

**MORPHOLOGY, CHARACTERISTICS AND
CLASSIFICATION OF SOILS IN INTEGRATED
WATERSHED DEVELOPMENT PROJECT (IWDP) AREA-
DHOBAKIA NALA MINI WATERSHED (ORM-3-16-7-3),
G. UDAYAGIRI IN PHULBANI DISTRICT**

A THESIS SUBMITTED TO
THE ORISSA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY, BHUBANESWAR
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
MASTER OF SCIENCE IN AGRICULTURE
(AGRICULTURAL CHEMISTRY, SOIL SCIENCE AND BIOCHEMISTRY)

BY
Magiram Jaha.



**DEPARTMENT OF AGRICULTURAL CHEMISTRY, SOIL SCIENCE AND BIOCHEMISTRY
COLLEGE OF AGRICULTURE**

Orissa University of Agriculture and Technology

BHUBANESWAR

1993

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DEDICATED TO
MY BELOVED PARENTS

APPROVAL SHEET


MORPHOLOGY, CHARACTERISTICS AND CLASSIFICATION OF SOILS IN
INTEGRATED WATERSHED DEVELOPMENT PROJECT (IWDP)
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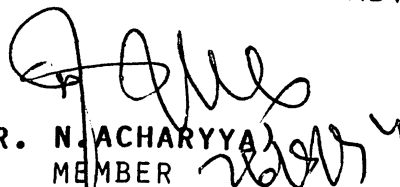
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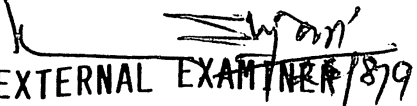
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CERTIFICATE

This is to certify that the thesis entitled "MORPHOLOGY, CHARACTERISTICS AND CLASSIFICATION OF SOILS IN INTEGRATED WATERSHED DEVELOPMENT PROJECT (IWDP) AREA-DHOBAKIA NALA MINI WATERSHED (ORM-3-16-7-3), G.UDAYAGIRI IN PHULBANI DISTRICT" submitted in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE IN AGRICULTURE (Agril. Chemistry, Soil Science and Biochemistry) to the Orissa University of Agriculture and Technology, Bhubaneswar is a faithful record of bona fide research work carried out by Sri Magiram Sahoo under my guidance and supervision during the academic session 1992-93. No part of this thesis has been presented in any form for any other degree or diploma.

All possible helps and sources of information availed during the course of this investigation have been duly acknowledged.


(G. C. SAHU)
6.8.94

ACKNOWLEDGEMENT

I avail this opportunity to express my deep sense of gratitude and indebtedness to Dr. G.C.Sahu, Reader, Department of Agricultural Chemistry, Soil Science and Biochemistry, College of Agriculture, OUAT, Bhubaneswar, the Chairman of my Advisory Committee for suggesting me this problem and his sustained interest, valuable guidance, constant supervision, constructive criticism and encouragement during the entire course of this investigation and helping in the preparation of this manuscript.

I am very much grateful to Dr. N.Acharya, Professor and head, Dept. of Agril. Chemistry, Soil Science and Biochemistry, College of Agriculture, OUAT, Bhubaneswar and former Asso. Director of Research (IWDP) for providing necessary laboratory facilities to carry out this research work.

I express my special gratitude to Dr. S.S.K.Nanda, Dean, College of Agriculture, Bhubaneswar for his constructive criticism and valuable advice during the investigation as well as in preparation of this manuscript.

I also owe heartfelt gratefulness and thanks to the Director of Soil Conservation, Orissa, Bhubaneswar, who recommended my name for higher study.

I am very much thankful to Sri N.Patro, Reader, Department of Agronomy, College of Agriculture, Bhubaneswar for his encouragement throughout the period of investigation.

I am very much thankful to Sri K.K.Rout, Lecturer, Department of Agril. Chemistry, Soil Science and Biochemistry, College of Agriculture, OUAT, Bhubaneswar for his co-operation during the preparation of this thesis.

I am also thankful to Dr. S.K.Patnaik, Sri R.K.Patra, Lecturers, Sri B.B.Sahoo, S.R.A. and other staff members of the Department of Agril. Chemistry, Soil Science and Biochemistry, College of Agriculture, Bhubaneswar for their help during the period of research work.

I am also indebted to my classmates Laxmidhar, Hemanta, Ajaya, Khatris and others who cooperated and encouraged me in the completion of my work.

I am thankful to Miss Sabita Jena for typing this manuscript neatly.

Last but not the least, I express my reverence and gratefulness to my parents, my wife susamarani, children Debasis, Ashis, Smutirekha and other family members who like to see me great and whose inspiration and co-operation only could bring me to this stage of success.

Bhubaneswar,
Dated, August 6, 1994

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(Magiram Sahoo)

TITLE OF THE THESIS : "Morphology, characteristics and classification of soils in Integrated watershed Development Project (IWDP) area - Dhobakia Nala Mini Watershed (ORM-3-16-7-3), G.Udayagiri in Phulbani District.

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DEGREE FOR WHICH THESIS IS SUBMITTED : Master of Science in Agriculture (Agricultural Chemistry, Soil Science & Biochemistry)

YEAR OF SUBMISSION : 1994

ABSTRACT

Village Nilungia under the Dhobakia Nala Mini Watershed was surveyed in detail and four pedons from upper pediment (P_1), ridge slope (P_2), valley top (P_3) and valley slope (P_4) were characterised. Besides, sixteen composite surface samples were also collected and analysed to know the fertility status of the area. It is a sloping terrain, with 5-8% slope and moderate soil erosion and is situated in the foot hills of the Eastern ghat region.

