3	N.A.	3.50	98.4	204	77.3	118	76	33.63	3.1086	16.51	76.04	12.03
54	45.3	0.39	4.17	14.7	N.A.	2.90	88.0	184	63.3	130	78	45.25	3.0400	18.60	72.56	16.56
55	47.0	0.49	5.84	13.6	60.21	2.90	75.9	272	52.6	156	118	5.75	3.1239	21.72	88.78	2.05
56	66.3	0.19	1.52	12.1	67.38	2.80	144.3	140	64.9	130	94	49.75	3.1288	18.07	65.20	17.69
57	37.4	0.29	5.32	12.5	N.A.	3.30	92.9	106	48.8	132	70	57.38	2.6731	21.48	63.03	23.88
58	35.0	0.29	5.23	12.2	N.A.	2.90	79.9	131	89.0	138	72	54.25	3.0766	19.51	70.59	19.61

*Sample code:- Block No./ sample site No. and surface(A) or subsurface(B)
**N.A: Not analysed

Appendix III.

Raw Data generated by the analytical work on the soils of the western part of the main campus, KAU

No.	*Sample Code	Phase	Gravel %	Fine earth %	Sand %	Silt %	Clay %	Textural class	pH	EC dS/m	Buffer pH	Lime R. (t ha^{-1})	Org. C (%)	Av. P (µg g^{-1})	Av. K (µg g^{-1})	Av. Na (µg g^{-1})	Av. Ca (µg g^{-1})	Av. Mg (µg g^{-1})
59	27 / 6A	22	58.00	42.00	50.10	28.83	21.07	Sandy Clay Loam	4.98	0.029	4.9	33.6	1.64	2.96	70	22	105.0	33.00
60	27 / 6B	22	54.00	46.00	45.50	32.68	21.82	Loam	5.11	0.013	4.9	33.6	1.26	0.42	87	32	149.0	31.00
61	27 / 7A	16	50.00	50.00	N.A.				5.19	0.023	5.3	26.7	1.20	0.75	27	32	195.5	31.50
62	27 / 7B	16	50.66	49.34	N.A.				5.10	0.005	5.2	28.5	1.01	0.83	21	27	182.0	29.00
63	27 / 8A	22	56.00	44.00	N.A.				4.88	0.017	5.0	31.8	1.02	1.29	43	24	136.5	31.00
64	27 / 8B	22	55.30	44.70	N.A.				4.94	0.286	5.2	28.5	0.75	0.29	63	118	205.5	31.00
65	27 / 9A	22	57.00	43.00	N.A.				4.94	0.056	5.1	30.2	1.02	8.79	31	17	56.0	23.00
66	27 / 9B	22	43.66	56.34	N.A.				4.91	0.023	5.0	31.8	1.09	2.17	36	11	45.0	15.00
67	27 / 10A	22	45.00	55.00	N.A.				5.08	0.025	5.0	31.8	0.99	6.08	93	30	129.5	28.50
68	27 / 10B	22	39.33	60.67	N.A.				5.09	0.010	5.1	30.2	0.58	4.58	62	21	113.5	27.00
69	27 / 11A	22	57.00	43.00	51.66	22.75	25.59	Sandy Clay Loam	5.27	0.012	5.2	28.5	0.81	0.21	41	25	193.0	30.50
70	27 / 11B	22	32.00	68.00	46.25	24.54	29.21	Sandy Clay Loam	5.13	0.019	5.3	26.7	0.71	3.58	94	33	141.5	33.50
71	27 / 12A	32	68.00	32.00	N.A.				5.04	0.020	5.6	21.8	0.87	9.42	40	34	239.0	32.50
72	27 / 12B	32	44.00	56.00	N.A.				5.08	0.010	5.3	26.7	0.80	0.46	29	31	201.0	30.50
73	27 / 13A	32	69.00	31.00	54.24	27.19	18.57	Sandy Loam	5.61	0.019	5.4	25.3	1.40	2.25	35	37	245.0	33.00
74	27 / 13B	32	48.00	52.00	50.91	27.68	21.41	Sandy Clay Loam	5.38	0.008	5.2	28.5	0.89	0.83	103	26	177.5	31.50
75	27 / 14A	33	71.00	29.00	61.38	8.76	29.86	Sandy Loam	5.97	0.038	5.5	23.3	1.25	1.96	74	75	312.0	37.50
76	27 / 14B	33	47.30	52.70	55.10	10.67	34.23	Sandy Clay Loam	4.99	0.014	6.0	15.2	0.75	0.29	111	39	304.0	17.00
77	27 / 15A	33	70.00	30.00	N.A.				5.03	0.028	6.3	10.5	1.53	4.38	31	26	149.5	32.00
78	27 / 15B	33	41.30	58.70	N.A.				5.11	0.009	6.6	5.3	0.99	3.50	20	20	138.0	27.00
79	27 / 16A	33	64.00	36.00	N.A.				5.87	0.056	5.1	30.2	1.65	6.83	93	40	141.5	35.00
80	27 / 16B	33	42.00	58.00	N.A.				5.30	0.023	4.8	34.9	0.80	2.00	107	26	208.5	36.00
81	27 / 17A	37	57.00	43.00	58.52	19.36	22.12	Sandy Clay Loam	4.84	0.012	5.3	26.7	0.81	1.75	41	20	152.0	31.50
82	27 / 17B	37	35.00	65.00	52.50	22.66	24.84	Sandy Clay Loam	5.07	0.010	5.1	30.2	0.77	0.08	28	33	227.5	33.50
83	27 / 18A	33	66.00	34.00	N.A.				5.64	0.015	5.4	25.3	1.07	3.79	76	28	254.5	36.00
84	27 / 18B	33	42.60	57.40	N.A.				5.73	0.010	5.2	28.5	0.78	1.00	85	19	203.5	34.50
85	27 / 19A	37	71.00	29.00	45.75	17.06	37.19	Sandy Clay	4.94	0.012	5.1	30.2	0.92	1.79	8	19	134.5	28.00
86	27 / 19B	37	42.66	57.34	42.10	18.55	39.35	Clay Loam	5.14	0.012	5.2	28.5	0.78	0.13	39	30	252.5	35.00
87	27 / 20A	19	68.00	32.00	55.20	10.43	34.37	Sandy Clay Loam	5.04	0.001	5.0	31.8	1.28	2.21	23	12	84.0	27.50

*Sample code:- Block No./ sample site No. and surface(A) or subsurface(B)

**N.A: Not analysed

Appendix III.

Raw Data generated by the analytical work on the soils of the western part of the main campus, KAU

No.	Av. Mn ($\mu g\ g^{-1}$)	Av. Zn ($\mu g\ g^{-1}$)	Av. Cu ($\mu g\ g^{-1}$)	Av. Fe ($\mu g\ g^{-1}$)	P- fix.cap. %	Exch. Fe ($\mu g\ g^{-1}$)	Exch. Mn ($\mu g\ g^{-1}$)	Exch. Ca ($\mu g\ g^{-1}$)	Exch. Mg ($\mu g\ g^{-1}$)	Exch. Na ($\mu g\ g^{-1}$)	Exch. K ($\mu g\ g^{-1}$)	Exch. Al ($\mu g\ g^{-1}$)	CEC cmol(+) kg^{-1}	Na sat. %	BSP %	Al sat. %
59	39.2	0.29	8.15	9.7	N.A.	2.90	9.2	180	71.0	128	78	50.13	2.8421	19.59	78.84	19.62
60	48.6	0.39	4.96	10.5	N.A.	2.70	86.9	90	65.1	124	74	36.50	2.4464	22.05	70.08	16.60
61	56.8	0.29	7.38	13.5	48.79	3.20	131.7	251	67.4	134	60	29.25	3.3623	17.34	75.72	9.68
62	40.6	0.29	3.19	14.1	58.47	2.80	93.8	213	61.4	208	102	42.75	3.5630	25.39	76.79	13.35
63	36.9	0.39	3.65	12.7	N.A.	3.20	72.2	181	67.9	192	114	41.38	3.3251	25.12	77.91	13.84
64	51.2	0.19	1.52	14.0	N.A.	2.70	114.4	151	73.4	322	144	19.38	3.7697	37.15	82.98	5.72
65	6.2	0.29	3.38	16.6	N.A.	2.90	11.8	85	48.0	180	112	29.63	2.2723	34.46	83.15	14.50
66	8.8	0.29	2.09	16.0	N.A.	2.50	16.8	70	32.0	172	112	38.50	2.1463	34.86	76.78	19.95
67	50.0	0.49	4.71	20.8	N.A.	3.10	81.1	166	60.4	194	134	41.13	3.2775	25.75	76.70	13.96
68	30.1	0.39	1.90	21.2	N.A.	2.80	78.0	298	61.4	158	112	49.25	3.8109	18.03	77.91	14.38
69	43.7	0.59	6.81	11.6	52.58	3.10	95.1	249	81.1	188	98	18.50	3.5440	23.07	84.11	5.81
70	51.6	0.79	6.03	17.6	56.70	2.50	103.9	212	74.2	178	138	24.75	3.4604	22.37	80.85	7.96
71	36.6	0.59	1.08	20.3	N.A.	2.70	84.9	188	61.2	172	110	29.50	3.1201	23.98	79.27	10.52
72	37.6	0.29	3.66	16.8	N.A.	2.70	63.2	321	58.1	166	94	33.75	3.6608	19.72	83.20	10.26
73	38.4	0.89	1.81	13.3	59.20	2.30	63.3	278	89.0	202	128	12.75	3.7090	23.69	89.74	3.82
74	33.0	0.69	6.50	14.7	64.80	2.40	69.5	290	73.1	186	102	21.25	3.6195	22.35	86.24	6.53
75	25.1	0.59	5.22	12.1	59.70	2.40	36.5	330	85.9	196	176	6.13	3.8693	22.03	94.58	1.76
76	36.6	0.39	6.17	16.3	63.98	2.50	63.6	329	58.5	172	154	44.63	4.0054	18.68	81.60	12.39
77	28.2	0.79	1.82	12.2	N.A.	2.60	66.5	228	78.9	168	102	36.63	3.4398	21.24	80.85	11.84
78	18.6	0.79	2.63	15.6	N.A.	2.30	40.9	214	56.5	170	94	44.13	3.1628	23.38	79.51	15.52
79	38.7	0.89	1.40	24.6	N.A.	2.10	52.7	332	78.1	196	150	12.25	3.8746	22.00	91.34	3.52
80	17.4	0.49	3.66	14.1	N.A.	2.40	41.6	246	78.2	170	162	17.25	3.3793	21.88	89.59	5.68
81	29.2	0.59	2.56	35.5	61.38	2.20	67.6	215	68.1	180	120	41.38	3.4395	22.76	79.24	13.38
82	30.6	0.49	5.67	16.7	75.30	2.10	72.4	253	81.2	174	94	50.75	3.7662	20.10	77.81	14.99
83	29.9	0.69	1.28	10.2	N.A.	2.00	60.4	271	81.1	162	128	14.75	3.4456	20.45	88.65	4.76
84	26.3	0.59	3.07	11.3	N.A.	2.40	62.5	237	77.7	158	150	25.38	3.4138	20.13	84.82	8.27
85	35.1	0.59	2.00	13.0	51.84	2.40	71.2	203	65.6	196	146	50.50	3.6104	23.61	77.02	15.56
86	24.3	0.49	5.67	13.4	63.40	2.50	54.6	206	75.6	222	128	24.75	3.4282	28.17	85.91	8.03
87	52.2	0.49	5.67	16.8	56.74	2.50	110.9	273	55.0	200	124	46.63	3.9361	22.10	76.34	13.18

*Sample code:- Block No./ sample site No. and surface(A) or subsurface(B)

**N.A: Not analysed

Appendix III.

Raw Data generated by the analytical work on the soils of the western part of the main campus, KAU

No.	*Sample Code	Phase	Gravel %	Fine earth %	Sand %	Silt %	Clay %	Textural class	pH	EC dS/m	Buffer pH	Lime R. (t ha^{-1})	Org. C (%)	Av. P (μg g^{-1})	Av. K (μg g^{-1})	Av. Na (μg g^{-1})	Av. Ca (μg g^{-1})	Av. Mg (μg g^{-1})
88	27 / 20B	19	42.50	57.50	51.24	11.83	36.93	Sandy Clay	4.72	0.006	5.2	28.5	0.81	5.38	24	10	86.0	25.00
89	27 / 21A	24	59.00	41.00	56.33	23.68	19.99	Sandy Clay Loam	5.69	0.049	5.4	25.3	1.53	2.46	115	37	345.0	35.00
90	27 / 21B	24	37.30	62.70	48.65	15.88	35.47	Sandy Clay Loam	4.83	0.080	5.2	28.5	1.10	2.42	60	27	246.5	32.50
91	27 / 22A	24	47.00	53.00	57.79	26.07	16.14	Sandy Loam	5.38	0.200	5.3	26.7	1.05	1.13	69	35	184.5	37.00
92	27 / 22B	24	31.46	68.54	46.98	15.18	37.84	Sandy Clay	5.89	0.001	5.5	23.3	0.50	0.29	48	35	173.5	35.00
93	27 / 23A	24	33.00	67.00	N.A.				5.36	0.100	5.7	20.1	1.64	2.45	106	75	446.5	39.50
94	27 / 23B	24	38.53	61.47	N.A.				5.08	0.057	5.3	26.7	1.26	0.30	96	50	321.9	40.00
95	27 / 24A	24	40.00	60.00	N.A.				4.86	0.006	5.1	30.2	1.25	4.38	38	20	154.0	31.00
96	27 / 24B	24	39.53	60.47	N.A.				4.89	0.014	5.1	30.2	0.86	0.13	29	12	109.0	26.00
97	28 / 1A	17	53.00	47.00	N.A.				4.98	0.037	5.2	28.5	1.32	2.08	24	17	113.5	28.00
98	28 / 1B	17	32.00	68.00	N.A.				5.02	0.005	5.0	31.8	0.92	0.13	22	11	121.5	29.00
99	28 / 2A	17	62.00	38.00	55.50	16.38	28.12	Sandy Clay Loam	4.92	0.004	5.1	30.2	1.19	1.66	41	10	70.4	25.00
100	28 / 2B	17	36.20	63.80	48.60	17.45	33.95	Sandy Clay Loam	4.89	0.001	5.8	18.6	0.95	2.54	31	10	59.5	27.00
101	28 / 3A	17	61.00	39.00	N.A.				5.17	0.014	5.4	25.3	1.25	1.92	26	10	65.5	20.00
102	28 / 3B	17	33.46	66.54	N.A.				5.27	0.001	5.6	21.8	0.83	2.79	17	11	100.0	25.50
103	28 / 4A	17	53.30	46.70	N.A.				5.18	0.028	5.5	23.3	1.73	5.58	19	24	249.5	30.00
104	28 / 4B	17	35.60	64.40	N.A.				4.73	0.007	5.4	25.3	1.07	2.04	17	13	149.0	25.50
105	28 / 5A	13	59.00	41.00	N.A.				4.61	0.049	5.3	26.7	1.05	9.79	66	12	81.5	23.00
106	28 / 5B	13	34.20	65.80	N.A.				4.84	0.018	5.7	20.1	0.65	3.21	41	8	47.0	12.50
107	28 / 6A	19	71.00	29.00	58.23	18.74	23.03	Sandy Clay Loam	6.11	0.012	6.3	10.5	0.87	6.33	59	25	340.5	29.50
108	28 / 6B	19	38.53	61.47	53.61	21.52	24.87	Sandy Clay Loam	6.12	0.003	6.3	10.5	0.61	2.21	65	29	356.0	28.00
109	28 / 7A	17	53.00	47.00	N.A.				4.96	0.016	5.8	18.6	0.87	9.33	37	12	75.5	21.50
110	28 / 7B	17	41.66	58.34	N.A.				5.04	0.006	5.5	23.3	0.60	1.04	40	16	136.5	28.00
111	29 / 1A	15	77.00	23.00	N.A.				5.02	0.017	5.6	21.8	1.13	7.42	60	11	65.0	21.00
112	29 / 1B	15	22.00	78.00	N.A.				4.89	0.009	5.7	20.1	0.95	2.00	59	8	17.5	8.50
113	29 / 2A	15	53.00	47.00	57.77	10.70	31.53	Sandy Clay Loam	4.86	0.009	5.3	26.7	1.19	8.96	37	9	40.0	15.00
114	29 / 2B	15	34.40	65.60	55.16	11.16	33.68	Sandy Clay Loam	4.05	0.147	5.2	28.5	1.11	4.46	24	17	48.0	11.50
115	29 / 3A	13	77.00	23.00	N.A.				4.29	0.027	5.3	26.7	1.26	3.46	11	11	46.5	11.50
116	29 / 3B	13	43.53	56.47	N.A.				4.74	0.010	5.2	28.5	1.25	1.33	14	10	46.0	17.50

*Sample code:- Block No./ sample site No. and surface(A) or subsurface(B)

**N.A: Not analysed

Appendix III.

Raw Data generated by the analytical work on the soils of the western part of the main campus, KAU

No.	Av. Mn (µg g-1)	Av. Zn (µg g-1)	Av. Cu (µg g-1)	Av. Fe (µg g-1)	P- fix.cap. %	Exch. Fe (µg g-1)	Exch. Mn (µg g-1)	Exch. Ca (µg g-1)	Exch. Mg (µg g-1)	Exch. Na (µg g-1)	Exch. K (µg g-1)	Exch. Al (µg g-1)	CEC cmol(+) kg-1	Na sat. %	BSP %	Al sat. %
88	68.8	0.39	5.77	18.7	66.04	2.30	147.2	152	43.7	176	112	38.00	3.1385	24.39	69.20	13.47
89	51.5	1.09	5.09	13.5	55.95	2.30	104.7	340	63.1	240	224	10.63	4.3437	24.03	88.31	2.72
90	34.3	0.59	6.22	15.0	60.45	2.80	87.3	287	72.0	214	158	28.63	4.0088	23.22	83.88	7.94
91	41.2	0.49	2.70	19.2	49.70	2.10	86.4	250	83.0	216	160	26.88	3.9029	24.07	84.09	7.66
92	37.4	0.29	0.72	15.1	57.41	2.00	91.9	236	79.7	202	132	33.13	3.7624	23.35	81.12	9.79
93	58.8	1.09	4.69	24.2	N.A.	1.90	67.1	393	75.6	238	190	10.63	4.4776	23.12	91.75	2.64
94	49.1	0.79	8.53	15.6	N.A.	5.30	94.3	326	93.6	230	166	14.50	4.3489	23.00	87.96	3.71
95	33.6	0.49	6.32	13.6	N.A.	2.30	81.6	230	72.1	192	126	28.25	3.5203	23.72	82.40	8.93
96	65.6	0.49	2.47	19.0	N.A.	2.30	154.4	179	46.5	184	122	51.75	3.5360	22.63	67.59	16.28
97	100.8	0.39	7.61	19.3	N.A.	2.40	162.8	113	43.0	182	166	49.25	3.2842	24.10	65.01	16.68
98	70.5	0.29	3.17	15.8	N.A.	2.60	166.9	71	16.8	178	142	45.50	2.7537	28.12	59.22	18.38
99	57.8	0.29	5.54	14.2	61.12	2.30	62.3	322	64.8	232	172	15.63	4.0012	25.22	89.78	4.34
100	76.7	0.29	2.69	13.1	58.22	2.30	44.9	330	61.9	224	158	11.38	3.8361	25.40	92.23	3.30
101	59.1	0.29	3.33	17.0	N.A.	2.60	98.9	37	16.0	176	156	66.88	2.5944	29.51	57.09	28.67
102	57.9	0.19	1.15	13.1	N.A.	2.70	154.3	126	41.5	174	130	60.75	3.3080	22.88	62.30	20.43
103	64.3	0.79	12.80	28.3	N.A.	2.70	130.0	198	56.1	196	132	61.88	3.8130	22.36	69.28	18.05
104	38.3	0.29	7.18	17.3	N.A.	3.40	75.3	91	40.0	174	144	40.50	2.6462	28.60	72.16	17.02
105	61.1	1.99	12.28	34.4	N.A.	2.40	200.0	220	67.3	238	146	38.63	4.2289	24.48	72.42	10.16
106	54.3	1.19	5.47	21.8	N.A.	2.50	195.7	186	62.5	198	120	33.25	3.7038	23.25	70.54	9.99
107	33.3	0.79	5.38	10.1	58.03	2.70	122.6	149	58.4	180	124	49.38	3.3309	23.51	69.82	16.49
108	26.3	0.39	2.54	11.5	69.29	2.60	138.6	117	55.2	176	126	45.63	3.1485	24.31	67.56	16.12
109	49.9	0.29	3.83	12.4	N.A.	2.40	139.0	110	44.2	176	120	39.75	2.9430	26.01	67.49	15.02
110	53.8	0.29	1.57	10.2	N.A.	2.90	127.6	143	55.1	182	104	55.25	3.3156	23.88	67.14	18.54
111	28.0	0.29	3.03	12.6	N.A.	2.20	137.8	287	62.0	206	110	15.00	3.7990	23.59	82.20	4.39
112	38.3	0.29	1.53	15.1	N.A.	2.40	112.7	189	52.9	184	106	26.25	3.1627	25.31	77.52	9.23
113	28.8	0.29	4.13	15.9	N.A.	4.00	53.2	62	21.9	166	120	54.50	2.3334	30.94	65.11	25.98
114	30.7	0.39	5.50	14.3	N.A.	2.70	59.2	65	20.1	174	112	63.63	2.4666	30.68	62.18	28.69
115	23.2	0.29	3.20	15.4	65.80	2.80	56.1	80	39.8	160	98	54.88	2.4988	27.85	67.00	24.43
116	41.2	0.29	2.21	14.9	67.35	10.60	183.8	80	33.3	170	98	50.50	2.9330	25.21	56.74	19.15