The soil colour is yellowish red on the upper pediment which gradually changes to light reddish brown along the sloping terrain. The profiles are deep at the bottom region than upper pediment. The surface soil texture varies from sandy loam to sandy clay loam whereas, it is sandy clay loam to clay down the profile. In the upper region profiles the clay content increases down the depth with presence of thin, patchy clay cutans in the sub surface horizons qualifying for argillic horizon.

Soil reaction is almost medium acidic in different horizons of all the profiles. The organic carbon content is medium on the surface (0.42-0.74%) which decreases gradually (0.18-0.21%) down the depth in all the pedons. The CEC values of soil are comparatively less on the surfaces and it increases gradually with depth and have a linear correlation with the clay content ($r=0.837$). The exchange complex in all the profiles are dominated by Ca^{++} followed by Mg^{++} , K^+ and Na^+ . The percentage base saturation values in general increases from the surface downwards. The rating for available N, P and K are medium, the values ranging from 220 to 320 kg/ha, 1.0 to 20.6 kg/ha and 280 to 780 kg/ha respectively. Lime requirement for ridges varies from 2.7 to 5.0 tons/ha and that of valley slope soils from 1.5 to 3.6 tons/ha. For composite surface soil samples the value varies from 0.8 to 5.1 tons/ha.

The upper pediment, ridge slope, valley top soils of the area are classified under the order **Alfisols**, suborder **Ustalfs**. The soils of upper pediment are classified under great group **Kandiustalfs** and sub-group **Aridic-Rhodic-Kandiustalfs**. Soils of ridge slope are classified under great group **Paleustalfs** and sub-group **Ultic Paleustalfs** whereas soils of valley top are classified under great group **Paleustalfs** and sub-group **Kandic Paleustalfs**. The valley slope soils are classified under the order **Entisols**, sub-order **Fluvents**, great group **Ustifluvents** and sub-group **Typic Ustifluvents**. In the family level, soils of all the profiles are placed under fine loamy, mixed, hyperthermic.

Necessary suggestive treatments are given for integrated watershed development in the study area.

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CHAPTER I

INTRODUCTION

CHAPTER-I
INTRODUCTION

Increase in food production can be achieved only when the soil on which agriculture and all human life depends is conserved. Erosion of soil is a part of a vicious circle, wherein the soils are impoverished by erosion dislocated from one place to the other leading to the deposition of the soil on lands in the lower regions, in reservoirs, in waterways and harbours. We face disastrous floods all over the country so often.

The deterioration of natural resources of an area in this manner can be contained and the total resources properly developed only by adopting the watershed approach in which the basic unit of development is a watershed, a manageable hydrological unit. In this approach development is done of agricultural lands, the barren hill slopes and the stream beds, and all the resources of the area - water, fuel, fodder livestock, fish - and the most important one, the human resources, are developed into a harmonious system. This involves the exploration and development of the complex inter-relationship between the watershed resources and its living population.

There is a need to bridge the gap in productivity and production potential in the vast rainfed areas of the country. A vast area of land is degraded annually by various factors and unless the valuable surface soils are restored in situ, the production potential is found to decrease.

Annual soil loss estimates in different regions of India are as follows (Dhruva Narayan and Ram Babu 1983).

Sl. No.	Land resource region	Area (000' km ²)	Soil loss (tonnes/km ²)	Major land use
1.	North Himalayan forest region	131.70	287	Forest
2.	Punjab-Haryana alluvial plains	101.25	330	Agriculture
3.	Upper Gangetic alluvial plains including ravines	200.00	1410-3320	Agriculture or wasteland
4.	Lower Gangetic alluvial plains	145.50	287-940	Agriculture
5.	North-eastern forest region	161.002	2780-4095	Agriculture, shifting cultivation
6.	Gajarat alluvial plain region including ravines	62.75	240-3320	Agriculture
7.	Red soil region	68.8	240-360	Agriculture
8.	Black soil region	67.34	2370-11250	Agriculture
9.	Lateritic soils	61.0	3930	Agriculture

To feed the overwhelming population of our country, there is a need to produce about 250 million tonnes of food grains by 2000 A.D. This could be achieved by taking two area development approaches in the field of Agriculture and rural development:

(1) **Command area development**, which is adopted for comprehensive development of irrigated areas, and (2) **watershed area development**, which is pursued in rainfed areas where availability of water is dependant on erratic amount, intensity and distribution of rainfall. In command area development although, the availability of water is almost assured and intensive production system of specialised nature are practised for maximising production, the total area under irrigation is only 27% in our country and the production potential is decreasing due to development of salinity, alkalinity, waterlogging etc. in the irrigated tracts. Hence much emphasis has been given in the VIII Five Year Plan for integrated watershed area development for "ending the neglect of vast rainfed and dryland areas".

Watershed is a geohydrological unit or a piece of land that drains at a common point. This natural unit is evolved through the interaction of rain water with land mass and typically comprises of aerable lands, non-aerable lands and natural drainage lines in rainfed areas. The definitions of catchment, watershed, etc. are as follows.

(i) **A primary river** is a big river having a catchment of several lakh acres (several forty thousand hecets) which has a number of tributaries of 1st, 2nd, 3rd, 4th or even 5th order. The primary river generally discharges its load to the sea.

A **catchment** is the drainage area that contributes to the flow of a primary river having an area of a few lakh acres or more.