*Sample code:- Block No./ sample site No. and surface(A) or subsurface(B)

**N.A: Not analysed

Appendix III.
Raw Data generated by the analytical work on the soils of the western part of the main campus, KAU

No.	*Sample Code	Phase	Gravel %	Fine earth %	Sand %	Silt %	Clay %	Textural class	pH	EC dS/m	Buffer pH	Lime R. (t ha^{-1})	Org. C (%)	Av. P (µg g^{-1})	Av. K (µg g^{-1})	Av. Na (µg g^{-1})	Av. Ca (µg g^{-1})	Av. Mg (µg g^{-1})
117	29 / 4A	13	59.00	41.00				N.A.	5.27	0.003	5.7	20.1	1.41	2.50	22	22	240.0	32.50
118	29 / 4B	13	26.66	73.34				N.A.	4.94	0.253	5.7	20.1	0.80	1.42	31	44	203.0	31.00
119	29 / 5A	13	58.00	42.00				N.A.	5.00	0.090	5.3	26.7	1.61	5.04	60	27	200.0	33.50
120	29 / 5B	13	48.53	51.47				N.A.	5.11	0.027	5.6	21.8	0.98	2.04	30	15	83.0	25.50
121	29 / 6A	13	50.00	50.00				N.A.	4.84	0.093	5.3	26.7	1.22	10.16	76	12	81.5	24.00
122	29 / 6B	13	60.20	39.80				N.A.	4.85	0.017	5.3	26.7	1.19	4.50	42	9	26.5	12.50
123	29 / 7A	13	63.00	37.00				N.A.	4.55	0.026	5.1	30.2	1.13	7.83	46	17	25.5	11.50
124	29 / 7B	13	49.20	50.80				N.A.	4.14	0.051	5.3	26.7	1.14	4.50	24	10	19.0	6.50
125	29 / 8A	13	58.00	42.00				N.A.	4.70	0.013	5.4	25.3	1.26	7.66	26	11	61.0	13.50
126	29 / 8B	13	41.86	58.14				N.A.	4.69	0.009	5.3	26.7	0.90	1.96	16	15	25.5	9.50
127	29 / 9A	13	57.00	43.00				N.A.	5.54	0.056	5.8	18.6	1.94	26.50	192	30	254.0	38.00
128	29 / 9B	13	60.66	39.34				N.A.	4.93	0.052	5.3	26.7	1.11	9.29	143	13	30.0	19.00
129	29 / 10A	13	63.00	37.00				N.A.	4.98	0.001	5.1	30.2	1.37	3.96	20	7	15.5	7.50
130	29 / 10B	13	56.46	43.54				N.A.	4.95	0.009	5.2	28.5	1.22	2.08	16	13	21.5	7.50
131	29 / 11A	15	68.00	32.00	53.08	15.60	31.32	Sandy Clay Loam	4.88	0.009	5.3	26.7	1.49	1.92	25	16	82.5	27.00
132	29 / 11B	15	29.86	70.14	50.10	17.47	32.44	Sandy Clay Loam	5.08	0.001	5.4	25.3	0.77	3.58	17	18	92.5	26.00
133	29 / 12A	16	61.00	39.00				N.A.	4.99	0.014	5.4	25.3	1.37	6.46	26	13	55.0	24.50
134	29 / 12B	16	43.60	56.40				N.A.	5.10	0.001	5.4	25.3	0.86	4.17	16	12	45.0	26.50
135	29 / 13A	13	48.00	52.00	59.91	10.16	29.93	Sandy Clay Loam	4.76	0.001	5.4	25.3	0.87	1.92	15	15	47.5	24.00
136	29 / 13B	13	50.73	49.27	55.75	14.09	30.16	Sandy Clay Loam	4.95	0.001	5.4	25.3	0.77	1.88	12	17	46.5	26.50
137	29 / 14A	13	53.00	47.00				N.A.	5.03	0.001	5.1	30.2	1.57	2.46	20	14	58.5	21.50
138	29 / 14B	13	44.66	55.34				N.A.	4.40	0.084	5.3	26.7	0.99	2.08	18	18	66.0	24.50
139	29 / 15A	13	49.00	51.00				N.A.	5.10	0.001	5.1	30.2	1.34	1.92	19	15	55.5	24.00
140	29 / 15B	13	45.26	54.74				N.A.	5.45	0.127	5.5	23.3	0.92	1.00	19	22	84.0	26.50
141	29 / 16A	16	58.00	42.00	56.45	12.87	30.68	Sandy Clay Loam	4.88	0.021	5.4	25.3	1.40	4.79	19	15	62.0	25.00
142	29 / 16B	16	38.00	62.00	51.36	14.78	33.86	Sandy Clay Loam	4.27	0.108	5.5	23.3	0.87	2.25	14	18	73.0	24.00
143	29 / 17A	15	63.00	37.00				N.A.	4.60	0.025	5.4	25.3	1.01	8.75	49	12	44.0	15.50
144	29 / 17B	15	45.26	54.74				N.A.	4.57	0.053	5.3	26.7	1.02	7.83	61	24	43.5	13.50
145	29 / 18A	15	68.00	32.00				N.A.	4.61	0.038	5.3	26.7	1.25	9.04	71	15	29.5	18.00

*Sample code:- Block No./ sample site No. and surface(A) or subsurface(B)
**N.A: Not analysed

Appendix III.

Raw Data generated by the analytical work on the soils of the western part of the main campus, KAU

No.	Av. Mn (µg g^{-1})	Av. Zn (µg g^{-1})	Av. Cu (µg g^{-1})	Av. Fe (µg g^{-1})	P- fix.cap. %	Exch. Fe (µg g^{-1})	Exch. Mn (µg g^{-1})	Exch. Ca (µg g^{-1})	Exch. Mg (µg g^{-1})	Exch. Na (µg g^{-1})	Exch. K (µg g^{-1})	Exch. Al (µg g^{-1})	CEC cmol(+) kg^{-1}	Na sat. %	BSP %	Al sat. %
117	27.7	0.59	5.75	19.9	N.A.	2.30	106.9	234	73.6	194	108	10.75	3.4128	24.73	84.85	3.50
118	36.6	0.29	1.44	20.1	N.A.	1.90	32.6	238	62.5	244	122	17.25	3.3951	31.26	90.65	5.65
119	43.4	0.59	3.34	35.1	N.A.	1.90	67.9	248	77.6	208	152	13.75	3.5791	25.28	88.63	4.27
120	71.7	0.39	1.59	27.0	N.A.	1.60	86.4	154	56.3	178	122	27.38	2.9444	26.30	78.78	10.34
121	33.6	0.49	3.52	13.5	N.A.	1.80	90.6	115	49.0	176	164	53.00	3.0891	24.78	70.03	19.08
122	19.5	0.29	4.81	11.3	N.A.	2.00	60.7	34	22.8	170	134	51.50	2.2408	33.00	64.25	25.56
123	25.8	0.39	2.35	14.4	N.A.	2.30	64.9	34	21.8	172	130	63.25	2.3781	31.46	60.13	29.58
124	34.6	0.29	2.18	14.5	N.A.	2.30	73.7	23	10.1	152	108	58.25	2.0600	32.10	55.12	31.45
125	33.1	0.49	2.68	15.4	N.A.	2.40	64.8	39	34.9	172	242	50.63	2.6569	28.16	69.60	21.19
126	43.4	0.39	1.35	16.5	N.A.	1.70	98.7	288	92.7	208	304	15.13	4.4188	20.47	87.92	3.81
127	89.6	1.29	3.22	33.5	42.67	2.00	69.7	47	18.7	172	110	46.25	2.1937	34.10	64.66	23.45
128	35.7	1.19	3.00	21.0	59.99	2.20	63.4	96	30.5	168	112	42.13	2.4555	29.76	71.20	19.08
129	37.6	1.19	2.28	22.7	N.A.	2.40	98.9	19	13.6	158	104	60.75	2.2046	31.17	52.63	30.65
130	49.0	0.29	1.75	17.3	N.A.	2.00	115.6	31	12.0	154	94	64.88	2.3137	28.95	50.31	31.19
131	63.9	0.39	4.52	17.1	55.68	3.40	123.2	125	54.3	166	102	47.13	3.0397	23.75	67.60	17.24
132	62.7	0.19	2.09	21.6	71.25	2.40	123.2	151	52.1	170	100	30.38	2.9740	24.86	73.27	11.36
133	76.8	0.29	3.96	19.9	N.A.	1.50	179.0	90	49.1	136	82	45.63	2.8199	20.98	58.70	18.00
134	53.8	0.39	2.01	15.5	N.A.	1.50	96.7	86	48.0	140	76	46.50	2.5030	24.33	65.06	20.66
135	15.1	0.39	5.65	44.6	N.A.	1.50	43.6	67	46.5	130	72	41.00	2.0875	27.09	70.29	21.85
136	4.8	0.19	3.14	30.7	N.A.	1.50	12.5	74	52.2	130	70	39.63	2.0358	27.78	75.85	21.65
137	75.2	0.29	5.74	16.9	N.A.	1.50	174.3	112	39.5	136	78	45.75	2.8249	20.94	59.33	18.01
138	69.6	0.09	1.94	15.4	N.A.	3.60	142.7	92	47.5	134	74	40.25	2.6032	22.39	62.35	17.20
139	44.9	0.19	5.45	28.6	56.17	3.70	109.0	86	46.4	128	74	40.50	2.4185	23.02	64.42	18.63
140	64.7	0.19	2.12	14.1	63.86	8.30	146.0	124	48.8	136	72	50.38	2.9189	20.27	61.58	19.20
141	46.1	0.19	5.17	21.6	N.A.	2.80	110.4	110	66.1	128	72	42.75	2.7224	20.45	67.40	17.47
142	55.9	0.09	2.04	11.4	N.A.	2.80	113.3	105	46.1	136	190	55.50	3.0218	19.58	65.59	20.43
143	49.0	0.19	3.27	35.1	N.A.	2.60	101.4	76	37.6	122	86	54.13	2.4206	21.92	59.49	24.87
144	60.3	0.09	3.01	21.5	N.A.	2.60	124.8	86	22.1	156	108	60.25	2.7005	25.13	58.01	24.82
145	72.0	0.39	6.16	25.9	N.A.	3.00	125.8	58	28.9	126	110	53.63	2.4224	22.62	56.03	24.62

*Sample code:- Block No./ sample site No. and surface(A) or subsurface(B)
**N.A: Not analysed

Appendix III.

Raw Data generated by the analytical work on the soils of the western part of the main campus, KAU

No.	*Sample Code	Phase	Gravel %	Fine earth %	Sand %	Silt %	Clay %	Textural class	pH	EC dS/m	Buffer pH	Lime R. (t ha^{-1})	Org. C (%)	Av. P ($\mu g\ g^{-1}$)	Av. K ($\mu g\ g^{-1}$)	Av. Na ($\mu g\ g^{-1}$)	Av. Ca ($\mu g\ g^{-1}$)	Av. Mg ($\mu g\ g^{-1}$)
146	29 / 18B	15	44.46	55.54	N.A.				4.17	0.144	5.5	23.3	1.20	2.42	43	11	52.5	19.50
147	30 / 1A	15	66.00	34.00	56.22	27.54	16.24	Sandy Loam	5.02	0.009	5.6	21.8	1.60	9.38	58	18	60.0	23.00
148	30 / 1B	15	52.33	47.67	50.23	24.54	25.23	Sandy Clay Loam	4.96	0.007	5.7	20.1	1.01	2.50	28	17	94.0	26.50
149	30 / 2A	15	66.00	34.00	N.A.				5.77	0.005	5.5	23.3	1.17	9.21	28	10	22.5	16.00
150	30 / 2B	15	55.60	44.40	N.A.				5.01	0.001	5.5	23.3	0.83	1.54	28	11	27.5	18.00
151	30 / 3A	17	50.00	50.00	51.74	21.48	26.78	Sandy Clay Loam	4.64	0.031	5.5	23.3	1.01	4.54	23	12	50.5	17.50
152	30 / 3B	17	47.30	52.70	46.40	23.04	30.56	Sandy Clay Loam	5.01	0.003	5.6	21.8	0.81	1.71	24	14	121.0	26.50
153	30 / 4A	15	58.60	41.40	58.63	26.84	14.53	Sandy Loam	4.62	0.008	5.8	18.6	1.19	6.58	16	14	25.0	12.50
154	30 / 4B	15	40.46	59.54	50.50	29.03	20.47	Loam	4.68	0.004	6.5	7.0	0.78	3.04	13	14	23.0	8.50
155	30 / 5A	16	64.60	35.40	N.A.				4.77	0.002	6.6	5.3	0.93	2.79	17	12	16.0	7.00
156	30 / 5B	16	55.60	44.40	N.A.				4.87	0.002	6.7	4.1	0.71	1.00	14	10	22.0	7.50
157	30 / 6A	16	40.60	59.40	57.52	12.40	30.08	Sandy Clay Loam	4.61	0.016	5.2	28.5	0.80	21.41	21	9	30.5	9.00
158	30 / 6B	16	55.90	44.10	51.50	13.26	35.24	Sandy Clay Loam	4.60	0.017	5.4	25.3	0.68	2.61	33	9	22.5	8.00
159	30 / 7A	15	66.00	34.00	N.A.				4.97	0.029	6.0	15.2	1.13	23.96	111	12	50.0	20.50
160	30 / 7B	15	55.60	44.40	N.A.				4.83	0.021	5.6	21.8	0.99	6.46	76	10	28.0	11.50
161	30 / 8A	13	47.30	52.70	N.A.				4.45	0.032	5.3	26.7	0.98	6.86	39	12	33.0	16.00
162	30 / 8B	13	56.30	43.70	N.A.				4.83	0.006	5.4	25.3	0.69	0.96	26	15	77.0	20.00
163	30 / 9A	13	68.00	32.00	N.A.				4.85	0.004	5.4	25.3	0.93	3.50	23	10	42.5	20.00
164	30 / 9B	13	43.13	56.87	N.A.				5.05	0.002	5.7	20.1	0.66	1.16	26	15	122.0	30.50
165	30 / 10A	16	70.00	30.00	N.A.				4.53	0.026	5.6	21.8	1.11	8.25	37	10	26.5	14.50
166	30 / 10B	16	46.60	53.40	N.A.				4.61	0.003	5.6	21.8	0.78	1.04	23	11	39.5	13.50
167	30 / 11A	13	77.00	23.00	48.46	9.60	41.94	Sandy Clay	4.75	0.006	5.2	28.5	1.02	6.79	42	16	40.0	15.50
168	30 / 11B	13	48.93	51.07	42.87	10.15	46.98	Sandy Clay	4.82	0.003	5.3	26.7	0.81	2.13	26	12	53.0	16.50
169	30 / 12A	16	69.00	31.00	N.A.				4.60	0.012	5.6	21.8	0.96	11.46	14	7	13.5	6.50
170	30 / 12B	16	44.93	55.07	N.A.				4.88	0.010	5.7	20.1	0.74	2.58	14	10	31.0	12.00
171	31 / 1A	19	68.00	32.00	N.A.				4.36	0.170	5.4	25.3	0.92	1.58	57	24	55.5	23.50
172	31 / 1B	19	44.93	55.07	N.A.				4.33	0.100	5.3	26.7	0.72	0.17	31	22	93.5	27.00
173	31 / 2A	22	60.00	40.00	59.01	12.65	28.34	Sandy Clay Loam	5.14	0.006	5.6	21.8	1.22	6.25	34	21	119.0	29.50
174	31 / 2B	22	47.06	52.94	52.70	14.52	32.78	Sandy Clay Loam	5.07	0.002	5.7	20.1	0.78	4.04	30	19	115.0	28.00

*Sample code:- Block No./ sample site No. and surface(A) or subsurface(B)

**N.A: Not analysed

Appendix III.

Raw Data generated by the analytical work on the soils of the western part of the main campus, KAU

No.	Av. Mn ($\mu g\ g^{-1}$)	Av. Zn ($\mu g\ g^{-1}$)	Av. Cu ($\mu g\ g^{-1}$)	Av. Fe ($\mu g\ g^{-1}$)	P- fix.cap. %	Exch. Fe ($\mu g\ g^{-1}$)	Exch. Mn ($\mu g\ g^{-1}$)	Exch. Ca ($\mu g\ g^{-1}$)	Exch. Mg ($\mu g\ g^{-1}$)	Exch. Na ($\mu g\ g^{-1}$)	Exch. K ($\mu g\ g^{-1}$)	Exch. Al ($\mu g\ g^{-1}$)	CEC cmol(+) kg^{-1}	Na sat. %	BSP %	Al sat. %
146	73.5	0.19	8.56	17.5	N.A.	3.30	154.2	108	39.8	126	102	57.63	2.8907	18.96	58.00	22.17
147	68.2	0.79	9.40	17.9	N.A.	2.30	40.0	56	47.5	128	94	42.75	2.0975	26.54	69.99	22.67
148	51.7	0.39	4.46	19.3	N.A.	3.10	115.1	144	59.3	132	84	32.13	2.7845	20.62	71.72	12.83
149	72.1	0.79	7.46	23.5	N.A.	2.50	128.5	48	32.2	120	84	50.75	2.2831	22.86	54.39	24.73
150	61.0	0.29	2.55	21.1	N.A.	3.00	122.8	61	34.4	122	84	39.00	2.2252	23.85	59.93	19.50
151	81.8	0.69	6.47	25.4	57.36	2.60	152.4	154	37.7	116	76	50.25	2.9023	17.39	61.30	19.26
152	82.9	0.29	3.14	28.9	57.52	2.70	184.4	30	55.6	132	82	38.88	2.5049	22.92	55.55	17.26
153	66.4	0.29	5.19	18.2	59.30	2.60	139.8	38	26.5	118	74	41.75	2.0933	24.52	53.06	22.19
154	78.2	0.09	6.40	29.3	69.01	2.60	112.0	60	31.0	110	72	35.13	2.0255	23.62	60.12	19.29
155	51.4	0.29	3.62	25.5	N.A.	2.70	97.8	12	10.8	114	74	42.13	1.6683	29.72	49.99	28.09
156	51.4	0.09	1.79	23.7	N.A.	2.70	93.8	12	12.0	116	74	39.63	1.6445	30.68	51.85	26.80
157	32.0	0.29	4.41	31.9	N.A.	9.80	139.0	77	40.6	122	146	37.38	2.5801	20.57	62.91	16.11
158	36.0	0.29	3.54	34.8	N.A.	3.10	57.4	19	10.9	112	86	52.25	1.6931	28.77	52.67	34.33
159	89.7	0.69	4.53	26.8	N.A.	3.00	49.5	45	16.6	110	76	42.63	1.6995	28.15	60.87	27.90
160	77.5	0.49	3.69	22.4	N.A.	2.50	118.1	44	18.0	120	102	51.88	2.1669	24.09	53.12	26.63
161	61.8	0.39	4.29	15.5	N.A.	2.30	128.2	77	25.0	120	80	46.38	2.3081	22.61	57.07	22.35
162	111.4	0.29	2.09	17.0	N.A.	2.00	171.2	95	34.1	120	68	46.13	2.5950	20.11	55.94	19.77
163	71.2	0.29	3.36	20.6	N.A.	2.70	145.2	74	37.4	116	68	56.00	2.5175	20.04	53.88	24.74
164	94.4	0.29	1.42	21.8	N.A.	2.70	181.3	153	65.7	124	68	31.50	3.0391	17.75	66.44	11.53
165	44.0	0.39	3.02	18.3	N.A.	2.50	96.2	36	29.9	116	76	32.88	1.8499	27.28	60.82	19.77
166	77.5	0.19	1.37	26.5	N.A.	2.40	140.1	56	31.1	118	70	49.88	2.3017	22.30	53.36	24.10
167	99.0	0.69	3.64	23.1	59.56	2.80	193.7	59	32.8	122	82	47.00	2.5433	20.87	51.32	20.56
168	106.2	0.49	3.31	17.1	71.06	2.80	205.0	87	40.6	134	80	52.00	2.8913	20.16	53.84	20.01
169	32.9	0.39	2.65	17.4	N.A.	2.40	65.0	75	15.5	132	80	48.75	2.0688	27.75	61.94	26.21
170	36.0	0.19	0.89	22.1	N.A.	2.70	104.5	53	21.3	132	76	28.00	1.9104	30.05	63.28	16.30
171	106.1	0.39	6.17	13.3	N.A.	2.50	204.5	135	56.8	140	100	48.13	3.2959	18.48	60.90	16.24
172	93.4	0.29	1.97	15.9	N.A.	2.90	181.9	212	78.7	152	90	25.00	3.5497	18.63	73.22	7.83
173	83.9	0.49	4.37	14.3	N.A.	2.80	181.7	129	73.0	146	88	27.25	3.0805	20.62	68.36	9.84
174	70.5	0.39	1.38	24.4	N.A.	2.40	120.0	215	79.0	142	92	15.50	3.1960	19.33	80.67	5.39

*Sample code:- Block No./ sample site No. and surface(A) or subsurface(B)

**N.A: Not analysed

Appendix III.

Raw Data generated by the analytical work on the soils of the western part of the main campus, KAU

No.	*Sample Code	Phase	Gravel %	Fine earth %	Sand %	Silt %	Clay %	Textural class	pH	EC dS/m	Buffer pH	Lime R. (t ha^{-1})	Org. C (%)	Av. P (µg g^{-1})	Av. K (µg g^{-1})	Av. Na (µg g^{-1})	Av. Ca (µg g^{-1})	Av. Mg (µg g^{-1})
175	31 / 3A	16	59.00	41.00	N.A.				5.26	0.017	5.3	26.7	1.12	2.96	79	29	200.0	35.50
176	31 / 3B	16	56.86	43.14	N.A.				5.11	0.002	5.7	20.1	0.54	0.83	57	25	153.0	34.00
177	31 / 4A	22	63.00	37.00	N.A.				5.01	0.001	5.5	23.3	0.65	1.54	21	23	151.5	35.00
178	31 / 4B	22	50.66	49.34	N.A.				4.98	0.001	5.6	21.8	0.56	1.21	20	23	148.0	36.00
179	31 / 5A	13	58.00	42.00	47.95	16.06	35.99	Sandy Clay	4.88	0.012	5.2	28.5	1.36	7.04	40	21	147.0	31.50
180	31 / 5B	13	46.13	53.87	45.46	16.29	38.25	Sandy Clay	4.71	0.007	5.5	23.3	0.93	3.71	32	19	94.0	32.00
181	31 / 6A	17	60.60	39.40	N.A.				4.84	0.016	5.6	21.8	1.11	8.71	44	13	83.5	29.50
182	31 / 6B	17	55.73	44.27	N.A.				5.36	0.001	5.8	18.6	0.72	1.50	29	11	111.5	27.00
183	32 / 1A	16	53.30	46.70	56.78	11.43	31.79	Sandy Clay Loam	4.88	0.017	5.7	20.1	1.23	8.33	67	18	22.5	31.00
184	32 / 1B	16	50.60	49.40	53.25	12.58	34.17	Sandy Clay Loam	4.83	0.006	5.6	21.8	1.06	3.21	36	10	23.5	18.00
185	32 / 2A	20	63.00	37.00	55.23	23.03	21.74	Sandy Clay Loam	4.99	0.063	5.7	20.1	0.91	8.28	119	29	211.0	36.50
186	32 / 2B	20	54.66	45.34	50.36	15.86	33.78	Sandy Clay Loam	4.49	0.034	5.3	26.7	1.39	1.81	49	16	286.5	26.50
187	32 / 3A	20	70.00	30.00	N.A.				5.43	0.051	6.0	15.2	1.57	3.44	82	38	202.0	39.50
188	32 / 3B	20	33.86	66.14	N.A.				5.00	0.032	5.5	23.3	0.94	1.53	44	28	200.5	36.50
189	32 / 4A	20	69.50	30.50	54.80	22.29	22.91	Sandy Clay Loam	4.99	0.016	5.5	23.3	1.06	1.33	27	26	187.5	37.00
190	32 / 4B	20	25.93	74.07	50.20	16.31	33.49	Sandy Clay Loam	5.06	0.001	5.6	21.8	0.91	0.69	14	26	187.5	33.50
191	32 / 5A	20	70.00	30.00	N.A.				5.28	0.056	5.7	20.1	1.27	4.06	88	38	321.5	38.00
192	32 / 5B	20	41.60	58.40	N.A.				5.19	0.012	5.5	23.3	1.09	1.22	65	31	263.0	36.00
193	32 / 6A	22	54.60	45.40	N.A.				4.71	0.096	5.6	21.8	1.05	3.69	44	34	242.5	35.50
194	32 / 6B	22	34.06	65.94	N.A.				4.61	0.108	5.8	18.6	0.68	1.87	41	36	253.0	35.00
195	32 / 7A	20	50.00	50.00	N.A.				5.03	0.072	5.8	18.6	0.94	2.50	67	35	269.5	36.50
196	32 / 7B	20	39.93	60.07	N.A.				5.23	0.003	5.5	23.3	1.00	1.58	22	36	279.5	34.50
197	32 / 8A	14	61.30	38.70	57.30	13.11	29.59	Sandy Clay Loam	5.56	0.187	5.7	20.1	1.35	3.25	26	43	345.5	41.00
198	32 / 8B	14	30.73	69.27	50.97	12.65	36.38	Sandy Clay	5.11	0.013	5.8	18.6	0.79	1.42	18	37	308.5	39.00
199	32 / 9A	22	47.00	53.00	N.A.				4.75	0.078	5.7	20.1	0.88	7.67	45	27	240.0	14.00
200	32 / 9B	22	38.66	61.34	N.A.				5.18	0.006	5.5	23.3	0.81	3.50	27	20	201.0	31.50
201	32 / 10A	22	56.00	44.00	N.A.				5.67	0.010	6.0	15.2	0.99	2.00	32	40	378.0	41.00
202	32 / 10B	22	37.06	62.94	N.A.				5.74	0.005	5.8	18.6	0.87	0.72	26	39	356.0	41.50
203	32 / 11A	22	42.00	58.00	N.A.				5.50	0.008	5.8	18.6	1.18	1.64	92	36	295.0	38.00

*Sample code:- Block No./ sample site No. and surface(A) or subsurface(B)
**N.A: Not analysed

Appendix IIII.

Raw Data generated by the analytical work on the soils of the western part of the main campus, KAU

No.	Av. Mn ($\mu g\ g^{-1}$)	Av. Zn ($\mu g\ g^{-1}$)	Av. Cu ($\mu g\ g^{-1}$)	Av. Fe ($\mu g\ g^{-1}$)	P- fix.cap. %	Exch. Fe ($\mu g\ g^{-1}$)	Exch. Mn ($\mu g\ g^{-1}$)	Exch. Ca ($\mu g\ g^{-1}$)	Exch. Mg ($\mu g\ g^{-1}$)	Exch. Na ($\mu g\ g^{-1}$)	Exch. K ($\mu g\ g^{-1}$)	Exch. Al ($\mu g\ g^{-1}$)	CEC cmol(+) kg^{-1}	Na sat. %	BSP %	Al sat. %
175	78.3	0.49	4.77	15.9	N.A.	2.60	137.6	242	94.9	144	106	15.75	3.5739	17.53	80.82	4.90
176	88.9	0.39	2.71	15.3	N.A.	3.30	170.0	234	89.1	150	112	23.25	3.7315	17.48	76.17	6.93
177	57.6	0.29	1.73	13.9	N.A.	2.90	120.0	222	85.6	142	88	40.38	3.5536	17.38	74.78	12.64
178	25.8	0.39	0.98	48.0	N.A.	2.80	203.9	210	77.8	150	98	46.50	3.8630	16.89	67.14	13.39
179	83.3	0.59	6.85	17.3	55.70	6.00	71.1	195	82.9	144	86	39.38	3.2219	19.44	77.71	13.59
180	84.7	0.49	4.01	16.7	59.83	2.80	193.9	215	76.0	122	82	28.75	3.4766	15.26	70.21	9.20
181	72.5	0.49	4.65	13.5	N.A.	3.30	158.8	140	74.1	130	100	30.88	3.0644	18.45	69.54	11.21
182	49.9	0.19	1.55	14.5	N.A.	2.80	79.0	169	68.8	122	84	38.75	2.8854	18.39	74.75	14.94
183	37.7	0.69	6.83	13.9	59.88	3.10	85.0	170	73.0	118	98	34.50	2.9190	17.58	75.87	13.15
184	33.6	0.29	8.39	11.0	62.37	3.70	75.7	64	41.0	98	76	50.88	2.1328	19.99	59.92	26.53
185	55.7	0.99	8.42	25.3	53.71	3.50	113.6	296	84.6	142	150	13.75	3.7566	16.44	84.59	4.07
186	58.5	0.19	8.93	15.7	61.99	3.40	119.7	124	60.4	122	96	59.00	2.9975	17.70	63.16	21.89
187	30.4	0.79	4.97	12.9	N.A.	3.10	69.4	324	110.7	168	132	9.88	3.9730	18.39	90.60	2.76
188	27.3	0.59	2.27	13.5	N.A.	3.40	113.9	279	78.9	124	62	29.63	3.4987	15.42	78.38	9.42
189	56.3	0.59	10.59	15.4	N.A.	2.90	123.1	249	36.9	110	62	32.00	3.0002	15.95	72.85	11.86
190	46.5	0.39	55.19	14.6	N.A.	4.50	60.1	245	68.7	114	74	35.13	3.1012	15.99	79.83	12.60
191	63.3	0.99	7.87	25.9	N.A.	2.90	104.9	339	90.0	150	108	6.13	3.8248	17.06	87.96	1.78
192	86.5	0.59	8.13	20.3	N.A.	3.30	153.8	272	75.4	146	100	16.38	3.6252	17.52	79.21	5.02
193	35.1	0.59	4.22	12.1	N.A.	2.90	71.3	248	76.5	142	84	21.38	3.2098	19.24	84.18	7.41
194	35.4	0.19	1.42	12.9	N.A.	2.90	66.0	290	76.6	156	88	11.00	3.3571	20.21	88.89	3.64
195	43.3	0.59	16.56	12.1	N.A.	3.10	81.6	275	85.6	150	102	2.00	3.3233	19.63	90.06	0.67
196	32.5	0.59	14.33	10.2	N.A.	2.70	66.3	290	78.6	150	78	12.50	3.3389	19.54	88.32	4.16
197	34.3	0.79	3.99	16.4	55.41	2.50	65.0	345	98.9	162	76	7.75	3.7698	18.69	91.20	2.29
198	41.9	0.69	2.81	11.6	62.09	2.70	80.3	322	95.7	154	72	5.88	3.6190	18.51	89.85	1.81
199	33.6	0.49	8.58	12.2	N.A.	2.90	65.6	239	67.9	144	86	24.63	3.1233	20.05	83.25	8.77
200	41.0	0.39	5.46	20.2	N.A.	2.70	84.0	247	66.7	138	78	45.00	3.3997	17.66	76.00	14.72
201	31.6	0.79	6.06	59.9	N.A.	2.20	38.7	350	99.0	156	78	6.50	3.6639	18.52	93.97	1.97
202	30.1	0.59	4.52	34.9	N.A.	2.30	45.0	317	95.4	156	76	2.00	3.4374	19.74	94.35	0.65
203	41.4	0.39	9.34	12.8	N.A.	3.60	77.1	307	92.9	152	118	6.00	3.6229	18.25	90.05	1.84

*Sample code:- Block No./ sample site No. and surface(A) or subsurface(B)

**N.A: Not analysed

Appendix IIII.

Raw Data generated by the analytical work on the soils of the western part of the main campus, KAU

No.	*Sample Code	Phase	Gravel %	Fine earth %	Sand %	Silt %	Clay %	Textural class	pH	EC dS/m	Buffer pH	Lime R. (t ha^{-1})	Org. C (%)	Av. P (µg g^{-1})	Av. K (µg g^{-1})	Av. Na (µg g^{-1})	Av. Ca (µg g^{-1})	Av. Mg (µg g^{-1})
204	32 / 11B	22	31.33	68.67	N.A.				5.13	0.020	5.6	21.8	0.94	0.33	120	40	257.5	28.00
205	32 / 12A	14	40.00	60.00	N.A.				5.44	0.031	5.4	25.3	0.90	0.94	78	60	341.0	39.00
206	32 / 12B	14	30.00	70.00	N.A.				4.75	0.137	5.7	20.1	0.32	1.28	97	72	298.5	37.50
207	32 / 13A	14	40.00	60.00	56.32	17.61	26.07	Sandy Clay Loam	5.51	0.001	5.5	23.3	0.63	1.42	45	52	295.0	36.50
208	32 / 13B	14	33.60	66.40	49.66	15.95	34.39	Sandy Clay Loam	5.38	0.001	5.8	18.6	0.49	1.19	44	60	329.5	37.00
209	32 / 14A	14	61.00	39.00	57.54	14.55	27.91	Sandy Clay Loam	5.14	0.010	5.5	23.3	1.00	3.03	44	40	254.0	38.00
210	32 / 14B	14	42.66	57.34	51.33	15.92	32.75	Sandy Clay Loam	4.34	0.184	5.5	23.3	0.65	1.06	63	46	219.0	34.50
211	32 / 15A	22	60.00	40.00	N.A.				5.44	0.013	5.7	20.1	0.99	1.94	61	42	263.5	37.00
212	32 / 15B	22	49.60	50.40	N.A.				5.74	0.007	5.8	18.6	0.85	1.44	70	46	300.5	40.50
213	32 / 16A	22	48.60	51.40	N.A.				5.10	0.001	5.5	23.3	0.75	0.58	87	35	229.5	37.00
214	32 / 16B	22	42.60	57.40	N.A.				5.06	0.009	5.6	21.8	0.66	0.11	58	50	280.5	37.00
215	32 / 17A	22	52.60	47.40	N.A.				4.73	0.142	5.6	21.8	1.00	4.94	76	51	267.0	33.50
216	32 / 17B	22	40.20	59.80	N.A.				4.96	0.008	5.3	26.7	0.84	1.77	40	25	127.0	28.00
217	32 / 18A	13	70.00	30.00	N.A.				5.07	0.038	5.4	25.3	1.45	1.33	135	34	199.5	32.00
218	32 / 18B	13	46.80	53.20	N.A.				5.14	0.004	5.5	23.3	0.79	0.36	84	34	181.5	36.00
219	32 / 19A	19	60.00	40.00	60.54	21.84	17.62	Sandy Loam	5.09	0.024	5.4	25.3	1.23	1.77	134	23	97.5	33.50
220	32 / 19B	19	51.60	48.40	54.40	23.86	21.74	Sandy Clay Loam	4.84	0.009	5.3	26.7	0.75	7.44	49	23	67.5	31.00
221	32 / 20A	19	49.00	51.00	N.A.				4.81	0.017	5.1	30.2	1.08	2.11	69	20	100.0	32.50
222	32 / 20B	19	47.86	52.14	N.A.				4.94	0.008	5.3	26.7	0.81	4.12	41	29	125.5	32.00
223	32 / 21A	19	50.00	50.00	N.A.				5.06	0.005	5.5	23.3	1.29	5.50	94	23	118.0	33.00
224	32 / 21B	19	34.73	65.27	N.A.				5.11	0.001	5.6	21.8	0.94	0.88	83	14	112.5	27.00
225	32 / 22A	32	68.00	32.00	53.99	11.19	34.82	Sandy Clay	5.26	0.004	6.0	15.2	1.11	7.08	53	17	175.0	29.50
226	32 / 22B	32	51.00	49.00	52.20	12.72	35.08	Loam	4.80	0.003	6.1	13.4	1.30	1.03	65	9	92.0	24.50
227	32 / 23A	32	50.67	49.33	N.A.				4.30	0.182	5.7	20.1	0.91	8.33	78	31	101.0	28.50
228	32 / 23B	32	54.06	45.94	N.A.				4.83	0.363	5.4	25.3	1.29	6.31	82	32	259.3	36.00
229	32 / 24A	32	50.00	50.00	N.A.				5.17	0.018	5.1	30.2	1.42	8.36	45	28	343.0	33.00
230	32 / 24B	32	61.00	39.00	N.A.				4.80	0.002	5.0	31.8	1.29	5.69	37	16	170.0	29.00
231	32 / 25A	6	54.67	45.33	N.A.				5.08	0.029	5.5	23.3	1.06	4.50	125	13	117.0	32.50
232	32 / 25B	6	39.86	60.14	N.A.				5.02	0.012	5.7	20.1	0.90	1.53	59	9	105.5	30.50

*Sample code:- Block No./ sample site No. and surface(A) or subsurface(B)

**N.A: Not analysed

Appendix III.

Raw Data generated by the analytical work on the soils of the western part of the main campus, KAU

No.	Av. Mn ($\mu g\ g^{-1}$)	Av. Zn ($\mu g\ g^{-1}$)	Av. Cu ($\mu g\ g^{-1}$)	Av. Fe ($\mu g\ g^{-1}$)	P- fix.cap. %	Exch. Fe ($\mu g\ g^{-1}$)	Exch. Mn ($\mu g\ g^{-1}$)	Exch. Ca ($\mu g\ g^{-1}$)	Exch. Mg ($\mu g\ g^{-1}$)	Exch. Na ($\mu g\ g^{-1}$)	Exch. K ($\mu g\ g^{-1}$)	Exch. Al ($\mu g\ g^{-1}$)	CEC cmol(+) kg^{-1}	Na sat. %	BSP %	Al sat. %
204	38.5	0.29	7.08	14.9	N.A.	2.60	63.1	292	86.8	142	132	23.25	3.6273	17.03	86.28	7.13
205	54.9	0.69	8.10	14.2	N.A.	2.30	97.6	342	102.5	164	98	5.50	3.9423	18.09	89.23	1.55
206	54.8	0.29	3.34	12.9	N.A.	2.70	105.2	307	99.1	166	104	4.88	3.7855	19.07	88.20	1.43
207	26.3	0.39	5.10	14.1	62.49	2.20	45.4	311	88.0	152	86	6.88	3.4100	19.39	92.68	2.24
208	23.0	0.29	2.99	4.5	54.66	4.30	38.4	311	86.1	148	76	8.00	3.3460	19.24	92.70	2.66
209	29.8	0.49	12.00	21.3	N.A.	2.60	46.6	281	84.4	134	72	14.00	3.2013	18.21	89.55	4.86
210	33.3	0.39	9.96	20.8	N.A.	2.20	61.2	258	79.3	138	84	12.63	3.1289	19.18	88.14	4.49
211	33.3	0.39	9.65	18.0	N.A.	5.60	58.3	314	87.3	142	86	13.13	3.5044	17.63	89.21	4.17
212	26.3	0.29	7.18	15.9	N.A.	3.40	37.9	333	100.7	150	90	8.00	3.6156	18.05	93.39	2.46
213	53.0	0.29	5.11	16.3	N.A.	2.40	98.1	278	79.2	134	98	18.00	3.4413	16.94	83.55	5.82
214	68.8	0.29	2.94	20.5	N.A.	2.30	118.9	306	84.9	142	84	6.88	3.5788	17.26	85.54	2.14
215	40.0	0.49	10.96	20.4	N.A.	2.90	74.8	344	81.4	164	98	16.75	3.8230	18.66	87.73	4.87
216	31.6	0.99	8.87	19.7	N.A.	2.90	57.5	231	57.7	132	78	41.88	3.0890	18.59	77.81	15.08
217	59.1	0.39	8.96	17.7	52.62	2.90	111.9	266	85.5	136	134	7.88	3.4733	17.03	85.45	2.52
218	56.9	0.09	3.84	17.0	63.45	2.40	110.5	281	88.1	136	100	15.50	3.5607	16.61	83.62	4.84
219	51.2	0.29	14.17	28.2	66.93	2.80	96.8	217	78.4	124	130	28.63	3.2829	16.43	79.26	9.70
220	42.0	0.19	5.92	30.4	71.23	3.40	85.8	172	70.3	116	84	38.13	2.9066	17.36	74.24	14.59
221	71.4	0.49	11.95	24.1	N.A.	2.40	130.8	198	79.0	122	92	39.50	3.3303	15.93	72.25	13.19
222	61.8	0.19	4.18	15.9	N.A.	2.50	121.7	220	75.4	126	74	28.38	3.2255	16.99	76.20	9.79
223	57.4	0.59	23.97	29.8	N.A.	2.60	153.8	286	105.4	178	156	13.38	4.1887	18.48	82.86	3.55
224	60.2	0.29	8.68	17.2	N.A.	2.60	155.0	294	77.5	188	160	14.38	4.0683	20.10	81.97	3.93
225	66.9	1.59	9.62	17.5	62.35	2.70	170.6	337	96.9	178	132	12.88	4.3683	17.72	82.28	3.28
226	69.3	0.49	15.68	16.9	71.58	2.60	182.9	236	74.6	188	172	27.63	4.0341	20.27	75.65	7.62
227	63.1	0.39	15.76	21.5	N.A.	3.00	170.5	251	89.4	204	158	27.13	4.2154	21.05	77.86	7.16
228	43.7	0.69	17.09	15.3	N.A.	1.50	101.4	353	112.3	228	170	6.00	4.5570	21.76	90.32	1.46
229	39.7	1.19	32.31	29.8	N.A.	2.30	102.7	364	93.5	228	122	6.50	4.3477	22.81	89.55	1.66
230	51.6	0.89	63.54	25.8	N.A.	2.00	140.7	289	84.8	160	98	19.50	3.8258	18.19	80.76	5.67
231	34.1	0.59	18.05	25.0	N.A.	2.10	92.4	228	96.9	116	136	27.38	3.4383	14.67	81.14	8.86
232	34.3	0.39	4.22	19.4	N.A.	3.00	102.0	208	94.0	176	148	23.25	3.5984	21.27	82.20	7.19

*Sample code:- Block No./ sample site No. and surface(A) or subsurface(B)

**N.A: Not analysed

Appendix III.