(ii) A **Secondary river** is a tributary of a primary river having drainage area of more than a lakh acres (forty thousand hectares).

A **sub-catchment** is the drainage area of a secondary river, having area more than a lakh acre (forty thousand ha).

(iii) A **Tertiary stream** is a tributary of a secondary river having a watershed area of 10,000 to 1,00,000 acres (4-40 thousand ha).

A **watershed** is a drainage area that contributes to the flow of a tertiary river, having an area of 10-100 thousand acres (4-40 thousand ha).

(iv) A **Quarternary stream** is a tributary of a tertiary having drainage area which varies between 5 to 10 thousand acres (2-4 thousand ha).

A **sub-watershed** is the drainage area of a quarternary having an area of 5-10 thousand acres (2-4 thousand ha).

(v) A **pentad stream-let** is a tributary of a quarternary having a drainage area of 1-5 thousand acres (400-2000 ha).

A **mini-watershed** is the drainage area of a pentad having an area of 1-5 thousand acres (400 to 2000 ha).

(vi) A **Hexad stream-let** is a tributary to a pentad having more than 1000 acres drainage area (400 ha).

A **micro-watershed** is the drainage area of a hexad having less than one thousand acres (400 ha) as its area.

The watershed approach has been followed in India since yearly sixties for sectoral projects aiming at control of siltation in reservoirs or mitigation of floods. The objective in VIII Five Year Plan (1990-1995) will specially focus on

I) Conservation, upgradation and utilisation of natural resources like land, water, plant, animal and human-beings in a harmonious and integrated manner;

ii) generation of massive employment during the project period and regular employment after the completion of the project;

iii) improvement of production environment and restoration of ecological balance through scientific management of land and rain water;

iv) reduction of inequalities between irrigated and rainfed areas, and

v) in addition to food, production of fuel, fodder, vegetables, spices etc. in suitable areas.

The world bank aided integrated watershed development project has been sanctioned to O.U.A.T. with a purpose to provide research support to the developmental activities of

this project being operated by the state Department of Soil Conservation. The operational area of the project are two watersheds of G.Udayagiri Block, three watersheds of Khajuriapada Block of Phulbani district and one watershed of Jagannath Prasad and one watershed of Soroda Block of Ganjam district. The operational research started from August, 1992.

For the present investigation the Mini-watershed Dhobakia Nala (ORM-3-16-7-3) in G. Udayagiri Block of Phulbani district has been selected as pilot watershed. The criteria for selection of this particular watershed as pilot project were :

1. The mini-watershed area approachable by all weather road from the district headquarters phulbani as well as from the state capital.
2. Within the mini-watershed necessary infrastructure facilities are available.
3. Govt. farms are situated near to the watershed for raising vertiver nursery.
4. The mini-watershed area have a good range of on-farm and off-farm land management problems that need to be tackled.
5. The mini-watershed forms the catchment of kakalbaki M.I.P.

The mini watershed has been surveyed by the soil survey staff, G. Udayagiri, Soil Survey sub-division. The mini-watershed is located in Mahanadi catchment of Salki sub-catchment, kakalbaki watershed, Sirikinala sub-watershed. The Dhobakia nala is a pentad stream-let of the watershed system. The mini watershed comprises of eleven number of villages, the total area of which is 2237 ha.

OBJECTIVE

The objectives in the present investigation are:

- i) to traverse the area and survey the Nilungia village in detail (Fig. 1),
- ii) to select the profile sites from different physiographic regions and have a morphological study of different profiles,
- iii) to characterise the soils of the region,
- iv) to classify the soils as per Soil Taxonomy,
- v) to study the fertility status of the region, and
- vi) to suggest suitable land use management for sustainable production.

CHAPTER II

REVIEW OF LITERATURE

CHAPTER-II

REVIEW OF LITERATURE

The literature pertaining to the present investigation has been reviewed under the following sections.

- A. Morphological and physical characteristics
- B. Chemical characteristics
- c. Genesis of soil
- D. Classification of soils

A. Morphological and physical characteristics

Sinha et al. (1962) studied the morphology of some red laterite soils of Ranchi in relation to topography of the land. They observed that down the slope, the depth of profile increases, texture varies from lighter to heavier, structure changes from single grained or granular to blocky or prismatic, pH changes from acidic to neutral, status of organic carbon and nitrogen increases. Variation in colour of surface soil is also in harmony with the topography in which these soils are found to occur. The profiles are encountered by iron stone gravels of irregular shape which appear to be undergoing dissolution. In these gravels, resistant materials such as quartz stand out sharply from the surface. The vesicular

and indurated character of the surface crust is due to its exposure by which certain horizons had been washed by erosion.

The toposequence stretches a distance of 57 km in a north easterly direction from the Troodos summit at 1952 m altitude to a point near Nicosia at an altitude of 212 m (Bojeklein 1983) in Cyprus. Geomorphologically, it is divisible into a steeply sloping area of sandy loam soils under fruit and vine culture, a transitional foot hill region of little differentiated stony soils leading to a high plain dissected by valleys on which occur deep, clearly differentiated cereal growing soils of loamy clay texture. The typical soils of the steep slopes are magmatite derived carbonate free soils (eutric lithosols) of pH 6-7, and soils derived from limestone and lime containing sedimentary rocks (calcareous lithosols, calcareous regosols, calcareous cambisols). The soils of the plain are typical red mediterranean soils which are classified as chromic cambisols.

Curi and Franzneir (1984) studied on the toposequence of oxisol from the central plateau of Brazil. In the toposequence of oxisols developed from basalt in the central plateau of Brazil, moist soil colour changed from dark reddish brown (2.5 YR 3/4) in upper slope position to dark yellowish brown (10 YR 4/4) in lower slope position. Soil colour is a reliable indicator of iron oxide mineralogy which reflect the genesis of soil and influence properties that affect plant growth. This colour should be used at a relatively high categorical level in soil classification system to define classes of latosols and oxisols.

Venugopal and Koshy (1985) studied the morphology in the soil profiles from a catena in Kerala. A toposequence of soils in the mid-upland laterite region of Kerala showed a change from a reddish colour at the crest to grey in the valley.

Challa and Gaikward (1986) studied seven soil pedons of the catenary sequence from Dadra and Nagar Haveli; the pati soils of flat topped hills, talavli soils from foot hill slopes and surangi soils of flood plain have the dark reddish brown colour and medium to slightly acidic pH (5.6-6.4) whereas, kanadi, vasona and saili soils of piedmont plain and dapada soils of flood plain have dark greyish brown to dark brown colour and slightly acidic to moderately alkaline pH (5.8-7.9). Kanadi soils are slightly calcareous with powdery lime mixed with soil matrix. Rest of the soil are non-calcareous. The soil of the piedmont plain have relatively higher clay and CEC, lesser coarse fragments and well developed pedon with intersecting slickensides as compared with the soils of flat topped hills, hill slopes and flood plains. The soils could be classified into Entisols, Inceptisols and Vertisols in the sequence.

Soil samples from ten places in Sikkim having varying altitudes have been analysed by Lahiri and Chakravarti (1989) for soil texture, NPK and micronutrient status and distribution and nature of organic matter. Soils contain

high nitrogen, low available potassium and medium available phosphorus. The contents of available iron, manganese, zinc and copper as judged by the critical values seem to be adequate. The clay content decreases and organic matter increases with increase in altitude of the places. ✓

Soil profiles representing four different physiographic units, viz. upland with steep slopes, strongly sloping land, valley land and the land in the vicinity of streams were studied (Singh et al. 1990) in mid-Shiwalik ranges of Himachala Pradesh. A great deal of heterogeneity is seen in soil characteristics. The soils are classified into four soil series namely Samlon, Trandol, Khanot and Mator from upland to down stream respectively. Samlon soils had 5 YR as a dominant hue, in other soils it was found 10 YR. Small iron and manganese concretions of irregular shape and coarse fragments were present in Samlon, Trandol and Khanot soils whereas the fragments of bigger size were present in Mator soils in abundance throughout the profile. Trandol and Khanot series had medium textured soils whereas Samlon and Mator soils were found to be coarse textured. All soils were characterised by granular structure in the surface horizon and structureless in sub-surface horizons except Khanot soils which had blocky structure in B horizon.

✓ Datta et al. (1990) studied the erodibility characteristics of soils in relation to soil characteristics and topography. There was an appreciable movement of clay from upland to

lowland situations in soils collected from south districts of Tripura. On the contrary, there was a marked enrichment in silt content in lowland soils as compared to upland ones in both north and west districts. Naturally, soil texture varied widely. The lowland soils were found to have more pore space than those from uplands in all the districts.

Based on reconnaissance survey, four typical pedons of soil series occurring on different landforms were studied by Singh and Chamuah (1991). Hill slope soils (P_1) developed on gneisses under excessively drained condition are dark grey at the surface and reddish brown to red at sub-surface. This could possibly be due to the presence of high amount of organic matter at the surface and formation of non-hydrated iron oxide under excessively drained condition. Soils on piedmont (P_2) and lower flood plain (P_3) developed on alluvium under poorly drained conditions are grayish brown at the surface and grey to light grey with red and brown mottles in subsurface horizons. Soils on active flood plain, however, exhibited no conspicuous changes in colour with depth.

Qian and Cao (1992) studied the characteristics and classification of major soils in a mountainous area of south Anhui. The soils are strongly weathered and leached, and enriched in alumina. Their characteristics vary with their altitude. Below 600-700 m a.s.l., the soils belong to the yellow-red sub-group of red soils (Acrisols). In their B

B horizons, the colour is 5 YR 5/6-5/8, the silt:clay ratio ≤ 1.00 , the co-efficient of weathering and leaching ≤ 0.35 , base saturation $\leq 35\%$ and the $\text{SiO}_2:\text{Al}_2\text{O}_3$ ratio of the clay fraction ≤ 2.4 . The dominant clay mineral is kaolinite. The activity of iron oxides is low. The humic acid:fulvic acid ratio of top soil is ≤ 0.35 . However, above 600-700 m a.s.l., the soils are classified as yellow earths (cambisols). In their B horizons, the colour is 2.5 Y 8/6 or 10 YR 6/6-6/8, the silt:clay ratio > 1.00 , the co-efficient of weathering and leaching > 0.35 , base saturation $\leq 35\%$, and the $\text{SiO}_2:\text{Al}_2\text{O}_3$ ratio of the clay fraction > 2.3 . The clay minerals are predominantly vermiculite and kaolinite, with some gibbsite. The iron oxide activity is high. The humic acid:fulvic acid ratios of top soil are between 0.35-0.75.