Raw Data generated by the analytical work on the soils of the western part of the main campus, KAU

No.	*Sample Code	Phase	Gravel %	Fine earth %	Sand %	Silt %	Clay %	Textural class	pH	EC dS/m	Buffer pH	Lime R. (t ha^{-1})	Org. C (%)	Av. P (µg g^{-1})	Av. K (µg g^{-1})	Av. Na (µg g^{-1})	Av. Ca (µg g^{-1})	Av. Mg (µg g^{-1})
233	32 / 26A	22	62.60	37.40	N.A.				5.45	0.029	6.3	10.5	1.08	1.61	108	23	268.5	37.00
234	32 / 26B	22	51.13	48.87	N.A.				5.23	0.020	6.2	12.1	0.78	0.55	97	21	234.0	36.00
235	32 / 27A	24	68.00	32.00	N.A.				5.12	0.028	6.4	9.0	0.90	6.75	65	13	191.5	33.00
236	32 / 27B	24	51.80	48.20	N.A.				5.11	0.012	6.4	9.0	0.50	4.69	62	7	23.0	27.00
237	32 / 28A	22	65.00	35.00	33.03	39.00	27.97	Clay Loam	5.05	0.016	6.3	10.5	1.15	0.58	66	17	122.5	36.00
238	32 / 28B	22	54.00	46.00	30.21	34.90	34.90	Sandy Clay Loam	5.01	0.002	6.2	12.1	0.69	0.06	41	19	162.0	35.50
239	32 / 29A	24	70.00	30.00	55.29	13.39	31.32	Sandy Clay Loam	5.14	0.025	5.9	17.2	0.82	3.69	58	14	155.5	32.00
240	32 / 29B	24	44.80	55.20	50.40	16.21	33.39	Sandy Clay Loam	5.01	0.001	6.1	13.4	0.93	1.56	65	26	312.5	32.50
241	32 / 30A	22	61.00	39.00	N.A.				4.71	0.041	5.8	18.6	1.36	1.56	52	14	87.0	33.50
242	32 / 30B	22	63.73	36.27	N.A.				4.83	0.008	5.8	18.6	0.78	0.14	37	14	91.5	31.50
243	32 / 31A	24	60.00	40.00	N.A.				5.06	0.040	6.1	13.4	1.35	5.03	84	24	226.0	37.50
244	32 / 31B	24	59.60	40.40	N.A.				5.40	0.020	5.8	18.6	0.91	1.22	48	8	32.5	22.50
245	32 / 32A	24	60.00	40.00	56.32	16.15	27.53	Sandy Clay Loam	5.36	0.025	6.3	10.5	1.33	15.50	105	22	216.5	36.50
246	32 / 32B	24	43.60	56.40	52.89	18.45	28.66	Sandy Clay Loam	5.13	0.001	6.3	10.5	0.74	22.00	80	18	135.5	30.50
247	32 / 33A	19	50.00	50.00	N.A.				4.89	0.003	6.3	10.5	1.06	1.08	64	15	80.5	33.00
248	32 / 33B	19	56.00	44.00	N.A.				4.99	0.001	5.8	18.6	0.75	0.36	60	12	64.5	31.50
249	32 / 34A	22	54.60	45.40	N.A.				5.11	0.031	5.7	20.1	1.30	12.30	132	26	250.5	40.00
250	32 / 34B	22	51.76	48.24	N.A.				4.68	0.063	5.7	20.1	0.41	21.55	132	27	172.0	35.50
251	32 / 35A	22	70.00	30.00	N.A.				4.80	0.020	6.1	13.4	0.88	4.97	71	17	174.5	33.50
252	32 / 35B	22	51.90	48.10	N.A.				4.73	0.043	5.7	20.1	0.63	2.31	88	18	113.5	32.50
253	32 / 36A	22	71.00	29.00	N.A.				5.45	0.015	6.0	15.2	1.18	2.66	78	18	188.0	35.00
254	32 / 36B	22	51.30	48.70	N.A.				4.78	0.138	5.7	20.1	0.77	0.55	68	34	308.0	39.50
255	32 / 37A	22	60.00	40.00	N.A.				5.01	0.002	5.7	20.1	0.97	0.36	64	14	105.5	32.50
256	32 / 37B	22	46.50	53.50	N.A.				4.96	0.010	5.7	20.1	0.77	0.13	81	16	99.5	29.50
257	32 / 38A	22	61.00	39.00	N.A.				4.95	0.012	5.5	23.3	1.26	1.55	50	16	135.5	35.00
258	32 / 38B	22	45.60	54.40	N.A.				4.62	0.008	5.5	23.3	0.82	2.61	42	16	120.0	30.00
259	32 / 39A	16	61.00	39.00	N.A.				4.96	0.036	5.6	21.8	1.27	5.44	61	15	155.5	30.50
260	32 / 39B	16	41.93	58.07	N.A.				4.69	0.017	5.7	20.1	0.71	0.95	54	12	108.0	32.00
261	32 / 40A	19	59.00	41.00	N.A.				5.22	0.017	5.8	18.6	1.20	4.75	62	15	159.0	34.00

*Sample code:- Block No./ sample site No. and surface(A) or subsurface(B)

**N.A: Not analysed

Appendix IIII.
Raw Data generated by the analytical work on the soils of the western part of the main campus, KAU

No.	Av. Mn ($\mu g\ g^{-1}$)	Av. Zn ($\mu g\ g^{-1}$)	Av. Cu ($\mu g\ g^{-1}$)	Av. Fe ($\mu g\ g^{-1}$)	P- fix.cap. %	Exch. Fe ($\mu g\ g^{-1}$)	Exch. Mn ($\mu g\ g^{-1}$)	Exch. Ca ($\mu g\ g^{-1}$)	Exch. Mg ($\mu g\ g^{-1}$)	Exch. Na ($\mu g\ g^{-1}$)	Exch. K ($\mu g\ g^{-1}$)	Exch. Al ($\mu g\ g^{-1}$)	CEC cmol(+) kg^{-1}	Na sat. %	BSP %	Al sat. %
233	71.4	0.89	17.22	17.4	N.A.	2.30	151.2	327	124.8	206	182	11.25	4.7075	19.03	85.47	2.66
234	46.7	0.69	6.03	25.4	N.A.	2.20	123.4	302	121.0	190	166	11.38	4.3405	19.04	86.55	2.92
235	61.5	1.19	13.72	18.2	N.A.	3.00	151.9	283	101.0	120	96	24.50	3.8500	13.56	78.28	7.08
236	32.6	0.49	3.78	15.7	N.A.	2.50	89.9	185	77.5	182	162	41.25	3.5639	22.21	77.69	12.87
237	25.7	0.69	11.72	14.0	63.08	2.20	83.6	272	122.1	202	164	20.13	4.1991	20.92	87.23	5.33
238	36.4	0.49	4.56	17.2	70.43	2.60	115.1	264	115.5	196	130	15.25	4.0536	21.03	85.25	4.18
239	62.2	1.19	11.44	16.6	41.35	2.50	148.5	268	99.6	168	144	6.88	3.8848	18.81	83.89	1.97
240	10.5	0.39	4.41	14.9	57.28	2.80	24.1	313	93.0	190	146	4.13	3.6739	22.49	96.09	1.25
241	57.2	0.99	6.66	34.4	N.A.	3.10	128.9	210	96.4	158	130	26.75	3.6410	18.88	78.64	8.17
242	36.1	0.39	2.61	18.5	N.A.	3.70	107.6	226	49.7	160	128	35.75	3.3650	20.68	76.15	11.82
243	33.5	0.99	5.40	26.6	N.A.	2.00	85.8	298	85.2	168	146	21.63	3.8554	18.95	85.47	6.24
244	16.5	0.49	4.60	22.0	N.A.	1.70	48.1	103	37.2	136	118	50.75	2.4602	24.04	69.69	22.95
245	43.9	1.19	8.82	35.6	N.A.	2.00	85.6	296	101.8	164	170	39.25	4.2214	16.90	82.11	10.34
246	29.1	0.69	4.99	30.4	N.A.	2.50	75.6	250	103.0	182	188	18.88	3.8643	20.49	87.21	5.43
247	45.4	0.79	4.13	17.5	N.A.	2.00	125.6	176	100.0	168	154	9.63	3.3991	21.50	83.19	3.15
248	33.5	0.59	7.25	19.8	N.A.	2.30	109.2	185	53.0	162	150	53.63	3.4518	20.41	70.96	17.28
249	51.1	1.49	6.44	25.0	N.A.	2.00	97.0	161	82.1	154	138	37.88	3.2851	20.39	76.21	12.82
250	22.9	1.39	1.93	35.0	N.A.	1.90	65.6	264	69.7	154	188	59.50	3.9518	16.95	77.04	16.75
251	34.0	1.29	11.90	16.1	N.A.	1.80	95.6	254	108.9	178	216	10.75	3.9670	19.52	88.05	3.01
252	44.7	1.59	4.17	24.7	N.A.	1.90	133.2	230	38.9	178	166	30.38	3.4985	22.13	76.29	9.66
253	54.5	0.79	11.63	20.7	65.94	2.00	113.0	298	59.2	178	180	32.63	3.9933	19.39	80.43	9.09
254	33.6	0.89	5.59	20.5	67.29	2.00	95.3	319	127.9	212	144	63.38	4.9971	18.45	78.81	14.11
255	52.6	1.19	10.22	23.3	56.41	1.90	129.7	217	72.6	176	140	26.00	3.5743	21.42	78.51	8.09
256	36.9	0.89	4.13	19.2	58.18	1.80	114.8	196	58.8	158	142	10.13	3.0514	22.52	82.40	3.69
257	88.5	1.19	8.38	15.0	N.A.	1.90	166.6	276	100.4	96	60	69.63	4.1651	10.03	66.68	18.59
258	74.6	0.59	3.55	28.6	N.A.	2.10	169.2	253	79.0	104	62	48.38	3.6877	12.27	68.50	14.59
259	73.0	1.09	6.88	21.2	N.A.	1.70	146.2	285	96.5	148	114	72.38	4.4979	14.31	70.13	17.90
260	46.7	0.69	1.81	27.0	N.A.	1.70	115.9	226	96.4	170	128	70.25	4.1997	17.61	71.20	18.61
261	73.2	1.29	12.32	25.3	N.A.	1.90	148.9	268	77.5	168	132	36.75	4.0038	18.25	76.08	10.21

*Sample code:- Block No./ sample site No. and surface(A) or subsurface(B)

**N.A: Not analysed

Appendix III.
Raw Data generated by the analytical work on the soils of the western part of the main campus, KAU

No.	*Sample Code	Phase	Gravel %	Fine earth %	Sand %	Silt %	Clay %	Textural class	pH	EC dS/m	Buffer pH	Lime R. (t ha^{-1})	Org. C (%)	Av. P (µg g^{-1})	Av. K (µg g^{-1})	Av. Na (µg g^{-1})	Av. Ca (µg g^{-1})	Av. Mg (µg g^{-1})
262	32 / 40B	19	31.00	69.00	N.A.				5.11	0.002	5.6	21.8	1.03	2.64	60	10	111.0	29.50
263	32 / 41A	19	50.00	50.00	N.A.				5.16	0.005	5.5	23.3	1.07	3.08	35	10	131.5	30.00
264	32 / 41B	19	38.66	61.34	N.A.				5.17	0.020	5.7	20.1	0.75	1.47	35	18	201.5	32.50
265	32 / 42A	16	50.00	50.00	N.A.				5.38	0.020	5.6	21.8	1.35	1.38	92	19	208.0	35.00
266	32 / 42B	16	26.00	74.00	N.A.				5.08	0.192	5.6	21.8	0.97	0.88	96	61	223.5	33.50
267	32 / 43A	16	43.30	56.70	N.A.				4.66	0.001	5.3	26.7	1.20	5.54	16	4	13.0	10.50
268	32 / 43B	16	40.66	59.34	N.A.				4.41	0.025	5.4	25.3	1.07	2.79	15	6	20.5	9.00
269	33 / 1A	13	50.00	50.00	N.A.				4.82	0.007	5.6	21.8	1.20	13.79	18	11	91.5	30.00
270	33 / 1B	13	45.33	54.67	N.A.				4.83	0.001	5.5	23.3	1.13	16.79	20	12	105.0	28.50
271	33 / 2A	13	61.00	39.00	N.A.				5.26	0.039	5.9	17.2	1.07	7.00	55	19	190.0	39.50
272	33 / 2B	13	46.00	54.00	N.A.				5.14	0.001	5.5	23.3	0.84	10.08	16	13	115.0	29.00
273	33 / 3A	6	60.00	40.00	N.A.				5.50	0.006	5.6	21.8	1.04	5.92	79	18	194.5	38.50
274	33 / 3B	6	38.66	61.34	N.A.				4.88	0.001	5.5	23.3	0.71	1.25	29	6	55.5	29.00
275	33 / 4A	6	58.00	42.00	N.A.				5.57	0.002	5.5	23.3	0.78	4.00	73	23	135.5	31.00
276	33 / 4B	6	36.00	64.00	N.A.				4.99	0.001	5.7	20.1	0.47	5.00	35	17	107.0	29.00
277	33 / 5A	6	48.00	52.00	56.18	13.47	30.35	Sandy Clay Loam	5.35	0.050	5.7	20.1	1.16	5.21	51	22	170.5	39.00
278	33 / 5B	6	26.66	73.34	52.90	18.64	28.46	Sandy Clay Loam	4.92	0.023	5.7	20.1	0.74	3.04	28	22	60.0	30.50
279	33 / 6A	6	69.00	31.00	N.A.				4.94	0.001	5.2	28.5	0.94	8.33	15	10	31.5	17.50
280	33 / 6B	6	45.33	54.67	N.A.				4.93	0.001	5.4	25.3	0.68	8.92	20	17	64.5	25.00
281	33 / 7A	13	60.00	40.00	60.45	14.77	24.78	Sandy Clay Loam	5.21	0.005	5.6	21.8	0.96	1.00	32	16	121.5	30.50
282	33 / 7B	13	46.00	54.00	58.87	14.48	26.65	Sandy Clay Loam	4.90	0.024	5.5	23.3	0.79	3.08	46	22	70.5	30.50
283	33 / 8A	13	60.00	40.00	N.A.				5.10	0.001	5.7	20.1	1.04	1.21	27	14	55.0	30.00
284	33 / 8B	13	38.66	61.34	N.A.				4.66	0.017	5.5	23.3	0.82	4.75	33	22	107.0	23.00
285	34 / 1A	13	59.00	41.00	N.A.				4.65	0.103	5.3	26.7	0.99	4.67	84	26	233.0	29.50
286	34 / 1B	13	30.00	70.00	N.A.				4.86	0.014	5.3	26.7	1.09	8.63	73	29	27.0	29.00
287	34 / 2A	30	59.00	41.00	N.A.				4.82	0.004	5.1	30.2	0.93	1.00	36	11	53.0	16.00
288	34 / 2B	30	36.60	63.40	N.A.				4.79	0.005	5.6	21.8	0.62	1.25	26	19	67.0	21.00
289	34 / 3A	33	63.00	37.00	N.A.				4.75	0.014	5.2	28.5	0.85	2.21	68	16	65.0	31.50
290	34 / 3B	33	33.60	66.40	N.A.				4.81	0.001	5.6	21.8	0.54	1.29	69	17	153.5	30.00

*Sample code:- Block No./ sample site No. and surface(A) or subsurface(B)
**N.A: Not analysed

Appendix IIII.

Raw Data generated by the analytical work on the soils of the western part of the main campus, KAU

No.	Av. Mn ($\mu g\ g^{-1}$)	Av. Zn ($\mu g\ g^{-1}$)	Av. Cu ($\mu g\ g^{-1}$)	Av. Fe ($\mu g\ g^{-1}$)	P- fix.cap. %	Exch. Fe ($\mu g\ g^{-1}$)	Exch. Mn ($\mu g\ g^{-1}$)	Exch. Ca ($\mu g\ g^{-1}$)	Exch. Mg ($\mu g\ g^{-1}$)	Exch. Na ($\mu g\ g^{-1}$)	Exch. K ($\mu g\ g^{-1}$)	Exch. Al ($\mu g\ g^{-1}$)	CEC cmol(+) kg^{-1}	Na sat. %	BSP %	Al sat. %
262	50.1	1.39	16.33	30.5	N.A.	2.20	160.3	222	83.4	156	130	23.88	3.6645	18.52	76.61	7.25
263	33.9	1.39	12.66	31.4	N.A.	1.50	113.1	254	82.0	166	116	19.00	3.5921	20.10	82.50	5.88
264	34.0	0.49	4.76	13.5	N.A.	1.90	94.1	286	97.7	176	110	21.13	3.8653	19.81	84.88	6.08
265	76.6	1.49	13.24	27.9	N.A.	2.20	151.0	315	93.7	126	110	66.63	4.4743	12.25	70.97	16.56
266	76.0	1.19	8.22	17.4	N.A.	2.00	147.0	333	22.1	244	170	58.63	4.5374	23.39	73.68	14.37
267	42.6	0.59	16.23	22.3	48.36	1.70	89.6	420	31.8	146	100	38.38	4.0117	15.83	81.08	10.64
268	46.7	0.89	10.26	14.8	53.54	1.70	112.4	66	87.4	140	92	26.00	2.5981	23.44	72.88	11.13
269	60.2	1.29	13.03	19.4	N.A.	2.70	147.7	238	72.0	180	104	90.38	4.3842	17.86	64.59	22.93
270	52.6	1.49	13.55	22.2	N.A.	2.00	132.6	417	69.3	184	120	58.38	4.9018	16.33	76.76	13.25
271	60.0	1.49	15.05	16.9	N.A.	1.50	88.0	460	125.6	184	142	50.13	5.3806	14.87	83.58	10.36
272	48.9	1.49	7.73	24.4	N.A.	1.80	117.6	427	96.6	132	80	61.38	4.8261	11.90	76.85	14.15
273	57.6	0.79	9.50	19.0	N.A.	1.70	68.6	390	90.4	114	94	16.88	3.8738	12.80	88.55	4.85
274	47.9	0.69	3.24	21.6	N.A.	1.10	108.7	336	88.9	176	126	69.50	4.6722	16.39	74.90	16.55
275	53.1	1.59	7.80	23.1	N.A.	1.80	88.4	409	97.4	178	158	14.63	4.5159	17.14	89.13	3.60
276	40.7	0.69	3.33	26.6	N.A.	2.10	83.6	410	139.7	196	138	21.00	4.9507	17.22	88.98	4.72
277	59.4	1.59	17.03	18.1	52.48	1.30	72.4	233	93.4	178	138	34.25	3.7101	20.87	82.50	10.27
278	81.0	1.09	10.36	23.1	57.77	2.00	161.8	279	59.7	170	126	37.63	3.9628	18.66	74.39	10.56
279	38.3	0.89	9.04	21.3	N.A.	1.90	101.1	207	76.8	148	104	47.63	3.4814	18.49	74.02	15.22
280	52.7	1.19	5.01	38.3	N.A.	1.90	121.1	298	75.0	138	92	11.13	3.5142	17.08	83.74	3.52
281	76.8	0.89	7.27	31.6	N.A.	1.00	49.7	334	77.1	136	96	26.00	3.6154	16.36	86.90	8.00
282	54.7	1.09	5.21	32.9	N.A.	1.50	155.9	377	86.6	144	110	38.75	4.5094	13.89	77.74	9.56
283	61.7	0.99	9.29	39.3	N.A.	5.00	136.6	318	90.0	130	98	16.25	3.8428	14.71	81.89	4.70
284	86.1	1.09	7.21	23.3	N.A.	2.00	164.6	310	74.5	152	98	20.88	3.9135	16.89	78.57	5.93
285	94.8	0.79	20.12	34.0	64.10	1.50	187.1	423	87.2	180	154	37.50	5.1131	15.31	78.42	8.16
286	72.4	1.79	10.64	49.9	71.40	1.80	120.4	490	85.5	198	150	31.00	5.1882	16.60	84.78	6.65
287	59.8	0.69	15.68	32.0	N.A.	1.70	121.6	190	50.9	156	112	29.00	3.1053	21.85	75.16	10.39
288	84.4	0.39	14.05	29.4	N.A.	2.00	147.2	270	63.8	150	96	31.50	3.6665	17.80	75.63	9.56
289	41.2	1.09	15.73	47.4	N.A.	2.00	81.1	332	89.5	154	130	28.13	4.0142	16.69	84.67	7.79
290	36.3	0.39	6.31	39.9	N.A.	2.00	77.4	306	85.4	142	122	32.63	3.8144	16.19	82.91	9.51

*Sample code:- Block No./ sample site No. and surface(A) or subsurface(B)

**N.A: Not analysed

Appendix III.