Kaistha and Gupta (1993) studied the soils of the subhumid temperate highlands of the central Himalays. The morphological characteristics (Pedon-1. elevation 3200 m, slope 10-15%, undulating topography) indicate that pedon 1 had dark greyish brown (2.5 Y) colour up to 0.93 m depth with chroma of 2 due to imperfect drainage of the pedon facing towards north slope. On the other hand, (Pedon-2, elevation-3000 m, slope 3-4% flat topography) showed brighter colour with hues of 10 YR and chroma of 3, and thus is free of characteristics associated with wetness. Similar colour variations have also been observed by Sehgal et al. (1985). The texture of pedon-1, was sandy loam throughout the depth

and that of pedon-2, sandy loam to loam. The stony nature of the pedon-1 throughout its depth and low content of clay appear to have made the successive layers somewhat loose and friable, resulting in granular to subangular blocky structure.

B. Chemical characteristics

Gowalkar and Barde (1964) reported that heavy clays are observed on plane areas and loams on hills and steep hills. Lime kankers are also found on plane areas but absent on hill slopes. In plane areas therefore dominant exchangeable cation is Ca^{++} followed by Mg^{++} and the molar ratio indicated that montmorillonite type of clay. Similar results were obtained by Biswas et al. (1966) from a study of catenary soils of Andhra Pradesh, in which the morphological feature and mechanical composition were related to the toposequence.

Zouzou and Furley (1975) reported from a 2000 m transect study in Euphratas valley that with the distance and gradient of the slopes there is an increase in clay content, moisture status and soluble salts with depth.

Rajamannar and Krishnamoorthy (1978) studied the physico-chemical characters of forest soils of western ghat in South India and reported that the soils of 200 m altitude were colluvial in nature while the soils of 1010 m and 2237 m altitude were laterite in Origin. The clay content of the soil increases with increase in depth and varies from 5.8

to 8.1% for the soil of 200 m. But in other elevations the clay content on the surface varies from 39.9 and 24.2% respectively which increases in the sub soil layers and again decreases down wards. ✓ The bulk density is reduced slightly due to 0.m content. Organic carbon was 0.24% for 200 m, 1.17% for 2237 m elevation. [There is an increase in organic matter content due to altitude.] Their work corroborated the findings of Biddapa and Venkata Rao (1973) and Sharma et al. (1956). [The maximum water holding capacity, total pore space and moisture equivalent increases with increasing elevation. The CEC and total nitrogen bears positive relationship with elevation. Surface soil of higher elevation contains higher amount of P than those of lower elevation. The K and Ca content were more in lower altitude than in higher altitude soils. The Fe content of lower altitude were very low than higher altitude.

✓ Mountain and upper alluvial plain soils in the Caspian sea region of Iran are acidic with average pH values of 5.8-6.9 respectively (Hakimian 1978). The lower alluvial and coastal plain soils are neutral with pH 7.0 and 7.3 respectively. The base saturation per cent are lower for high land soil (68%) and higher for lowland soils (99%). The exchange acidity also follows the reverse trends. The average organic matter content of the lower alluvial plains is the highest (9%) and other soils having intermediate organic matter content.

✓ From a geomorphic study of the soils of Similiguda Research Station, Koraput (Orissa), Ray and Nanda (1979) have stated that with the increase in elevation, the organic carbon content, clay content, percentage base saturation decline and soil acidity have increased down the slope and clay mineralogy has changed from kaolinitic to mixed.

✓ Chakravorty and Chakravorti (1980) studied on physico-chemical characteristics of soils of Eastern Himalayan Region and reported that the organic component varies with altitude (foot hills to 3400 m) and climatological condition shows that (i) with increase in altitude, a decrease in the clay content, (ii) increase in organic matter and (iii) increase in the proportion of extractable fraction of humus are observed. —

✓ Singh and Datta (1983) reported the hill soils of Mezoram in relation to altitude. They are strongly acidic in reaction. High level of organic matter is associated with low pH values in the surface layer of hill range soil. With the increase of Al acidity down the profile, the pH instead of lowering down has shown a slight upward trend. Organic matter content decreases with fall in altitude. Mineralogical study indicated that clay is predominantly of highly degraded illite type, being stabilised through mica in silt and hydrobiotites in fine sand fraction. Highly micaceous parent material provides potash rich ionic environment. CEC of the soil does not reflect the nature of clay mineral and high values may be due to presence of organic matter.

Palomar Garcia-Villamil et al. (1984) studied morphological, analytical and chemical properties of five profiles in a toposequence near Terriente (Teruel, Spain), developed on colluvial deposits of clays, sand, marl and limestone. Horizons of all profiles have high carbonate contents. The two profiles at low altitude have fine textures, while the soils at higher altitude are coarser in texture. The $(\text{CaO} + \text{MgO}) / \text{Al}_2\text{O}_3$ ratios are lowest in profiles with less CaCO_3 and more clay, indicating a greater degree of weathering in the surface horizons of those profiles situated on the plain and the lower slopes.

Nair and Chamuah (1988) found that the soils except those on steep slopes in East Hill district of Meghalaya were very deep. High organic matter at the surface decreased with depth. The soils are strongly acidic throughout the solum. The cation exchange capacity of the soils range from 1.1 to 14.9 $\text{cmol}(p^+) \text{kg}^{-1}$ and the values decreased with depth. The percentage base saturation is also higher in surface soils as compared to the subsurface layers possibly because of plant recycling. The soils belong to the order Entisols and oxisols.

A study was undertaken to know the distribution of different forms of potassium in four typical, widely occurring soils in a toposequence developed from basaltic parent material in the Malwa plateau (Sharma & Dubey 1988). The water soluble k in the soils of the toposequence contributed to

0.03 to 0.06% of the total k and 2.6 to 4.5% of available k. It was the lowest in soils at the pediment and the highest in soils of alluvial plains. The surface soils had high water soluble k which, in most cases, decreased along the depth of the profile. The soils of the pediment and upper piedmont revealed lower exchangeable k status as compared with the piedmont plain and alluvial plain soils. The latter soils contain higher quantity of clay. The majority of the total k was in lattice in all the soil profiles located on a transect. The higher lattice k content in the pediment soils could be attributed to the presence of higher amounts of less weathered micaceous clay minerals.

✓ Singh and Datta (1988) reported that organic carbon and readily oxidizable organic matter contents rise with increasing elevation, with the former being significantly correlated to the altitude ($r=0.973$). ✓ The C/N ratios of the surface soils at higher altitudes have narrower values than of the surface soils at lower altitudes. The ratio also shows a narrowing trend with increase in soil depth. The total and other forms of nitrogen (available, ammoniacal and nitrate) increase with increase in altitude and decrease with depth. These bear significant positive correlations with altitude and also with organic carbon, besides positive and significant correlations among themselves. Multiple correlation study shows 89% of the variation in the total nitrogen content is due to associative influence of altitude, organic carbon

and pH; and 99% of the variation in available nitrogen is due to the combined effect of organic carbon, total nitrogen, NH_4^+ -N and NO_3 -N. On the whole, organic matter shows a greater contribution in the predictability of total and available nitrogen.

Gangopadhyaya et al. (1989) studied soils of three pedons within an altitudinal range of 1970 m and 2425 m in Sikkim forest division. All the soils are acidic. The translocation of clay in the profile is very much pronounced. The organic matter content of these soils is high at the surface and gradually decreased down the profile. Calcium is the dominant cation among the bases. The mobile form of Fe and Al increases down the profile.

✓ Datta et al. (1990) studied the erodability characteristics of soils in relation to soil characteristics and topography. They reported that pH of lowland soils increased gradually as compared to the upland soils, probably due to surface runoff. Similarly, higher organic carbon and lower total N were observed in lowland soils as compared to the overlying counterparts. The available phosphorous content varied from low to high and that of potassium, from low to medium.

✓ Unlike p and k, exchangeable Ca and Mg were observed to undergo an appreciable movement from upland to lowland topographic situations.

Singh and Chamuah (1991) studied four typical pedons of soil series occurring on different landforms (Hill slope

soils (P_1), soils on piedmont (P_2), soils on lower flood plain (P_3) and soils on active flood plain (P_4) in kamrup district of Assam. The soils are acidic at the surface and neutral at lower horizon except P_1 where pH values gradually decrease with depth. The differences may possibly be due to variation in exchangeable bases. The soils contain higher amounts of organic matter. The cation exchange capacity is low and does not show any relationship with the content of clay. In spite of acidic nature of the soils, exchange complex of all the soils is dominated by Ca and Mg. High values in subsurface horizon of P_4 may be due to its position where runoff water rich in Ca and Mg saturated the soil profile.

Ramanamurthy and Sharma (1992) reported that high altitude profiles had larger organic matter accumulation as compared with the low altitude profiles. Higher contents of organic carbon in northern and high altitude profiles is facilitated by lower temperatures which are conducive to organic matter accumulation.

The main features of an altitudinal sequence were determined from mapping soils on a late cenozoic volcanic plateau and from the analysis of 27 pedons sampled from 270 to 2030 m above sea level (Alexander et al. 1993). This sequence is characterised by thermic Rhodoxeracts in oak-grassland below 500 m mesic palexeralfs, mesic xeric Haplohumults, frigid Andic Haplohumults, and Haplocryands in conifer forest. Soil depth and clay content are the greatest in the lower

part of the conifer forest, but soils in the oak-grassland are slightly redder. The characteristics (not necessarily predominant) clay minerals, from low to high altitude, are smectite, kaolinite, halloysite, hydrated halloysite, and allophane. Soil reaction ranges from slightly acid at all depths in the oak-grassland to strongly acid in the surface and very strongly acid in the subsoil at higher altitude. The soil organic carbon content increases from 9 kg/m²-m in the oak-grassland to 11 in the lower part and 25 kg/m²-m or more in the upper part of the conifer forest. Soil organic carbon to total nitrogen ratios range from 11 to 14 in the oak-grassland and from 25-35 in the surface horizons in the conifer forest. Increase with elevation in the forest being relatively small compared to the abrupt increase in C:N ratio from grassland to forest.

Shrikanta et al. (1993) studied different land forms in Raisen district of Madhya Pradesh. Soils at higher elevations are less developed and have low pH, CaCO₃, clay content, CEC and exchangeable cations than the soils in lower elevations. Differences in soil development are due to differences in parent material, vegetation and elevation.

(C) Genesis of soil

The term toposequence was introduced by Jenny (1941). The topography and land form effect the air and water movement in soil by their effect on drainage, runoff and erosion to a great extent. Biswas and Gawande (1962) from the study

of drainage condition of Chhatisgarh basin postulated that differential transport of eroded material, leaching, translocation and redeposition of mobile soil constituents influence the genesis of soils. From well drainage to impeded drainage condition down the slope the solum depth increases and the profile character reflects the same. Some traditional and gradational changes also appear, like colour from red to dark grey brown; reaction from acidic to alkaline, structure from structureless to blocky, texture from sandy loam to clay; consistency from non-plastic to very plastic and finally presence or absence of CaCO_3 .