Raw Data generated by the analytical work on the soils of the western part of the main campus, KAU

No.	*Sample Code	Phase	Gravel %	Fine earth %	Sand %	Silt %	Clay %	Textural class	pH	EC dS/m	Buffer pH	Lime R. (t ha^{-1})	Org. C (%)	Av. P ($\mu g\ g^{-1}$)	Av. K ($\mu g\ g^{-1}$)	Av. Na ($\mu g\ g^{-1}$)	Av. Ca ($\mu g\ g^{-1}$)	Av. Mg ($\mu g\ g^{-1}$)
291	34 / 4A	30	62.00	38.00	45.42	25.43	29.15	Sandy Clay Loam	5.09	0.008	5.6	21.8	0.97	0.37	42	21	88.0	35.50
292	34 / 4B	30	43.30	56.70	36.40	30.85	32.75	Clay Loam	4.96	0.003	5.5	23.3	0.65	0.25	29	27	199.5	35.00
293	34 / 5A	17	61.00	39.00	N.A.				4.87	0.017	5.8	18.6	0.76	0.83	51	15	52.5	33.50
294	34 / 5B	17	57.30	42.70	N.A.				5.06	0.001	5.7	20.1	0.50	0.21	40	14	38.5	30.00
295	34 / 6A	33	51.00	49.00	45.36	9.75	44.89	Sandy Clay	4.68	0.014	5.0	31.8	1.26	0.21	27	12	63.0	27.00
296	34 / 6B	33	44.00	56.00	44.55	10.97	44.48	Sandy Clay	4.32	0.148	5.1	30.2	1.02	0.25	30	24	178.5	28.00
297	34 / 7A	33	70.00	30.00	N.A.				4.98	0.025	5.2	28.5	1.17	0.75	28	34	209.0	34.00
298	34 / 7B	33	36.60	63.40	N.A.				4.74	0.024	5.5	23.3	0.65	0.14	24	31	170.0	36.00
299	34 / 8A	33	61.00	39.00	55.32	17.68	27.00	Sandy Clay Loam	4.63	0.003	5.3	26.7	0.77	1.69	34	8	15.0	12.50
300	34 / 8B	33	46.00	54.00	50.12	20.76	29.12	Sandy Clay Loam	5.13	0.001	6.2	12.1	0.91	1.19	30	7	41.5	10.00
301	34 / 9A	30	69.00	31.00	N.A.				4.75	0.004	6.0	15.2	1.00	1.28	63	14	34.0	34.00
302	34 / 9B	30	34.60	65.40	N.A.				4.70	0.023	6.3	10.5	0.88	2.14	49	16	136.5	25.00
303	34 / 10A	17	64.00	36.00	53.69	18.01	28.30	Sandy Clay Loam	4.69	0.028	6.4	9.0	1.15	1.69	72	19	57.5	37.00
304	34 / 10B	17	46.60	53.40	51.20	18.53	30.27	Sandy Clay Loam	4.91	0.038	6.3	10.5	0.82	0.19	70	14	70.0	27.50
305	35 / 1A	6	73.00	27.00	N.A.				5.09	0.004	6.3	10.5	0.91	0.55	36	9	24.5	25.00
306	35 / 1B	6	36.60	63.40	N.A.				5.01	0.008	6.4	9.0	1.18	1.14	44	16	36.0	27.50
307	35 / 2A	6	68.00	32.00	N.A.				4.94	0.004	6.5	7.0	1.00	2.08	67	15	82.5	34.00
308	35 / 2B	6	45.60	54.40	N.A.				5.12	0.017	6.4	9.0	0.66	0.19	14	11	25.5	15.50
309	35 / 3A	13	59.00	41.00	N.A.				4.84	0.001	6.3	10.5	0.91	2.72	44	13	28.5	28.00
310	35 / 3B	13	48.00	52.00	N.A.				5.01	0.002	6.4	9.0	0.66	0.56	50	12	59.0	30.50
311	35 / 4A	2	45.00	55.00	N.A.				5.00	0.005	6.5	7.0	0.77	1.31	24	8	23.0	23.00
312	35 / 4B	2	76.00	24.00	N.A.				5.05	0.001	6.6	5.3	0.50	0.58	19	8	17.0	21.50
313	35 / 5A	6	55.30	44.70	N.A.				5.07	0.008	6.4	9.0	0.88	0.25	14	9	19.0	20.00
314	35 / 5B	6	62.60	37.40	N.A.				4.90	0.001	6.6	5.3	0.74	0.17	12	15	21.5	15.00
315	35 / 6A	16	48.00	52.00	N.A.				5.01	0.009	5.9	17.2	0.94	1.13	28	8	18.0	22.00
316	35 / 6B	16	68.00	32.00	N.A.				4.84	0.003	6.1	13.4	0.45	0.29	23	10	17.5	20.50
317	35 / 7A	6	58.00	42.00	N.A.				4.98	0.015	6.3	10.5	0.77	5.75	36	9	53.0	24.00
318	35 / 7B	6	64.00	36.00	N.A.				4.88	0.003	6.2	12.1	0.62	0.75	40	10	11.0	13.50
319	35 / 8A	6	50.00	50.00	N.A.				5.11	0.007	6.2	12.1	0.81	1.50	41	6	29.5	24.00

*Sample code:- Block No./ sample site No. and surface(A) or subsurface(B)

**N.A: Not analysed

Appendix IIII.

Raw Data generated by the analytical work on the soils of the western part of the main campus, KAU

No.	Av. Mn ($\mu g\ g^{-1}$)	Av. Zn ($\mu g\ g^{-1}$)	Av. Cu ($\mu g\ g^{-1}$)	Av. Fe ($\mu g\ g^{-1}$)	P- fix.cap. %	Exch. Fe ($\mu g\ g^{-1}$)	Exch. Mn ($\mu g\ g^{-1}$)	Exch. Ca ($\mu g\ g^{-1}$)	Exch. Mg ($\mu g\ g^{-1}$)	Exch. Na ($\mu g\ g^{-1}$)	Exch. K ($\mu g\ g^{-1}$)	Exch. Al ($\mu g\ g^{-1}$)	CEC cmol(+) kg^{-1}	Na sat. %	BSP %	Al sat. %
291	62.8	0.69	7.12	14.1	69.53	1.80	73.7	440	113.0	140	126	18.38	4.5404	13.41	89.45	4.50
292	62.1	0.29	1.94	24.4	52.06	1.80	76.0	379	103.7	142	126	28.88	4.2927	14.39	85.92	7.48
293	78.7	0.69	12.83	20.8	N.A.	1.60	156.2	296	103.7	140	110	25.63	4.0832	14.91	78.95	6.98
294	51.7	0.59	3.11	28.0	N.A.	1.90	126.0	205	78.9	148	108	15.88	3.2362	19.89	80.16	5.46
295	39.4	0.19	6.21	25.0	N.A.	1.70	124.2	215	87.4	148	100	10.50	3.2689	19.69	82.41	3.57
296	53.6	0.59	2.48	15.6	N.A.	2.00	104.3	333	78.2	168	96	7.38	3.7538	19.47	87.51	2.19
297	50.7	0.29	7.53	21.0	N.A.	1.40	102.8	454	108.7	164	94	40.50	4.9482	14.42	83.23	9.10
298	53.6	0.59	3.79	15.8	N.A.	2.20	107.9	443	54.1	156	80	35.25	4.3362	15.65	81.72	9.04
299	43.9	0.59	13.94	37.8	53.38	1.70	76.4	105	36.5	108	76	17.75	1.9712	23.83	75.57	10.02
300	24.8	0.49	8.16	32.8	78.79	4.30	56.0	84	98.4	96	68	46.75	2.5606	16.31	71.13	20.31
301	41.4	0.39	12.11	26.1	N.A.	1.70	73.6	235	89.8	152	132	7.50	3.2703	20.22	89.07	2.55
302	34.3	0.59	2.90	32.2	N.A.	1.60	66.9	194	121.4	150	116	22.75	3.4206	19.07	85.31	7.40
303	54.4	0.39	12.33	21.1	N.A.	1.70	101.9	378	76.8	170	144	15.63	4.1807	17.69	86.82	4.16
304	43.8	0.49	3.53	23.7	N.A.	2.00	134.8	294	77.0	154	142	45.25	4.1380	16.19	75.80	12.16
305	37.5	0.19	7.28	24.7	N.A.	2.10	114.7	185	44.0	126	126	53.63	3.1790	17.24	67.87	18.76
306	45.8	0.39	12.52	26.6	N.A.	1.70	119.1	229	74.8	152	122	48.75	3.7157	17.79	73.57	14.59
307	49.6	0.29	9.18	21.7	N.A.	2.10	114.9	319	89.9	148	122	20.13	3.9404	16.34	83.51	5.68
308	82.1	0.29	1.93	35.2	N.A.	1.80	180.1	133	48.1	138	122	33.63	3.0093	19.95	65.57	12.43
309	46.2	0.39	7.68	37.8	N.A.	2.30	118.3	164	72.0	142	104	55.13	3.3483	18.45	68.58	18.31
310	33.3	0.29	2.74	29.2	N.A.	1.90	67.4	226	31.2	110	80	44.75	2.8198	16.97	73.40	17.65
311	76.1	0.49	4.44	24.6	N.A.	2.20	157.4	140	57.7	108	72	39.63	2.8504	16.48	64.16	15.46
312	41.8	0.39	2.07	26.3	N.A.	1.60	74.9	96	17.5	104	66	11.13	1.6473	27.46	75.59	7.51
313	74.7	0.49	3.07	36.9	50.53	2.00	137.2	121	51.5	104	60	44.13	2.6321	17.19	62.11	18.65
314	82.3	0.39	2.02	40.0	58.69	1.70	160.3	120	38.4	110	62	36.13	2.5446	18.80	61.04	15.79
315	84.4	0.39	8.94	34.1	N.A.	1.70	182.7	122	60.6	112	72	33.63	2.8253	17.24	63.01	13.24
316	85.7	0.59	3.80	29.6	N.A.	1.90	242.0	186	71.1	148	114	42.75	3.8138	16.88	64.25	12.47
317	67.4	1.69	7.10	53.9	N.A.	1.50	142.8	324	81.8	150	122	37.38	4.1987	15.54	77.59	9.90
318	44.3	0.39	4.16	26.1	N.A.	2.20	142.5	97	50.8	136	120	52.13	2.9080	20.34	61.95	19.94
319	54.7	0.69	4.14	23.0	N.A.	2.20	144.0	209	75.0	132	114	38.38	3.4870	16.47	72.50	12.24

*Sample code:- Block No./ sample site No. and surface(A) or subsurface(B)

**N.A: Not analysed

Appendix III.

Raw Data generated by the analytical work on the soils of the western part of the main campus, KAU

No.	*Sample Code	Phase	Gravel %	Fine earth %	Sand %	Silt %	Clay %	Textural class	pH	EC dS/m	Buffer pH	Lime R. (t ha^{-1})	Org. C (%)	Av. P (µg g^{-1})	Av. K (µg g^{-1})	Av. Na (µg g^{-1})	Av. Ca (µg g^{-1})	Av. Mg (µg g^{-1})
320	35 / 8B	6	68.00	32.00	N.A.				5.02	0.008	6.2	12.1	0.90	0.38	39	6	30.5	19.50
321	35 / 9A	6	45.30	54.70	50.75	13.18	36.07	Sandy Clay	4.76	0.001	5.8	18.6	1.02	0.46	27	7	28.5	25.00
322	35 / 9B	6	67.30	32.70	57.70	13.45	28.85	Sandy Clay Loam	4.84	0.001	5.9	17.2	0.78	0.29	19	12	42.5	24.00
323	35 / 10A	7	47.30	52.70	58.32	13.34	28.34	Sandy Clay Loam	4.60	0.385	6.0	15.2	0.85	2.83	26	36	265.5	38.50
324	35 / 10B	7	45.30	54.70	50.24	17.63	32.13	Sandy Clay Loam	5.52	0.001	6.2	12.1	0.59	0.21	19	31	263.5	39.50
325	35 / 11A	6	47.30	52.70	N.A.				5.82	0.006	5.7	20.1	0.88	5.67	15	13	56.0	22.00
326	35 / 11B	6	37.30	62.70	N.A.				4.96	0.001	5.9	17.2	0.63	0.83	11	19	141.0	26.50
327	35 / 12A	6	46.00	54.00	N.A.				5.28	0.002	5.9	17.2	0.62	0.96	26	22	157.5	34.50
328	35 / 12B	6	50.66	49.34	N.A.				5.02	0.001	5.9	17.2	0.36	0.58	21	30	182.0	37.50
329	35 / 13A	16	48.00	52.00	53.47	15.06	31.47	Sandy Clay Loam	4.84	0.001	6.0	15.2	0.79	1.21	24	15	71.5	29.00
330	35 / 13B	16	50.00	50.00	48.25	18.80	32.95	Sandy Clay Loam	5.04	0.001	5.7	20.1	0.53	0.17	20	11	80.0	27.00
331	35 / 14A	18	41.00	59.00	57.36	17.53	25.11	Sandy Clay Loam	4.82	0.003	5.0	31.8	0.77	0.50	30	18	67.5	31.50
332	35 / 14B	18	39.33	60.67	50.62	20.57	28.81	Sandy Clay Loam	5.01	0.001	5.1	30.2	0.48	0.29	33	19	117.5	34.50
333	35 / 15A	6	40.60	59.40	N.A.				5.09	0.001	5.4	25.3	1.06	0.63	20	12	21.0	26.00
334	35 / 15B	6	33.33	66.67	N.A.				5.11	0.053	5.6	21.8	0.65	0.58	19	17	95.0	32.00
335	35 / 16A	6	34.60	65.40	N.A.				4.83	0.014	5.6	21.8	0.94	1.25	19	11	16.0	23.50
336	35 / 16B	6	50.66	49.34	N.A.				4.51	0.080	5.7	20.1	0.82	0.46	16	13	27.5	23.50
337	35 / 17A	2	63.00	37.00	64.50	9.91	25.59	Sandy Clay Loam	4.95	0.014	5.5	23.3	1.21	1.54	31	9	15.0	17.50
338	35 / 17B	2	32.00	68.00	52.41	17.41	30.18	Sandy Clay Loam	4.95	0.002	5.4	25.3	0.88	0.46	32	9	19.0	18.50
339	35 / 18A	18	60.00	40.00	58.38	16.09	25.53	Sandy Clay Loam	5.08	0.009	5.8	18.6	1.06	4.00	31	30	102.0	26.00
340	35 / 18B	18	40.00	60.00	50.35	16.13	33.52	Sandy Clay Loam	4.57	0.002	5.5	23.3	0.72	2.71	23	13	29.0	11.00
341	35 / 19A	2	53.50	46.50	N.A.				4.70	0.007	7.0	0.0	1.32	1.58	43	11	22.0	25.00
342	35 / 19B	2	33.30	66.70	N.A.				4.99	0.001	5.5	23.3	0.94	0.33	20	11	12.5	21.50
343	35 / 20A	1	40.00	60.00	60.15	14.40	25.45	Sandy Clay Loam	4.90	0.001	5.6	21.8	0.84	4.83	27	15	14.5	22.50
344	35 / 20B	1	39.30	60.70	55.10	16.16	28.74	Sandy Clay Loam	4.79	0.001	5.4	25.3	0.71	0.43	26	6	8.0	20.00
345	35 / 21A	18	62.60	37.40	56.65	13.87	29.48	Sandy Clay Loam	4.70	0.001	5.6	21.8	1.02	2.92	26	10	23.0	23.00
346	35 / 21B	18	30.66	69.34	51.11	18.37	30.52	Sandy Clay Loam	4.65	0.001	5.5	23.3	0.59	2.08	19	10	15.5	23.50
347	35 / 22A	6	43.50	56.50	N.A.				4.70	0.002	5.6	21.8	1.18	2.29	43	12	29.0	29.00
348	35 / 22B	6	42.00	58.00	N.A.				4.95	0.001	5.4	25.3	0.65	0.83	37	13	24.0	27.00

*Sample code:- Block No./ sample site No. and surface(A) or subsurface(B)

**N.A: Not analysed

Appendix III.

Raw Data generated by the analytical work on the soils of the western part of the main campus, KAU

No.	Av. Mn ($\mu g\ g^{-1}$)	Av. Zn ($\mu g\ g^{-1}$)	Av. Cu ($\mu g\ g^{-1}$)	Av. Fe ($\mu g\ g^{-1}$)	P- fix.cap. %	Exch. Fe ($\mu g\ g^{-1}$)	Exch. Mn ($\mu g\ g^{-1}$)	Exch. Ca ($\mu g\ g^{-1}$)	Exch. Mg ($\mu g\ g^{-1}$)	Exch. Na ($\mu g\ g^{-1}$)	Exch. K ($\mu g\ g^{-1}$)	Exch. Al ($\mu g\ g^{-1}$)	CEC cmol(+) kg^{-1}	Na sat. %	BSP %	Al sat. %
320	70.5	0.59	3.38	29.8	N.A.	2.50	194.6	250	69.0	134	122	48.00	3.9641	14.70	68.43	13.47
321	35.0	0.79	4.58	18.3	54.17	1.30	187.8	215	73.3	136	106	53.25	3.8216	15.48	66.49	15.50
322	17.8	0.49	2.60	15.8	49.56	1.70	50.4	266	65.8	138	98	41.00	3.3681	17.82	80.83	13.54
323	53.8	1.19	9.86	25.5	N.A.	2.40	167.1	493	114.0	210	106	15.50	5.3771	16.99	85.32	3.21
324	19.6	0.99	5.28	35.6	N.A.	1.90	53.2	488	121.8	184	96	12.38	4.8265	16.58	92.99	2.85
325	39.5	0.59	11.97	99.3	N.A.	2.60	130.2	309	76.5	160	110	38.38	4.0621	17.13	77.59	10.51
326	28.3	0.38	6.92	45.1	N.A.	1.30	182.8	443	121.7	174	104	24.75	5.1849	14.60	81.77	5.31
327	97.2	0.61	5.88	22.6	N.A.	2.40	261.2	447	101.5	170	112	12.75	5.1976	14.23	78.81	2.73
328	65.5	0.77	3.25	32.2	N.A.	2.60	240.7	297	70.1	154	106	37.63	4.3070	15.55	69.72	9.72
329	63.8	0.36	4.84	19.3	N.A.	2.80	181.4	367	78.9	150	102	44.75	4.5659	14.29	74.42	10.90
330	97.1	0.31	2.98	26.1	N.A.	2.30	200.9	388	137.9	176	104	2.88	4.8781	15.69	84.18	0.66
331	116.0	0.25	8.72	21.5	62.81	1.60	248.0	353	83.7	150	108	38.88	4.7235	13.81	71.61	9.15
332	94.5	0.23	4.60	22.0	58.40	1.60	124.7	391	90.0	150	106	38.63	4.5086	14.47	80.28	9.53
333	79.3	0.48	7.62	21.3	N.A.	1.70	175.1	221	82.0	140	100	53.38	3.8818	15.69	68.13	15.29
334	106.0	0.49	3.91	26.8	N.A.	2.10	122.0	423	111.4	172	108	42.75	4.9834	15.01	81.39	9.54
335	57.6	0.24	9.49	17.3	N.A.	1.90	152.5	143	57.0	124	92	48.63	3.0616	17.62	63.98	17.67
336	66.7	0.22	17.22	21.0	N.A.	2.00	156.7	196	62.9	108	68	43.88	3.2070	14.65	66.77	15.22
337	36.5	0.17	3.50	14.5	59.56	1.20	110.6	161	48.0	92	64	51.38	2.7423	14.59	64.32	20.84
338	49.3	0.06	2.31	19.3	55.71	2.30	137.7	205	60.2	100	76	54.63	3.2669	13.31	65.81	18.60
339	28.7	0.34	5.10	30.3	N.A.	1.60	60.5	367	57.6	86	56	39.63	3.4931	10.71	80.91	12.62
340	17.9	0.18	2.31	34.6	N.A.	1.70	41.3	135	19.1	86	54	64.38	2.2169	16.87	60.64	32.30
341	50.6	0.11	8.80	29.8	N.A.	1.80	105.7	180	62.3	110	80	43.38	2.9695	16.11	70.58	16.25
342	34.4	0.05	2.51	12.6	N.A.	1.80	85.6	134	47.9	96	64	56.00	2.5865	16.14	63.62	24.08
343	31.7	0.05	2.46	18.3	49.19	1.40	77.8	93	43.7	66	46	48.50	2.0571	13.96	59.76	26.23
344	46.4	0.13	2.42	28.3	55.91	1.40	94.8	110	48.6	68	44	48.00	2.2424	13.19	60.58	23.81
345	48.5	0.20	4.23	22.3	52.47	2.20	98.4	154	54.6	86	60	44.75	2.6108	14.33	66.91	19.07
346	45.6	0.06	2.24	33.8	57.20	1.70	119.1	162	70.4	128	82	36.38	3.0002	18.56	71.86	13.49
347	42.6	0.09	4.73	15.9	N.A.	1.60	108.9	277	91.8	138	104	41.75	3.8734	15.50	77.63	11.99
348	45.9	0.03	2.13	21.7	N.A.	1.60	114.8	199	84.7	126	88	55.38	3.5049	15.64	70.34	17.57

*Sample code:- Block No./ sample site No. and surface(A) or subsurface(B)

**N.A: Not analysed

Appendix III.