Kabachiev et al. (1972) reported from Bulgaria that from the granite parent material various types of soils have been formed depending upon the degree of slope. Towards the toe slope the soil contain CaCO_3 and on the foot hill position shallow acidic soils are formed.

Reports published by Klant and Beatty (1972) on the soil sequence in Brazil indicated that the soils developed on slopes or steep hills are less affected by weathering process than plateau soils.

Dan et al. (1972) studied the catenary soil relationships in Israel. The development of catena on northern slope consisted of grumusolic dark brown soils on flat hill tops; thick, non-calcareous brown soils on the moderate slope; typical brown rendzina on steep slope; brown rendzinic colluvial-alluvial

soils on gullies and on southern slope pale rendzina in place of brown rendzina and the brown rendzinic colluvial-alluvial were calcareous in nature.

Zouzou and Furley (1975) reported from a 2000 m transect study in Euphratas valley that having some parent material and different geo-morphological units Aridisols are formed at the top of the slope and Entisols at the bottom.

Fitzpatrick and Le Roux (1977) from a soil study over 200 m altitude in South Africa, reported that the top slope is non-vertic and bottom slope is vertic due to montomorillonite type of clay.

The North-Eastern part of India has the largest stretches of acid soils and the pH of Nagaland soils varying between 4.0 to 6.5 (Dutta 1980). The factor particularly dominant in the development of acid soils are rainfall, temperature, acid igneous rocks, hydrological condition and vegetation. The large variation in altitude ranging from 300 to 3300 m has given rise to diversity in climate and vegetation which are the pre-dominant factors for the classification of Nagaland soil into four orders - Entisol, Oxisol, Mollisol and Spodosol. Major processes involved in the genesis of acid soils in Nagaland are (i) Intensive leaching, (ii) laterization and (iii) podzolisation.

Lucas et al. (1984) studied the area consisting of a low plateau with intermediate surfaces down the slopes. Clayey yellow latosols (Acrorthox) occur on the plateau with gradual

transition to podzolic soils (Tropohumults) and sandy podzols (Tropohumods) on the intermediate surfaces.

Gavaud et al. (1985) described the soil landscapes of the Venezuelan territories of Amazonia. The soils form a sequence included lithosols, podzols, and peat at the highest altitude (2000 m), a number of ferrolitic soils (Petroferric Gibbsiorthox, petroplinthic Haplorthox, Acric Umbriorthox) from a 2000 to 100 m and sandy soils (Quartzi psamments) at lowest altitudes.

Five soils representing the major land forms on part of the watershed of the Jajerud river and Latyan reservoir in Iran were described by Rooyani et al. (1985). The soils occur on the Hezardareh formation, a poorly cemented conglomerate and volcanic ash; the green beds, which are thinly bedded mudstone; and on alluvial-colluvial materials derived from the Hezardareh and green beds. All the soils are calcareous and non-saline, with a pH range of 7.5 to 8.1. Organic carbon decreases regularly with depth. The soils on steep slope gradients, more than 10%, are classified as Torriorthents and calciorthids. The soils on nearly level slopes, less than 2% are classified as xerochrepts because of the mottling cambic horizons and more effective precipitation due to less runoff and less removal of weathering products by erosion.

Laffan et al. (1986) studied eight soil profiles ranging in altitude from 30 m to 820 m at Tennyson Inlet in the Marlborough

sounds, Newzealand. The soils are formed from grey wacke on forested hilly and steep land under a super humid climate. Profiles show eluvial and/or illuvial features typical of podzols and podzolized soils. The most strongly weathered soils occur at altitudes below about 200 m whereas less weathered soils occur at higher altitudes. Weathering and leaching is least on soils on very steep slopes ($> 38\%$) at altitudes above 200m. Strongly weathered soils dominated by kaolinite and less weathered soils dominated by Vermiculite. At altitudes below about 200-300 m profiles are relatively weakly podzolized, while podzolized soils and podzols occur at higher altitudes. The profile at highest altitude is dominated by smectite clays and the greyish-coloured solum is interpreted mainly as a relatively thick (80 cm) eluvial horizon resting directly on bed rock.

Twenty one profiles representing a 10 km toposequence in Omayed area of Egypt were described by Ismail et al. (1986). The soil characteristics studied were solum thickness, presence or absence of subsurface disgnostic horizons, and the natural vegetation cover. The soil on the upper end of the transect was identified as a Lithic Torripsamment and the soil on the lower end appeared as a typic Torripsamment. The intermediate profiles were noted to have characteristics of Aridisols (mostly calciorthids) due to the present arid climate. A few are salorthids, others are salt affected. The genesis of these soils appears to be controlled mostly

by their geomorphic surface, the age and the nature of their parent material. Two of the major pedological processes expressed in that sequence are migration and accumulation of calcium carbonate, mostly on old and sub actual deposits and salinization mostly on the most recent ones.

Three toposequences representing different stages in the degradation process were studied by Stoop *et al.* (1987). Most soils of uplands and upper and mid-slopes are prone to rapid degradation, whereas the soils of the lower slopes are more fertile and their moisture availability is more assured but may suffer from occasional waterlogging. The local agriculture will often permanently occupy the lower slopes and lowland fields, whereas the higher fields will be in fallow systems.