Raw Data generated by the analytical work on the soils of the western part of the main campus, KAU

No.	*Sample Code	Phase	Gravel %	Fine earth %	Sand %	Silt %	Clay %	Textural class	pH	EC dS/m	Buffer pH	Lime R. (t ha^{-1})	Org. C (%)	Av. P ($\mu g\ g^{-1}$)	Av. K ($\mu g\ g^{-1}$)	Av. Na ($\mu g\ g^{-1}$)	Av. Ca ($\mu g\ g^{-1}$)	Av. Mg ($\mu g\ g^{-1}$)
349	35 / 23A	1	38.00	62.00	56.42	24.42	19.16	Sandy Loam	4.69	0.004	5.5	23.3	1.00	1.58	33	13	29.0	23.00
350	35 / 23B	1	32.60	67.40	48.49	25.24	26.27	Sandy Clay Loam	5.08	0.001	5.6	21.8	0.60	0.46	26	12	42.5	25.00
351	35 / 24A	6	39.30	60.70	N.A.				4.72	0.009	5.4	25.3	0.99	1.13	26	10	34.0	23.50
352	35 / 24B	6	40.66	59.34	N.A.				4.87	0.006	5.5	23.3	0.82	0.13	24	14	35.5	27.00
353	35 / 25A	6	59.00	41.00	N.A.				4.86	0.005	5.2	28.5	0.84	3.63	29	16	29.5	18.50
354	35 / 25B	6	38.60	61.40	N.A.				4.54	0.009	5.8	18.6	0.69	2.17	28	9	17.0	15.00
355	35 / 26A	6	61.50	38.50	67.16	13.24	19.60	Sandy Loam	4.79	0.006	5.8	18.6	0.62	1.21	19	7	18.0	26.00
356	35 / 26B	6	45.30	54.70	51.68	18.81	29.51	Sandy Clay Loam	4.92	0.007	5.8	18.6	0.60	1.00	26	21	39.0	29.50
357	35 / 27A	7	60.00	40.00	56.23	17.71	26.06	Sandy Clay Loam	4.25	0.185	5.9	17.2	0.65	1.67	32	23	34.5	24.50
358	35 / 27B	7	47.30	52.70	49.33	19.50	31.17	Sandy Clay Loam	4.94	0.010	5.6	21.8	0.56	3.00	23	14	12.0	20.50
359	35 / 28A	7	60.00	40.00	62.49	13.26	24.25	Sandy Loam	5.10	0.002	5.8	18.6	0.57	1.46	24	30	79.5	28.50
360	35 / 28B	7	50.60	49.40	60.55	13.58	25.87	Sandy Clay Loam	4.86	0.051	5.8	18.6	0.81	1.42	28	28	76.5	29.50
361	35 / 29A	27	83.00	17.00	54.36	20.31	25.33	Sandy Clay Loam	4.38	0.231	5.8	18.6	0.94	1.83	56	48	95.0	30.00
362	35 / 29B	27	40.66	59.34	48.65	24.29	27.06	Sandy Clay Loam	5.38	0.117	5.9	17.2	1.25	3.21	137	52	246.5	36.50
363	35 / 30A	4	63.00	37.00	44.23	25.81	29.96	Clay Loam	5.14	0.015	5.7	20.1	0.62	0.42	40	30	94.5	32.50
364	35 / 30B	4	52.00	48.00	41.50	31.38	27.12	Clay Loam	5.96	0.017	5.8	18.6	1.06	4.21	44	34	97.0	31.50
365	35 / 31A	4	62.00	38.00	N.A.				5.18	0.017	5.9	17.2	0.96	0.17	67	33	131.5	34.00
366	35 / 31B	4	37.33	62.67	N.A.				4.63	0.115	5.9	17.2	0.62	0.08	49	43	107.5	34.50
367	35 / 32A	27	60.00	40.00	N.A.				4.84	0.007	5.5	23.3	1.08	0.92	43	26	62.5	28.00
368	35 / 32B	27	33.30	66.70	N.A.				4.89	0.006	5.6	21.8	0.84	0.96	27	27	51.0	24.00
369	35 / 33A	4	52.00	48.00	48.12	21.70	30.18	Sandy Clay Loam	4.27	0.062	5.2	28.5	1.12	1.63	41	27	23.5	22.00
370	35 / 33B	4	37.30	62.70	43.25	23.65	33.10	Clay Loam	4.04	0.023	5.4	25.3	0.71	0.13	52	25	32.0	26.50
371	35 / 34A	4	54.00	46.00	N.A.				4.89	0.017	5.4	25.3	0.93	1.58	55	25	55.5	27.00
372	35 / 34B	4	50.60	49.40	N.A.				4.91	0.012	5.5	23.3	0.75	0.62	31	31	106.0	27.50
373	35 / 35A	4	69.00	31.00	42.82	24.83	32.35	Clay Loam	5.02	0.017	5.3	26.7	1.27	6.00	57	35	149.0	33.50
374	35 / 35B	4	65.33	34.67	38.84	23.74	37.42	Clay Loam	4.99	0.004	5.5	23.3	0.74	0.08	38	31	101.0	34.00
375	35 / 36A	7	75.00	25.00	N.A.				5.09	0.002	5.4	25.3	0.99	0.29	39	32	124.0	31.50
376	35 / 36B	7	66.60	33.40	N.A.				5.23	0.010	5.4	25.3	1.33	3.17	36	34	174.0	33.00
377	35 / 37A	7	79.00	21.00	49.40	15.66	34.94	Clay Loam	4.26	0.041	5.5	23.3	0.90	1.46	48	78	200.5	33.00

*Sample code:- Block No./ sample site No. and surface(A) or subsurface(B)

**N.A: Not analysed

Appendix III.

Raw Data generated by the analytical work on the soils of the western part of the main campus, KAU

No.	Av. Mn ($\mu g\ g^{-1}$)	Av. Zn ($\mu g\ g^{-1}$)	Av. Cu ($\mu g\ g^{-1}$)	Av. Fe ($\mu g\ g^{-1}$)	P- fix.cap. %	Exch. Fe ($\mu g\ g^{-1}$)	Exch. Mn ($\mu g\ g^{-1}$)	Exch. Ca ($\mu g\ g^{-1}$)	Exch. Mg ($\mu g\ g^{-1}$)	Exch. Na ($\mu g\ g^{-1}$)	Exch. K ($\mu g\ g^{-1}$)	Exch. Al ($\mu g\ g^{-1}$)	CEC cmol(+) kg^{-1}	Na sat. %	BSP %	Al sat. %
349	72.0	0.21	6.01	17.8	57.87	1.60	122.0	250	20.5	120	84	50.88	3.1713	16.46	67.97	17.84
350	70.9	0.15	2.17	27.3	67.45	1.80	247.0	262	56.0	114	76	41.00	3.8228	12.97	64.38	11.93
351	74.5	0.25	4.55	20.7	N.A.	2.40	237.8	228	60.2	138	90	50.50	3.9019	15.38	63.20	14.40
352	99.1	0.31	3.08	26.1	N.A.	2.10	292.6	84	71.6	146	92	44.75	3.4501	18.41	54.48	14.43
353	46.8	0.32	4.57	16.9	N.A.	2.00	47.2	84	19.0	142	92	16.75	1.7946	34.42	79.64	10.38
354	52.5	0.24	6.84	16.6	N.A.	2.10	155.7	141	35.0	138	98	37.63	2.8368	21.16	65.00	14.75
355	50.5	0.24	17.77	14.0	43.02	1.90	169.7	170	59.0	142	94	27.88	3.1283	19.74	70.12	9.91
356	50.1	0.30	12.11	18.9	40.90	2.30	186.4	277	62.0	142	88	23.63	3.6876	16.75	74.25	7.13
357	45.5	0.16	3.69	14.5	N.A.	1.80	154.9	269	65.6	148	96	29.25	3.6699	17.54	75.59	8.87
358	31.4	0.14	1.80	16.6	N.A.	2.10	86.5	129	75.7	142	92	41.25	2.9023	21.28	73.08	15.81
359	66.6	0.18	6.64	15.7	51.60	1.80	235.8	352	83.4	142	86	17.88	4.3477	14.21	75.53	4.57
360	84.2	0.37	12.31	22.6	69.24	1.80	252.6	349	84.0	148	88	20.63	4.4606	14.43	74.10	5.14
361	81.0	0.33	5.99	12.5	N.A.	1.50	283.3	396	84.8	154	94	27.63	4.9322	13.58	72.75	6.23
362	49.3	0.90	24.40	12.8	N.A.	1.90	176.9	492	109.4	172	164	4.00	5.2233	14.32	86.69	0.85
363	74.5	0.45	3.27	22.8	42.56	1.90	151.7	270	69.8	130	90	22.88	3.5336	16.00	76.98	7.20
364	90.9	0.45	9.89	22.1	54.25	5.10	278.5	345	84.2	116	76	26.38	4.4424	11.36	70.16	6.60
365	103.1	0.42	5.82	24.1	N.A.	1.80	279.9	367	92.2	120	86	13.13	4.5071	11.58	74.01	3.24
366	120.3	0.45	2.90	26.3	N.A.	2.30	324.8	361	84.9	130	78	14.00	4.6151	12.25	70.83	3.37
367	76.7	0.44	8.91	25.3	N.A.	1.80	214.2	295	78.4	116	80	48.00	4.1496	12.16	68.19	12.87
368	72.0	0.41	4.98	27.6	N.A.	1.60	168.1	239	51.5	114	66	51.63	3.4755	14.27	65.70	16.52
369	52.4	0.54	12.13	28.0	N.A.	1.70	125.6	162	44.6	104	72	64.75	2.9972	15.09	60.51	24.03
370	47.0	0.32	3.73	21.9	N.A.	2.40	119.0	164	49.8	112	78	66.50	3.0980	15.73	61.86	23.88
371	56.7	0.80	13.01	23.0	N.A.	2.30	136.1	233	68.2	106	80	58.88	3.5506	12.99	67.37	18.44
372	48.5	0.56	4.16	20.2	N.A.	3.50	112.2	318	73.0	112	70	47.88	3.8105	12.78	74.98	13.98
373	24.4	0.73	10.70	29.9	36.26	1.70	62.7	393	99.3	116	80	31.63	4.0776	12.37	85.63	8.63
374	39.0	0.39	3.63	18.0	49.65	1.90	123.0	349	88.8	120	76	34.38	4.0291	12.95	79.23	9.49
375	53.9	0.44	6.08	55.0	N.A.	2.00	137.0	360	73.1	114	70	36.50	3.9884	12.43	77.14	10.18
376	81.4	0.86	16.71	23.0	N.A.	2.20	222.9	407	77.2	122	72	17.63	4.4006	12.06	76.93	4.46
377	70.8	0.83	16.43	23.7	59.32	1.70	233.6	464	104.8	234	110	22.63	5.5899	18.21	80.18	4.50

*Sample code:- Block No./ sample site No. and surface(A) or subsurface(B)

**N.A: Not analysed

Appendix III.

Raw Data generated by the analytical work on the soils of the western part of the main campus, KAU

No.	*Sample Code	Phase	Gravel %	Fine earth %	Sand %	Silt %	Clay %	Textural class	pH	EC dS/m	Buffer pH	Lime R. (t ha^{-1})	Org. C (%)	Av. P ($\mu g\ g^{-1}$)	Av. K ($\mu g\ g^{-1}$)	Av. Na ($\mu g\ g^{-1}$)	Av. Ca ($\mu g\ g^{-1}$)	Av. Mg ($\mu g\ g^{-1}$)
378	35 / 37B	7	52.60	47.40	45.69	14.79	39.52	Sandy Clay	5.09	0.038	5.5	23.3	0.78	0.21	24	31	138.0	30.00
379	35 / 38A	13	57.30	42.70	N.A.				4.69	0.018	5.5	23.3	1.00	1.67	38	22	39.5	24.00
380	35 / 38B	13	56.00	44.00	N.A.				4.42	0.085	5.3	26.7	1.21	3.25	36	25	36.5	24.50
381	35 / 39A	13	53.30	46.70	N.A.				4.73	0.043	5.5	23.3	0.90	1.33	47	31	101.5	29.50
382	35 / 39B	13	42.60	57.40	N.A.				4.56	0.070	6.6	5.3	0.62	0.38	48	48	157.5	29.50
383	35 / 40A	27	53.30	46.70	N.A.				4.66	0.032	5.6	21.8	1.20	1.71	30	31	105.0	27.50
384	35 / 40B	27	51.30	48.70	N.A.				4.89	0.009	5.9	17.2	1.00	0.50	27	28	105.5	28.00
385	35 / 41A	19	52.60	47.40	N.A.				4.61	0.024	5.2	28.5	0.75	6.38	25	28	37.0	21.50
386	35 / 41B	19	46.00	54.00	N.A.				4.88	0.012	5.6	21.8	0.79	0.42	20	22	27.0	19.00
387	35 / 42A	13	46.60	53.40	N.A.				4.49	0.185	5.4	25.3	1.15	1.67	36	20	32.5	23.50
388	35 / 42B	13	38.66	61.34	N.A.				5.03	0.018	5.8	18.6	0.93	0.38	30	40	47.0	23.50
389	35 / 43A	27	48.60	51.40	57.55	19.08	23.37	Sandy Clay Loam	4.64	0.008	5.6	21.8	0.79	1.88	33	26	87.0	20.50
390	35 / 43B	27	50.00	50.00	52.33	22.53	25.14	Sandy Clay Loam	4.76	0.001	6.4	9.0	0.62	2.17	36	22	38.5	17.50
391	36 / 1A	1	47.30	52.70	N.A.				4.45	0.018	5.8	18.6	0.77	0.92	62	20	23.5	18.00
392	36 / 1B	1	37.30	62.70	N.A.				4.66	0.072	6.0	15.2	0.65	0.66	62	36	48.5	23.50
393	36 / 2A	1	49.00	51.00	N.A.				4.84	0.018	5.8	18.6	0.13	1.75	83	24	53.5	28.00
394	36 / 2B	1	41.30	58.70	N.A.				4.71	0.049	5.9	17.2	0.68	0.50	104	31	64.5	28.00
395	36 / 3A	6	51.30	48.70	50.10	20.74	29.16	Sandy Clay Loam	4.65	0.060	5.6	21.8	1.30	1.71	67	23	47.5	26.50
396	36 / 3B	6	56.00	44.00	51.35	20.17	28.48	Sandy Clay Loam	4.86	0.005	5.4	25.3	0.84	1.33	62	36	125.0	33.50
397	36 / 4A	6	51.13	48.87	N.A.				4.73	0.037	5.4	25.3	1.00	1.33	89	23	34.0	24.50
398	36 / 4B	6	48.60	51.40	N.A.				4.67	0.045	5.5	23.3	0.74	0.66	102	35	101.0	32.00
399	36 / 5A	6	35.06	64.94	N.A.				4.74	0.018	5.5	23.3	0.82	1.71	70	40	68.0	28.00
400	36 / 5B	6	62.60	37.40	N.A.				4.74	0.081	5.8	18.6	0.54	0.58	73	35	112.0	32.00
401	36 / 6A	6	40.06	59.94	N.A.				4.88	0.025	5.5	23.3	1.03	13.13	27	18	12.0	13.00
402	36 / 6B	6	37.30	62.70	N.A.				4.27	0.090	5.6	21.8	0.77	2.38	20	15	14.5	13.00
403	36 / 7A	2	42.80	57.20	N.A.				4.52	0.051	5.5	23.3	0.94	1.75	46	20	48.0	26.50
404	36 / 7B	2	37.30	62.70	N.A.				4.89	0.004	5.9	17.2	0.60	0.58	34	24	78.0	28.00
405	36 / 8A	2	36.20	63.80	57.45	18.15	24.40	Sandy Clay Loam	4.47	0.107	5.6	21.8	0.88	1.63	31	31	92.5	32.00
406	36 / 8B	2	32.00	68.00	50.21	20.72	29.07	Sandy Clay Loam	4.86	0.046	5.7	20.1	0.66	0.42	30	45	91.0	33.00

*Sample code:- Block No./ sample site No. and surface(A) or subsurface(B)

**N.A: Not analysed

Appendix III.

Raw Data generated by the analytical work on the soils of the western part of the main campus, KAU

No.	Av. Mn ($\mu g\ g^{-1}$)	Av. Zn ($\mu g\ g^{-1}$)	Av. Cu ($\mu g\ g^{-1}$)	Av. Fe ($\mu g\ g^{-1}$)	P- fix.cap. %	Exch. Fe ($\mu g\ g^{-1}$)	Exch. Mn ($\mu g\ g^{-1}$)	Exch. Ca ($\mu g\ g^{-1}$)	Exch. Mg ($\mu g\ g^{-1}$)	Exch. Na ($\mu g\ g^{-1}$)	Exch. K ($\mu g\ g^{-1}$)	Exch. Al ($\mu g\ g^{-1}$)	CEC cmol(+) kg^{-1}	Na sat. %	BSP %	Al sat. %
378	71.7	0.65	12.68	29.3	65.47	2.10	227.8	426	83.3	170	90	36.38	5.0266	14.71	75.30	8.05
379	35.0	0.52	33.82	19.3	N.A.	1.80	107.1	209	51.8	152	114	65.25	3.5462	18.64	68.36	20.47
380	40.0	0.62	26.15	25.3	N.A.	1.90	125.2	324	60.5	168	124	68.88	4.3945	16.63	72.04	17.43
381	48.7	0.60	6.24	20.9	N.A.	1.60	156.1	330	67.5	158	134	53.38	4.4032	15.61	73.48	13.48
382	48.1	0.39	4.05	27.5	N.A.	1.50	155.4	346	65.2	158	142	48.50	4.4276	15.52	74.92	12.18
383	59.6	0.47	13.37	20.5	57.37	2.30	196.1	314	60.3	154	126	70.13	4.5605	14.69	67.06	17.10
384	47.7	0.29	2.84	19.5	61.07	2.00	162.1	420	89.9	156	114	23.75	4.6715	14.53	81.56	5.66
385	33.9	0.35	16.40	18.6	N.A.	2.20	90.3	260	68.8	156	140	52.25	3.8207	17.76	75.98	15.21
386	41.4	0.13	4.06	19.9	N.A.	2.40	116.4	383	79.0	168	144	26.50	4.3913	16.64	83.44	6.71
387	65.2	0.42	17.57	30.5	N.A.	2.50	182.9	359	73.5	168	120	60.13	4.7812	15.28	71.90	13.99
388	33.7	0.10	3.03	22.8	N.A.	1.60	90.4	361	75.0	154	112	35.38	4.1069	16.31	82.27	9.58
389	83.4	0.35	17.62	27.7	N.A.	2.40	268.2	142	42.6	150	96	52.88	3.5317	18.47	55.46	16.65
390	65.4	0.31	5.85	20.4	N.A.	2.80	240.3	173	37.2	146	90	44.88	3.4204	18.57	59.54	14.59
391	63.4	0.39	4.15	22.0	N.A.	2.30	164.6	270	61.5	144	92	59.38	3.9857	15.72	68.19	16.57
392	97.4	0.17	2.61	29.5	N.A.	7.10	17.9	354	74.4	144	94	54.50	3.9459	15.87	82.34	15.36
393	105.7	0.77	12.83	101.3	N.A.	2.30	221.1	328	66.2	116	70	40.88	4.1362	12.20	69.35	10.99
394	99.7	0.41	4.38	72.0	N.A.	3.30	189.4	309	71.2	120	66	20.50	3.7511	13.92	75.23	6.08
395	72.7	0.24	8.82	21.6	N.A.	1.70	141.9	174	32.8	110	70	60.75	2.9959	15.97	60.00	22.56
396	90.9	0.26	2.24	28.3	N.A.	1.20	161.6	88	27.7	166	66	34.50	2.5352	28.48	61.49	15.14
397	93.3	0.21	12.61	20.7	N.A.	2.10	196.4	192	61.4	120	68	28.25	3.1980	16.32	67.58	9.83
398	89.7	0.30	5.78	30.6	N.A.	2.20	139.1	196	51.5	116	66	30.75	2.9335	17.20	70.81	11.66
399	56.1	0.30	14.03	21.0	N.A.	2.10	121.5	103	47.2	104	66	43.63	2.4597	18.39	61.98	19.73
400	54.5	0.21	1.99	21.5	N.A.	1.90	124.2	155	32.9	108	68	38.75	2.5794	18.21	65.50	16.71
401	67.2	0.21	16.80	21.7	62.15	1.80	164.7	50	42.3	94	80	50.13	2.3752	17.21	51.01	23.47
402	80.4	0.19	17.40	18.6	64.86	5.10	184.9	119	25.4	104	72	54.75	2.7409	16.50	52.56	22.22
403	73.9	0.26	15.65	26.3	N.A.	2.00	186.1	128	33.5	94	64	53.50	2.7680	14.77	53.77	21.50
404	72.0	0.05	7.50	28.8	N.A.	1.60	150.1	108	52.3	96	62	53.88	2.6980	15.48	57.32	22.21
405	37.3	0.03	12.42	19.6	N.A.	2.10	78.9	224	62.2	106	64	48.50	3.0909	14.92	73.01	17.45
406	35.2	0.21	2.34	18.9	N.A.	2.10	84.1	242	69.8	96	56	26.13	2.9496	14.16	79.51	9.85

*Sample code:- Block No./ sample site No. and surface(A) or subsurface(B)

**N.A: Not analysed

Appendix III.

Raw Data generated by the analytical work on the soils of the western part of the main campus, KAU

No.	*Sample Code	Phase	Gravel %	Fine earth %	Sand %	Silt %	Clay %	Textural class	pH	EC dS/m	Buffer pH	Lime R. (t ha^{-1})	Org. C (%)	Av. P (µg g^{-1})	Av. K (µg g^{-1})	Av. Na (µg g^{-1})	Av. Ca (µg g^{-1})	Av. Mg (µg g^{-1})
407	36 / 9A	2	40.33	59.67	N.A.				4.98	0.018	5.5	23.3	1.26	4.33	27	24	33.5	19.00
408	36 / 9B	2	48.00	52.00	N.A.				5.06	0.005	5.4	25.3	0.97	2.71	20	16	29.0	15.00
409	36 / 10A	2	47.06	52.94	63.72	12.34	23.94	Sandy Clay Loam	4.46	0.048	5.4	25.3	0.90	1.71	31	30	114.0	28.00
410	36 / 10B	2	26.60	73.40	50.40	18.51	31.09	Sandy Clay Loam	4.93	0.001	5.5	23.3	0.74	1.71	27	29	74.5	25.00
411	36 / 11A	2	45.06	54.94	N.A.				4.81	0.004	5.3	26.7	0.79	1.42	31	19	35.0	18.50
412	36 / 11B	2	56.00	44.00	N.A.				4.37	0.102	5.3	26.7	0.68	2.00	30	27	64.0	24.00
413	36 / 12A	2	32.73	67.27	63.21	11.05	25.74	Sandy Clay Loam	4.99	0.007	5.5	23.3	1.00	3.79	59	18	17.5	16.00
414	36 / 12B	2	37.30	62.70	52.95	17.60	29.45	Sandy Clay Loam	4.38	0.036	5.5	23.3	0.96	2.17	45	24	52.5	18.50
415	36 / 13A	17	37.00	63.00	N.A.				5.08	0.042	5.5	23.3	1.30	1.79	85	31	123.0	33.50
416	36 / 13B	17	34.60	65.40	N.A.				5.07	0.023	6.0	15.2	0.81	0.92	112	32	121.0	32.00
417	36 / 14A	6	64.53	35.47	N.A.				5.16	0.021	5.6	21.8	1.28	1.00	51	37	107.5	33.00
418	36 / 14B	6	35.30	64.70	N.A.				4.79	0.108	5.8	18.6	1.08	0.33	43	52	137.5	33.00
419	36 / 15A	17	41.06	58.94	N.A.				4.92	0.024	5.6	21.8	1.03	2.00	63	31	101.5	30.00
420	36 / 15B	17	58.66	41.34	N.A.				5.02	0.003	5.6	21.8	0.71	0.08	54	25	77.5	27.00
421	36 / 16A	6	53.06	46.94	N.A.				4.81	0.047	5.8	18.6	0.90	0.54	37	26	75.0	29.50
422	36 / 16B	6	59.33	40.67	N.A.				5.41	0.001	5.5	23.3	0.66	0.67	22	27	83.5	28.50
423	36 / 17A	20	42.40	57.60	54.60	11.92	33.48	Sandy Clay Loam	5.25	0.003	5.6	21.8	1.02	1.54	20	22	73.0	28.50
424	36 / 17B	20	66.00	34.00	49.66	16.44	33.90	Sandy Clay Loam	4.91	0.004	5.5	23.3	0.96	1.08	18	22	74.0	29.00
425	36 / 18A	1	51.66	48.34	N.A.				5.06	0.012	5.6	21.8	0.88	2.13	58	26	63.0	29.50
426	36 / 18B	1	69.30	30.70	N.A.				5.05	0.002	5.9	17.2	0.67	0.71	46	25	36.0	19.50
427	36 / 19A	20	44.93	55.07	N.A.				4.59	0.085	5.9	17.2	0.79	1.38	40	20	24.0	22.50
428	36 / 19B	20	42.66	57.34	N.A.				4.99	0.002	5.9	17.2	0.63	0.50	52	21	32.0	24.50
429	36 / 20A	6	49.26	50.74	N.A.				4.92	0.013	5.6	21.8	1.08	3.79	27	26	28.5	20.00
430	36 / 20B	6	32.66	67.34	N.A.				4.97	0.003	5.9	17.2	0.75	0.79	30	28	33.0	19.00
431	36 / 21A	1	51.60	48.40	N.A.				4.48	0.016	5.8	18.6	0.79	2.04	73	30	65.5	47.00
432	36 / 21B	1	44.60	55.40	N.A.				4.58	0.106	5.7	20.1	0.62	0.54	38	39	136.0	30.50
433	36 / 22A	1	47.86	52.14	N.A.				4.85	0.042	5.5	23.3	1.08	7.63	53	27	84.5	28.00
434	36 / 22B	1	29.33	70.67	N.A.				4.39	0.090	5.2	28.5	1.06	4.42	26	28	64.0	22.50
435	36 / 23A	17	36.40	63.60	N.A.				5.13	0.021	5.6	21.8	0.97	3.46	42	37	136.0	28.00

*Sample code:- Block No./ sample site No. and surface(A) or subsurface(B)
**N.A: Not analysed

Appendix IIII.

Raw Data generated by the analytical work on the soils of the western part of the main campus, KAU

No.	Av. Mn ($\mu g\ g^{-1}$)	Av. Zn ($\mu g\ g^{-1}$)	Av. Cu ($\mu g\ g^{-1}$)	Av. Fe ($\mu g\ g^{-1}$)	P- fix.cap. %	Exch. Fe ($\mu g\ g^{-1}$)	Exch. Mn ($\mu g\ g^{-1}$)	Exch. Ca ($\mu g\ g^{-1}$)	Exch. Mg ($\mu g\ g^{-1}$)	Exch. Na ($\mu g\ g^{-1}$)	Exch. K ($\mu g\ g^{-1}$)	Exch. Al ($\mu g\ g^{-1}$)	CEC cmol(+) kg^{-1}	Na sat. %	BSP %	Al sat. %
407	43.4	0.38	20.24	20.7	N.A.	2.10	109.7	220	64.4	96	54	32.50	2.9541	14.14	73.99	12.24
408	28.8	0.20	29.12	19.9	N.A.	1.50	67.9	218	63.0	78	42	38.13	2.7318	12.42	75.23	15.52
409	25.3	0.21	13.81	22.6	63.54	1.60	56.3	104	39.7	78	44	44.88	2.0084	16.89	64.66	24.85
410	28.4	0.22	14.25	25.5	60.71	1.70	52.6	66	29.7	68	40	51.25	1.7402	17.00	55.89	32.76
411	67.5	0.34	10.56	21.5	N.A.	2.40	136.9	97	45.7	70	38	51.75	2.3454	12.98	53.84	24.54
412	58.3	0.19	2.47	21.6	N.A.	2.30	129.4	110	53.2	84	42	49.50	2.4906	14.67	58.65	22.11
413	29.0	0.24	51.10	23.1	61.25	2.40	70.8	177	43.4	122	74	38.13	2.6525	20.01	73.97	15.99
414	18.5	0.10	54.34	32.4	69.23	1.80	37.9	90	32.0	118	76	49.75	2.1188	24.22	67.07	26.12
415	50.7	0.54	40.66	15.5	N.A.	1.20	88.6	196	72.6	124	100	18.25	2.9025	18.58	81.75	6.99
416	35.7	0.13	5.96	14.8	N.A.	1.90	73.6	204	70.0	128	116	8.88	2.8230	19.72	86.77	3.50
417	59.1	0.44	17.15	17.5	N.A.	1.80	106.4	192	70.6	128	86	17.38	2.9048	19.17	79.79	6.65
418	59.6	0.32	15.40	15.3	N.A.	2.60	106.3	223	74.8	138	78	16.63	3.1116	19.29	81.32	5.94
419	34.8	0.46	32.20	12.9	51.76	2.10	65.6	166	66.0	124	86	66.63	3.1200	17.29	68.35	23.75
420	30.5	0.23	4.35	15.4	41.76	1.30	65.2	151	57.1	120	84	50.63	2.7669	18.86	70.90	20.35
421	100.4	0.29	8.36	35.4	N.A.	1.90	198.1	165	60.5	118	74	27.00	3.0538	16.81	66.33	9.83
422	66.6	0.09	3.17	28.3	N.A.	1.50	129.2	162	84.5	114	66	20.00	2.8683	17.29	75.66	7.76
423	48.1	0.79	17.25	19.8	N.A.	2.90	144.9	218	56.0	172	100	36.63	3.5001	21.38	72.99	11.64
424	38.8	0.59	4.13	12.9	N.A.	2.50	75.8	146	42.0	110	60	41.88	2.4583	19.46	69.46	18.95
425	44.7	0.79	5.04	21.5	N.A.	1.70	97.6	140	53.0	110	80	36.00	2.5811	18.54	70.48	15.51
426	37.4	0.39	4.51	16.7	N.A.	3.30	88.7	90	45.0	216	82	48.63	2.8452	33.02	69.23	19.01
427	51.4	0.69	3.65	15.6	N.A.	0.90	100.7	99	33.7	122	70	43.25	2.3330	22.75	63.53	20.62
428	56.3	0.39	2.23	14.6	N.A.	2.20	104.6	86	42.6	106	62	48.13	2.3242	19.84	60.25	23.03
429	44.1	0.59	0.04	16.4	N.A.	1.70	90.9	86	48.0	106	76	43.25	2.2986	20.06	64.41	20.93
430	37.4	0.29	14.31	17.4	N.A.	2.50	83.8	66	48.3	106	72	50.88	2.2527	20.47	60.94	25.12
431	50.4	0.39	7.80	13.9	N.A.	2.40	106.0	131	79.3	114	86	34.25	2.7989	17.72	72.29	13.61
432	38.1	0.29	2.20	16.7	N.A.	2.40	77.1	179	61.9	120	68	23.63	2.6524	19.68	79.19	9.91
433	45.3	0.99	17.76	34.7	54.39	4.40	70.9	164	61.7	114	78	45.75	2.8059	17.67	72.10	18.14
434	35.8	0.49	46.72	28.0	63.90	2.60	56.7	147	45.3	114	72	51.75	2.5792	19.23	69.32	22.32
435	31.6	0.59	18.67	21.0	N.A.	1.60	45.1	131	60.3	114	114	39.38	2.5466	19.47	76.13	17.20

*Sample code:- Block No./ sample site No. and surface(A) or subsurface(B)

**N.A: Not analysed

Appendix III.

Raw Data generated by the analytical work on the soils of the western part of the main campus, KAU

No.	*Sample Code	Phase	Gravel %	Fine earth %	Sand %	Silt %	Clay %	Textural class	pH	EC dS/m	Buffer pH	Lime R. ($t\ ha^{-1}$)	Org. C (%)	Av. P ($\mu g\ g^{-1}$)	Av. K ($\mu g\ g^{-1}$)	Av. Na ($\mu g\ g^{-1}$)	Av. Ca ($\mu g\ g^{-1}$)	Av. Mg ($\mu g\ g^{-1}$)
436	36 / 23B	17	37.30	62.70	N.A.				5.14	0.001	5.5	23.3	0.75	0.33	49	39	88.0	29.50
437	36 / 24A	17	48.06	51.94	56.10	9.16	34.74	Sandy Clay Loam	4.43	0.180	6.6	5.3	0.96	1.00	45	27	76.0	26.00
438	36 / 24B	17	39.30	60.70	51.40	11.35	37.25	Sandy Clay	4.53	0.152	6.0	15.2	0.71	0.54	105	27	66.0	27.50
439	36 / 25A	19	32.20	67.80	N.A.				5.36	0.019	5.6	21.8	1.14	1.71	46	35	159.0	32.50
440	36 / 25B	19	55.30	44.70	N.A.				5.38	0.001	5.8	18.6	0.85	0.75	34	35	34.0	31.00
441	36 / 26A	13	46.40	53.60	N.A.				4.55	0.072	5.6	21.8	1.34	4.88	51	44	141.0	33.50
442	36 / 26B	13	50.60	49.40	N.A.				4.96	0.001	5.8	18.6	0.81	1.25	30	32	134.0	23.50
443	36 / 27A	19	31.93	68.07	N.A.				5.07	0.001	5.9	17.2	1.30	1.67	27	30	142.0	35.50
444	36 / 27B	19	49.30	50.70	N.A.				5.06	0.003	5.8	18.6	0.89	0.54	23	30	138.0	32.50
445	36 / 28A	19	45.43	54.57	56.33	18.05	25.62	Sandy Clay Loam	5.04	0.018	5.5	23.3	1.26	1.54	78	28	52.0	30.50
446	36 / 28B	19	52.76	47.24	51.64	19.64	28.72	Sandy Clay Loam	4.70	0.037	5.8	18.6	0.83	0.25	91	35	34.5	23.00
447	36 / 29A	16	35.40	64.60	47.94	33.15	18.91	Loam	5.23	0.021	5.7	20.1	1.20	0.88	93	34	85.5	32.00
448	36 / 29B	16	51.33	48.67	37.30	33.76	28.94	Clay Loam	5.16	0.007	5.7	20.1	0.85	0.33	80	26	63.0	28.00
449	36 / 30A	19	37.06	62.94	N.A.				4.34	0.108	5.6	21.8	1.14	0.29	53	30	52.0	28.00
450	36 / 30B	19	48.00	52.00	N.A.				5.07	0.023	5.9	17.2	0.85	1.71	86	33	106.0	32.00
451	36 / 31A	6	29.06	70.94	N.A.				4.97	0.001	6.0	15.2	0.68	0.42	50	26	74.0	28.00
452	36 / 31B	6	34.60	65.40	N.A.				5.26	0.009	5.8	18.6	0.81	0.67	33	28	140.5	32.00
453	36 / 32A	6	44.60	55.40	55.03	21.14	23.83	Sandy Clay Loam	4.65	0.003	5.5	23.3	1.07	2.50	11	11	12.5	10.00
454	36 / 32B	6	32.00	68.00	46.86	24.85	28.29	Sandy Clay Loam	5.07	0.001	5.5	23.3	0.72	0.08	22	27	99.0	25.50
455	36 / 33A	13	37.80	62.20	N.A.				4.86	0.020	5.7	20.1	0.90	0.92	82	21	71.5	29.00
456	36 / 33B	13	48.00	52.00	N.A.				4.55	0.149	5.7	20.1	0.55	0.54	68	31	70.5	25.00
457	36 / 34A	27	55.33	44.67	59.33	17.92	22.75	Sandy Clay Loam	4.64	0.086	5.5	23.3	0.70	0.17	63	30	41.0	22.50
458	36 / 34B	27	32.67	67.33	51.47	23.10	25.43	Sandy Clay Loam	5.00	0.009	5.7	20.1	0.62	0.12	57	27	41.0	23.50
459	36 / 36A	2	38.93	61.07	N.A.				4.41	0.185	5.6	21.8	0.98	0.38	45	35	101.5	30.00
460	36 / 36B	2	43.30	56.70	N.A.				4.50	0.039	5.3	26.7	0.98	0.67	25	25	34.0	24.50
461	36 / 36A	2	54.96	45.04	62.35	12.25	25.40	Sandy Clay Loam	4.36	0.090	5.7	20.1	1.01	0.17	31	32	48.5	25.50
462	36 / 36B	2	39.30	60.70	51.20	18.15	30.65	Sandy Clay Loam	4.56	0.073	5.6	21.8	0.69	0.21	26	33	95.5	26.00
463	36 / 37A	6	34.20	65.80	N.A.				4.41	0.128	5.5	23.3	1.01	0.21	41	28	56.5	25.50
464	36 / 37B	6	64.60	35.40	N.A.				4.48	0.112	5.4	25.3	0.80	0.13	28	26	87.5	28.50

*Sample code:- Block No./ sample site No. and surface(A) or subsurface(B)

**N.A: Not analysed

Appendix III.

Raw Data generated by the analytical work on the soils of the western part of the main campus, KAU

No.	Av. Mn ($\mu g\ g^{-1}$)	Av. Zn ($\mu g\ g^{-1}$)	Av. Cu ($\mu g\ g^{-1}$)	Av. Fe ($\mu g\ g^{-1}$)	P- fix.cap. %	Exch. Fe ($\mu g\ g^{-1}$)	Exch. Mn ($\mu g\ g^{-1}$)	Exch. Ca ($\mu g\ g^{-1}$)	Exch. Mg ($\mu g\ g^{-1}$)	Exch. Na ($\mu g\ g^{-1}$)	Exch. K ($\mu g\ g^{-1}$)	Exch. Al ($\mu g\ g^{-1}$)	CEC cmol(+) kg^{-1}	Na sat. %	BSP %	Al sat. %
436	32.0	0.29	3.69	26.9	N.A.	1.50	69.3	127	48.0	106	72	48.25	2.4696	18.67	67.84	21.73
437	42.0	0.49	13.23	26.3	N.A.	1.80	72.0	154	66.7	128	78	36.50	2.7498	20.25	75.47	14.77
438	32.5	0.19	3.54	28.0	N.A.	1.80	63.0	192	68.7	132	76	27.63	2.8370	20.24	80.86	10.83
439	49.3	0.59	12.33	30.9	N.A.	2.10	71.1	210	72.7	164	78	22.13	3.0737	23.21	83.33	8.01
440	30.4	0.29	4.59	34.6	N.A.	2.60	61.3	213	68.2	124	68	31.50	2.9224	18.46	80.06	11.99
441	52.2	0.79	25.70	42.4	N.A.	2.30	90.1	152	70.3	128	74	49.75	2.9742	18.72	70.09	18.61
442	31.4	0.59	19.60	40.9	N.A.	2.90	57.8	200	41.3	124	70	50.75	2.8436	18.97	72.38	19.85
443	47.1	0.79	16.26	36.2	N.A.	1.90	84.1	197	80.4	118	64	32.25	2.9954	17.14	77.58	11.98
444	45.3	0.99	33.00	37.4	N.A.	2.40	85.8	153	75.3	114	60	33.38	2.7263	18.19	74.61	13.62
445	64.8	0.79	22.90	65.6	N.A.	2.00	117.6	98	71.0	110	90	47.00	2.7411	17.46	65.05	19.07
446	35.9	0.39	7.53	44.9	N.A.	1.80	66.2	197	49.4	104	90	48.38	2.8597	15.82	72.53	18.82
447	58.5	1.49	12.89	52.0	63.89	1.60	97.8	145	69.5	112	94	26.00	2.6756	18.21	75.67	10.81
448	38.8	0.59	6.28	41.2	72.19	1.70	73.6	159	60.5	108	88	41.88	2.7276	17.22	72.88	17.08
449	45.1	0.39	21.63	21.6	N.A.	3.70	109.0	202	64.0	126	90	40.88	3.1797	17.24	72.81	14.30
450	54.2	0.59	9.78	15.7	N.A.	2.20	116.7	144	75.9	120	96	34.38	2.9273	17.83	72.16	13.06
451	39.1	0.49	13.87	19.4	N.A.	1.30	92.0	227	58.4	116	78	45.38	3.1640	15.95	73.32	15.95
452	44.9	0.39	9.26	19.4	N.A.	1.80	96.3	228	71.2	120	78	20.00	3.0269	17.24	80.86	7.35
453	41.9	0.49	12.45	25.0	N.A.	3.70	108.5	107	41.2	108	60	48.50	2.4450	19.21	61.24	22.06
454	34.4	0.49	7.27	34.7	N.A.	2.70	83.5	180	50.0	100	54	46.25	2.7127	16.03	69.47	18.96
455	78.7	2.49	8.87	18.2	N.A.	2.20	164.1	143	65.4	100	76	31.63	2.8397	15.32	66.30	12.39
456	77.5	0.49	3.60	31.0	N.A.	2.00	169.3	169	58.9	114	82	34.00	3.0370	16.33	67.02	12.45
457	30.8	0.49	4.27	11.8	52.37	2.40	82.1	108	46.0	114	80	46.50	2.4438	20.29	66.25	21.17
458	45.9	0.39	2.95	23.5	61.58	2.70	120.6	119	45.6	106	72	49.50	2.6148	17.63	61.78	21.06
459	23.9	0.49	9.54	16.1	N.A.	2.10	58.6	197	65.6	116	70	40.13	2.8757	17.55	76.80	15.52
460	18.3	0.59	3.80	20.6	N.A.	2.40	47.4	101	47.3	96	54	50.25	2.1901	19.07	66.21	25.52
461	21.2	0.49	7.32	16.9	N.A.	2.10	45.5	119	55.2	186	58	51.63	2.7541	29.38	72.86	20.85
462	18.3	0.29	2.55	15.7	N.A.	1.90	44.4	159	55.5	106	54	51.75	2.5950	17.77	71.33	22.18
463	70.5	0.69	6.13	31.4	N.A.	2.40	167.1	126	61.4	120	76	47.00	2.9914	17.45	61.90	17.48
464	120.3	0.99	7.93	47.0	N.A.	2.00	196.5	169	68.0	124	74	29.00	3.1784	16.97	67.12	10.15

*Sample code:- Block No./ sample site No. and surface(A) or subsurface(B)

**N.A: Not analysed

Appendix III.

Raw Data generated by the analytical work on the soils of the western part of the main campus, KAU

No.	*Sample Code	Phase	Gravel %	Fine earth %	Sand %	Silt %	Clay %	Textural class	pH	EC dS/m	Buffer pH	Lime R. (t ha^{-1})	Org. C (%)	Av. P (μg g^{-1})	Av. K (μg g^{-1})	Av. Na (μg g^{-1})	Av. Ca (μg g^{-1})	Av. Mg (μg g^{-1})
465	36 / 38A	6	46.40	53.60	N.A.				4.91	0.008	5.3	26.7	1.13	0.04	42	33	109.5	33.00
466	36 / 38B	6	52.00	48.00	N.A.				5.03	0.001	5.6	21.8	0.72	0.38	26	36	130.5	32.50
467	36 / 39A	6	39.40	60.60	N.A.				4.94	0.001	5.5	23.3	0.55	0.13	33	27	77.5	26.00
468	36 / 39B	6	71.66	28.34	N.A.				4.83	0.002	5.4	25.3	0.85	0.08	38	23	31.5	22.50
469	36 / 40A	30	39.20	60.80	57.49	10.27	32.24	Sandy Clay Loam	5.00	0.002	5.6	21.8	1.08	0.17	89	38	130.0	32.50
470	36 / 40B	30	71.60	28.40	51.20	12.32	36.48	Sandy Clay	5.21	0.001	5.5	23.3	0.74	0.13	79	39	141.0	31.00
471	36 / 41A	1	28.53	71.47	55.26	22.71	22.03	Sandy Clay Loam	4.97	0.018	5.5	23.3	1.07	0.42	39	45	151.5	36.00
472	36 / 41B	1	50.00	50.00	49.91	24.92	25.17	Sandy Clay Loam	5.03	0.026	5.7	20.1	0.78	0.04	22	50	205.5	34.50
473	36 / 42A	1	46.93	53.07	N.A.				5.01	0.002	5.3	26.7	0.87	0.33	31	19	17.5	32.50
474	36 / 42B	1	35.30	64.70	N.A.				4.65	0.065	5.4	25.3	0.70	0.58	51	35	46.0	22.50
475	36 / 43A	1	48.66	51.34	N.A.				4.77	0.017	5.3	26.7	1.10	1.83	48	16	40.5	17.00
476	36 / 43B	1	57.30	42.70	N.A.				4.64	0.009	5.2	28.5	1.24	1.63	33	14	18.0	11.50
477	36 / 44A	1	33.33	66.67	N.A.				4.98	0.008	5.7	20.1	1.14	1.13	26	20	53.0	21.50
478	36 / 44B	1	46.60	53.40	N.A.				4.51	0.054	5.6	21.8	0.74	0.96	18	33	43.0	11.50
479	36 / 45A	1	46.06	53.94	N.A.				5.00	0.019	5.8	18.6	1.29	1.92	57	22	80.0	29.00
480	36 / 45B	1	55.30	44.70	N.A.				4.61	0.017	5.6	21.8	0.83	0.33	20	25	59.5	28.00
481	36 / 46A	17	53.66	46.34	N.A.				5.06	0.049	5.4	25.3	1.62	6.33	74	27	115.0	29.50
482	36 / 46B	17	64.00	36.00	N.A.				5.14	0.079	5.3	26.7	1.33	2.25	129	45	244.5	35.50
483	36 / 47A	17	47.53	52.47	N.A.				4.81	0.020	5.2	28.5	1.17	0.58	61	27	71.0	29.00
484	36 / 47B	17	52.00	48.00	N.A.				4.40	0.105	5.4	25.3	0.80	0.25	30	28	64.5	24.50
485	36 / 48A	17	52.33	47.67	N.A.				4.74	0.112	5.5	23.3	1.07	1.46	40	35	150.0	45.50
486	36 / 48B	17	46.00	54.00	N.A.				4.97	0.010	5.4	25.3	0.88	1.04	21	32	122.5	13.00
487	36 / 49A	17	34.13	65.87	60.24	13.98	25.78	Sandy Clay Loam	4.96	0.038	5.3	26.7	1.27	2.79	89	32	122.0	32.50
488	36 / 49B	17	50.00	50.00	48.91	17.50	33.59	Sandy Clay Loam	5.06	0.001	5.8	18.6	0.64	0.29	88	22	92.5	28.00
489	36 / 50A	20	47.00	53.00	56.10	10.43	33.47	Sandy Clay Loam	4.82	0.003	5.4	25.3	0.80	0.58	45	24	81.0	30.00
490	36 / 50B	20	40.60	59.40	50.10	12.10	37.80	Sandy Clay	4.92	0.001	5.5	23.3	0.68	0.08	33	25	71.0	30.50
491	36 / 51A	13	40.73	59.27	N.A.				5.02	0.020	6.3	10.5	1.59	1.13	59	44	159.0	40.00
492	36 / 51B	13	32.60	67.40	N.A.				4.62	0.001	5.6	21.8	0.98	0.33	51	42	110.0	37.50
493	36 / 52A	16	38.33	61.67	N.A.				5.33	0.018	5.5	23.3	1.39	2.54	42	47	75.0	36.50

*Sample code:- Block No./ sample site No. and surface(A) or subsurface(B)

**N.A: Not analysed

Appendix III.
Raw Data generated by the analytical work on the soils of the western part of the main campus, KAU

No.	Av. Mn ($\mu g\ g^{-1}$)	Av. Zn ($\mu g\ g^{-1}$)	Av. Cu ($\mu g\ g^{-1}$)	Av. Fe ($\mu g\ g^{-1}$)	P- fix.cap. %	Exch. Fe ($\mu g\ g^{-1}$)	Exch. Mn ($\mu g\ g^{-1}$)	Exch. Ca ($\mu g\ g^{-1}$)	Exch. Mg ($\mu g\ g^{-1}$)	Exch. Na ($\mu g\ g^{-1}$)	Exch. K ($\mu g\ g^{-1}$)	Exch. Al ($\mu g\ g^{-1}$)	CEC cmol(+) kg^{-1}	Na sat. %	BSP %	Al sat. %
465	81.8	0.49	6.09	22.4	N.A.	1.90	179.5	203	86.3	130	78	56.13	3.7748	14.98	65.97	16.54
466	79.9	0.39	2.13	20.2	N.A.	2.00	155.7	197	72.1	128	68	42.75	3.3586	16.58	68.75	14.16
467	34.4	3.99	3.65	73.9	N.A.	2.00	141.8	159	58.3	116	68	70.25	3.2581	15.49	59.95	23.98
468	80.1	3.79	6.38	85.0	N.A.	2.50	180.6	106	55.6	140	76	85.75	3.4112	17.85	52.50	27.96
469	67.2	1.19	9.70	51.9	47.53	9.90	144.5	254	78.2	102	78	47.63	3.6480	12.16	70.09	14.52
470	36.7	0.79	8.51	15.9	62.58	2.30	85.0	236	78.7	132	96	31.00	3.3099	17.35	79.98	10.42
471	68.8	0.79	13.15	19.7	N.A.	1.50	69.7	253	79.8	134	74	53.13	3.5439	16.45	76.01	16.67
472	56.3	1.19	5.15	58.0	N.A.	2.00	135.9	80	39.2	124	56	33.63	2.2811	23.64	61.60	16.40
473	47.7	0.69	8.81	16.5	N.A.	2.20	118.7	112	41.2	82	52	96.38	2.9008	12.30	47.88	36.96
474	61.4	0.29	1.98	21.7	N.A.	1.80	150.4	107	38.6	88	56	74.13	2.7572	13.88	50.00	29.90
475	49.4	0.59	5.17	22.5	53.39	2.10	140.2	61	30.8	94	64	94.63	2.7015	15.14	41.87	38.96
476	27.1	0.29	11.57	24.2	50.12	1.60	87.1	70	45.4	92	60	113.75	2.8654	13.97	44.58	44.16
477	49.7	0.39	2.28	16.4	N.A.	2.80	126.6	144	18.3	92	56	68.63	2.6483	15.11	53.39	28.82
478	47.7	0.29	1.82	25.0	N.A.	4.00	117.8	118	73.4	96	56	71.63	2.9948	13.94	58.60	26.60
479	68.8	0.49	3.58	20.8	N.A.	2.40	157.9	154	73.5	98	68	58.63	3.2106	13.28	61.52	20.31
480	35.3	0.29	3.46	13.6	N.A.	1.90	81.3	133	60.6	98	54	64.25	2.7456	15.53	62.94	26.03
481	74.6	0.89	5.54	29.1	N.A.	1.60	153.0	248	66.7	112	90	46.13	3.5821	13.60	69.97	14.32
482	73.8	0.99	4.65	30.6	N.A.	1.40	156.4	295	79.7	118	104	33.63	3.8586	13.30	75.42	9.69
483	42.9	0.39	4.76	23.6	N.A.	2.00	125.9	170	64.7	84	60	50.00	2.9230	12.50	65.05	19.03
484	38.8	0.29	2.25	16.7	N.A.	3.50	106.2	177	64.6	92	54	65.13	3.0785	13.00	63.50	23.53
485	31.4	0.69	11.86	26.3	N.A.	2.80	73.1	237	89.3	92	50	46.88	3.2456	12.33	75.43	16.07
486	30.9	0.29	25.88	31.2	N.A.	1.70	72.5	226	73.4	144	72	66.00	3.5488	17.65	71.70	20.69
487	24.3	0.29	1.91	24.4	N.A.	3.70	119.8	190	81.4	108	78	61.25	3.4199	13.74	66.94	19.92
488	49.5	0.59	5.68	22.0	N.A.	6.80	68.3	144	63.3	72	54	80.13	2.8565	10.96	59.24	31.20
489	46.7	0.49	23.56	20.4	62.50	3.90	114.9	133	63.2	124	80	84.50	3.3013	16.34	58.44	28.47
490	51.4	0.49	3.74	22.0	68.41	2.60	118.7	195	66.6	130	76	73.50	3.5420	15.96	64.46	23.08
491	37.3	0.69	9.28	13.3	N.A.	1.70	72.8	278	103.5	146	90	27.88	3.6883	17.22	84.24	8.41
492	59.1	0.19	8.84	22.9	N.A.	1.90	115.6	216	84.9	140	88	48.50	3.5799	17.01	72.98	15.07
493	36.6	0.69	4.21	14.9	N.A.	3.20	94.4	182	92.8	146	80	27.88	3.1786	19.98	79.07	9.75

*Sample code:- Block No./ sample site No. and surface(A) or subsurface(B)
**N.A: Not analysed

Appendix III.

Raw Data generated by the analytical work on the soils of the western part of the main campus, KAU

No.	*Sample Code	Phase	Gravel %	Fine earth %	Sand %	Silt %	Clay %	Textural class	pH	EC dS/m	Buffer pH	Lime R. (t ha^{-1})	Org. C (%)	Av. P (μg g^{-1})	Av. K (μg g^{-1})	Av. Na (μg g^{-1})	Av. Ca (μg g^{-1})	Av. Mg (μg g^{-1})
494	36 / 52B	16	34.00	66.00	N.A.				5.13	0.001	5.7	20.1	0.98	2.88	51	36	71.0	35.00
495	36 / 53A	16	47.66	52.34	N.A.				5.20	0.028	6.2	12.1	1.28	2.29	77	39	17.5	35.00
496	36 / 53B	16	33.90	66.10	N.A.				5.54	0.023	6.0	15.2	1.03	1.33	178	37	17.0	33.50
497	36 / 54A	13	35.33	64.67	N.A.				5.03	0.072	5.8	18.6	1.04	1.54	58	28	98.0	32.00
498	36 / 54B	13	21.20	78.80	N.A.				4.96	0.015	5.9	17.2	1.00	0.29	49	22	34.0	27.50
499	36 / 55A	13	44.66	55.34	N.A.				4.92	0.028	5.3	26.7	1.68	3.21	53	28	105.0	32.50
500	36 / 55B	13	33.30	66.70	N.A.				4.89	0.012	5.5	23.3	1.20	1.50	46	30	81.0	28.00
501	36 / 56A	6	52.00	48.00	N.A.				5.02	0.019	5.6	21.8	1.32	15.79	38	36	151.0	19.00
502	36 / 56B	6	36.60	63.40	N.A.				4.88	0.003	5.4	25.3	1.11	3.21	30	27	55.0	10.50
503	37 / 1A	1	46.00	54.00	N.A.				4.98	0.008	5.6	21.8	1.04	13.00	44	27	54.0	24.00
504	37 / 1B	1	30.00	70.00	N.A.				4.85	0.003	5.8	18.6	0.80	1.92	48	22	25.0	13.50
505	37 / 2A	1	38.00	62.00	N.A.				4.84	0.005	5.9	17.2	0.87	12.38	32	17	48.5	16.00
506	37 / 2B	1	36.00	64.00	N.A.				4.44	0.028	5.5	23.3	0.66	0.50	28	18	30.0	10.50
507	37 / 3A	1	24.66	75.34	N.A.				4.50	0.242	6.1	13.4	0.61	2.17	24	34	74.5	26.00
508	37 / 3B	1	36.00	64.00	N.A.				4.93	0.001	5.5	23.3	0.53	1.63	14	25	43.5	22.50
509	37 / 4A	1	31.33	68.67	56.52	19.84	23.64	Sandy Clay Loam	4.82	0.004	6.1	13.4	0.90	1.50	20	26	38.5	19.50
510	37 / 4B	1	41.30	58.70	51.12	18.97	29.91	Sandy Clay Loam	4.40	0.330	6.2	12.1	0.56	1.08	28	46	108.5	26.00
511	37 / 5A	6	28.00	72.00	N.A.				4.72	0.045	5.6	21.8	1.01	17.62	21	75	71.0	25.00
512	37 / 5B	6	64.00	36.00	N.A.				4.75	0.018	5.5	23.3	0.84	16.83	77	20	49.5	19.50
513	37 / 6A	6	42.00	58.00	N.A.				5.02	0.013	5.5	23.3	1.54	2.78	38	32	144.0	31.50
514	37 / 6B	6	64.00	36.00	N.A.				5.24	0.005	5.6	21.8	1.00	1.67	27	39	142.5	29.00
515	37 / 7A	6	37.00	63.00	50.32	16.17	33.51	Sandy Clay Loam	5.04	0.013	5.3	26.7	1.65	2.67	46	29	117.0	30.50
516	37 / 7B	6	48.00	52.00	39.79	24.92	35.29	Clay Loam	4.98	0.007	5.3	26.7	1.61	1.13	32	24	80.5	22.00
517	37 / 8A	6	25.33	74.67	N.A.				4.98	0.007	5.5	23.3	1.01	5.17	38	26	41.5	23.50
518	37 / 8B	6	43.30	56.70	N.A.				4.40	0.126	5.1	30.2	0.98	1.00	34	28	32.5	18.50

*Sample code:- Block No./ sample site No. and surface(A) or subsurface(B)

**N.A: Not analysed

Appendix III.

Raw Data generated by the analytical work on the soils of the western part of the main campus, KAU

No.	Av. Mn ($\mu g\ g^{-1}$)	Av. Zn ($\mu g\ g^{-1}$)	Av. Cu ($\mu g\ g^{-1}$)	Av. Fe ($\mu g\ g^{-1}$)	P- fix.cap. %	Exch. Fe ($\mu g\ g^{-1}$)	Exch. Mn ($\mu g\ g^{-1}$)	Exch. Ca ($\mu g\ g^{-1}$)	Exch. Mg ($\mu g\ g^{-1}$)	Exch. Na ($\mu g\ g^{-1}$)	Exch. K ($\mu g\ g^{-1}$)	Exch. Al ($\mu g\ g^{-1}$)	CEC cmol(+) kg^{-1}	Na sat. %	BSP %	Al sat. %
494	25.0	0.39	3.24	16.1	N.A.	2.40	60.2	203	79.6	122	74	79.63	3.5035	15.15	68.22	25.28
495	48.7	0.89	19.52	15.3	N.A.	2.00	92.1	288	84.3	134	90	1.25	3.3032	17.65	89.21	0.42
496	57.1	0.49	25.79	16.0	N.A.	3.10	116.0	223	76.2	124	150	22.38	3.3474	16.11	79.62	7.44
497	48.1	0.39	9.13	22.6	N.A.	2.00	107.9	211	72.2	122	88	39.25	3.2415	16.37	74.19	13.47
498	44.4	0.19	2.82	65.5	N.A.	9.00	114.4	149	57.9	112	78	71.25	3.1494	15.47	60.59	25.16
499	29.3	0.39	14.85	40.5	N.A.	2.30	73.2	192	78.2	124	80	73.63	3.4413	15.67	68.22	23.80
500	18.2	0.19	9.56	30.4	N.A.	2.30	35.8	155	63.2	110	70	61.63	2.7767	17.23	70.32	24.69
501	59.1	0.19	5.58	22.9	N.A.	2.80	118.1	257	45.8	130	72	31.88	3.2061	17.64	75.22	11.06
502	45.0	0.09	3.15	27.2	N.A.	1.80	13.8	122	33.3	116	66	56.88	2.2468	22.46	69.32	28.16
503	70.2	0.39	3.34	19.9	N.A.	2.90	35.2	159	48.9	120	78	47.38	2.5844	20.20	74.25	20.39
504	68.3	0.19	3.15	23.2	N.A.	4.20	145.5	76	28.8	118	82	59.63	2.5480	20.14	52.59	26.03
505	41.7	0.19	3.28	16.2	N.A.	2.70	114.9	192	36.0	114	66	65.75	3.0803	16.10	62.36	23.74
506	53.6	0.19	2.12	18.7	N.A.	2.70	145.6	37	10.8	110	68	102.63	2.6075	18.35	35.52	43.78
507	4.9	0.19	2.56	69.3	52.81	4.90	21.1	134	56.7	136	72	53.88	2.6060	22.70	73.38	23.00
508	3.1	0.09	1.10	51.2	48.18	4.90	17.9	87	48.0	120	64	46.38	2.1143	24.69	71.69	24.40
509	45.8	0.39	3.85	54.1	N.A.	2.60	156.8	84	46.0	118	70	78.00	2.9386	17.47	50.73	29.52
510	40.1	0.19	1.73	27.8	N.A.	3.60	131.9	171	57.8	134	70	58.25	3.2336	18.03	64.71	20.04
511	39.6	0.59	4.22	21.4	N.A.	2.90	142.1	151	62.0	124	112	57.38	3.2570	16.56	64.20	19.60
512	37.8	0.49	6.55	20.2	N.A.	4.50	108.0	87	40.9	114	100	70.13	2.7126	18.28	56.16	28.76
513	71.4	1.09	3.17	40.2	N.A.	2.60	191.9	245	72.2	140	74	15.13	3.4936	17.43	74.92	4.82
514	67.3	0.59	3.71	33.4	N.A.	2.60	147.6	207	65.0	134	72	43.50	3.3675	17.31	69.40	14.37
515	95.8	0.79	9.26	29.2	N.A.	2.60	183.2	186	66.4	128	78	51.00	3.4763	16.02	64.23	16.32
516	82.8	0.49	8.14	21.5	N.A.	2.90	172.9	172	65.1	136	80	58.88	3.4867	16.97	62.87	18.78
517	77.3	0.49	5.22	25.0	N.A.	2.90	191.9	121	59.7	130	82	54.63	3.1881	17.74	58.70	19.06
518	72.6	0.49	2.67	27.8	N.A.	3.90	188.3	120	45.0	124	74	79.38	3.2814	16.44	51.78	26.91

*Sample code:- Block No./ sample site No. and surface(A) or subsurface(B)
**N.A: Not analysed

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

ABSTRACT

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

By

K. SAJNANATH

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

Kerala Agricultural University is situated in Madakkathara panchayat in Thrissur district. It is having an area of about 380 ha in its main campus in Vellanikkara. The main campus includes three colleges and the areas of three Research Stations. In this campus, so many research works are going on in different fields. Thus the knowledge about the resource capacity may help in the production scenario of the University itself. In this inventory, the western part of the main campus, which includes the areas of Research stations and Farms occupied mostly by perennial crops.

For identification of sample sites, a 1:2000 scale map of the campus was used. A grid size of 80 m x 80m was used to locate the sites. The study area constitutes 12 blocks out of 37 in the campus. The samples were taken from both surface (0-20cm) and subsurface (20-40cm) layer. Altogether 518 soil samples, collected from the 23 phases of the study area, were analysed by standard procedures to record their physical, chemical and electrochemical properties. The surface and subsurface samples were analysed for available nutrients and other fertility parameters.

The soils are gravelly in nature in surface and subsurface samples. Still an increase in amount of fine earth from surface to subsurface level was noted. The particle size analysis of the soil samples revealed that most of the samples were sandy clay loam in nature. In most of the soils, the texture was same for surface and subsurface samples. The data obtained on the soil components were used for their textural classification. The most of the soil samples were acidic in nature. The electrical conductivity of almost all the samples was found to be very low in every phase. Buffer pH and hence the lime requirement of the samples has a very wide range among the soil phases.

The organic carbon contents were medium in most of the soil samples. It is high in surface layer than subsurface in majority of the phases. Available phosphorus was generally low in content in 60 - 90% of samples. About 25% were in medium class. The potassium content was rated as low in 56% of the surface samples and 66% of subsurface samples.

Among the secondary nutrients, both available calcium and magnesium were recorded in a wide range in the soils. In Micronutrients, manganese was the highest content followed by iron. All the soils are above critical range in both cases. In copper 96% of surface and 86% of subsurface contents were in above critical range. But in general, zinc was low in concentration. About 88% of surface and 94% of subsurface samples were in below critical range.

The P fixing capacity of all the soils was found to be high. In the exchangeable complex, the order of concentrations of the ions were Ca>Mn>Na>K>Al>Fe. The cation exchange capacity of the soil was low since a good amount of cations were leached off during the rainy season. The percentage base saturation was high. Percentage sodium saturation was higher than 15%.

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. The generated data were used for the study of nutrient interactions in the study area.

Using the potential of Geographic Information System (GIS), the soil fertility map of the study area for the major parameters such as soil texture, organic carbon, available P and K were prepared.

The present study outlines the need for significant changes to be made in soil survey and preparation of maps. The properties of soils, in phase wise manner were used for Fertility Capability Classification with its limitations. From the FCC notation, the problems and limitations of the soils can be estimated. Incorporation of fertility parameters of the already defined soil units will enhance the utility of soil maps. The soil maps with FCC units super imposed will help in the delineating areas with similar limitations and management requirement.

The information regarding the properties of soils of the western part of the main campus, can be manipulated for the planning and motivating the cultivating practices and thus attain the maximum output with available resources.