Two toposequences derived from granite in the Mt. Garnet area, North Queensland, were examined by Verster (1987). The dominant land surface feature is gently sloping, concave foot slopes covered by relatively thick colluvial deposits. It is assumed that these foot slopes are attributable to a retreating mid slope as well as the colluviation of materials during dry periods of the late mid-pleistocene. Granulometric parameters indicated a single source of parent material for the foot slope soils, although there would seem to be a temporal discontinuity between the A and B horizons. The distribution patterns of the foot slope soils could be explained by means

of a simple catenary model in which profile hydrology, caused by a water surplus generated by the physical environment, played the major role.

A detailed soil survey of the drainage pilot project at the Mundalana village (Sonapat, Haryana) in the mean annual rainfall zone of about 600 mm in a toposequence was taken by Bhargava (1988). Sodic soils occupied elevated positions and were with or without petrocalcic layer close to the surface, resting over a compact B horizon. Saline soils occupied toe slope and centre of the basin. Soils on the toe slope are loamy sand to loam and in the basin loam to clay.

Bravard and Righi (1989) studied the morphology and geochemical characteristics of soils in a toposequence, with a gradual transition down the slope from Oxisols through Ultisols to spodosols. All soils were strongly acidic, had a low base saturation and contained kaolinitic clay. Decrease in clay content down slope, from 80-90% in the oxisols to 2-5% in the spodosols, and concomitant increase in quartz were attributed to a combination of hydraulic weathering and either clay eluviation or selective clay erosion. The sequence of soils suggests that a podzolization process begins when a critical stage in impoverishment is reached.

Prasad et al. (1989) studied the morphology and other characteristics of the Nimkheda soils in Jabalpur, Madhya Pradesh in relation to topography. Taxonomically these soils

were classified into Alfisol, Entisol, Inceptisol, Mollisol and Vertisol. Entisols are the dominant soils of hillocks and convex erosional slopes, Alfisols are next dominant and Mollisols and Vertisols covers 16.7% and 12.5% of the area gradually down the slope gradient.

Studies were undertaken along a slope with a hardened Bt horizon which becomes plinthite overlain by iron pan at the lowest point of the slope, just above the colluvial valley bottom (Jaensch et al. 1991). Profile depth functions of texture, clay cutans on pore walls, Ca, Mg, K, acidity, total N, total C and weatherable P, Mg and K are presented for a chromic Luvisols under forest and a cultivated haplic Lixisol at the top of the slope (with erosion, runoff and loss of cations); a cultivated ferric Lixisol in the upper mid-slope zone (sand deposition, leaching); a eutric Plinthosol under grassland in the lower mid-slope zone (cation Enrichment, ground water input and iron pan formation); a eutric Fluvisol used for rice on the valley bottom (Colluvial, acidified), and a dystrio Gleysol used for rice near the river bed (acidification and Al release). The Luvisols and Lixisols have restricted rooting due to the Bt horizon, causing water stress even at times during the rainy season. In respect of depth, rooting and storage of available water, the Plinthosol is even poorer. The Fluvisol has a higher available water content, while the heavy texture of the Gleysol makes cultivation difficult.

A detailed soil survey was conducted by Singh et al. (1991) to characterise and classify the mid-altitude soils of outer Himalayas. The soils have developed on Shimla group of rocks overlain by Ifra-Karol and Karol series of the Carboniferous lower Mesozoic period under monsoon climate as conditioned by undulating topography and peculiar natural drainage system. The soils have been classified in the orders of Alfisol, Inceptisol and Entisol.

Wu and Ding (1992) studied the soil in Hunan province, China. The soil formation in this region is characterised by strong eluviation, distinct disilicification and allitization as well as marked biological activity. The soil sequence from mountain foot comprises mountain yellow red soil (400-650 m above sea level), mountain yellow soil (650-1000 m) and mountain para-yellow soil (above 1000 m). The occurrence of red limestone soil and yellow limestone soil depends on the distribution of calcareous rock.

Souza et al. (1993) studied six profiles representative of soils of Bai xio de Irece, Bahia, Brazil. The soils are distributed along a topographic sequence, with the most highly weathered at the top and the least weathered at the bottom of the slope or in depressions. They have developed from two parent materials: clastic sediments and limestones of the coating formation.

(D) Classification of soil

Luzio (1972) studied the soils developed on toposequence from granites and granodiorites and classified as, Ultic Haploxeralfs and Typic Xerofluvents respectively, from higher altitude to lower altitude.

Bakr et al. (1978) reported that Inceptisols and Entisols are common on hill slopes due to younger age and slopes, which do not allow profile differentiation. Cooler sites are congenial for the formation of Mollisols.

Zende (1987) conducted a reconnaissance soil survey of a part of Mokokching district of Nagaland. There was a good relationship between soils and physiography. Five major land forms viz. high hills, medium hills, low and very low hills, valleys and river terraces were recognised. The dominant soils are (i) Fine loamy, Typic Hapludults on very steep slopes of high hills, low hills, broad valleys and upper river terraces, (ii) Loamy skeletal, Typic Udorthent on narrow ridges of high hills, (iii) Loamy skeletal, Typic Hapludults on Broad ridges of high hills, medium hills and very steep slopes of medium hills, (iv) Fine loamy, Typic Paleudults on steep side slopes of high hills, straight slopes of high hills, steep slopes of medium hills and very low hills, (v) Sandy, Typic Udifluvents in narrow valleys and to some extent in broad valleys.

Tiwari et al. (1989) studied the red, black and yellow coloured soils in topographical sequence in Rajamahar Trap of Bihar. Red soils are Alfisols, while black soils are Inceptisols, Vertisols and Entisols. The yellow soils come under Inceptisols.

Singh et al. (1990) studied soil profiles representing four different physiographic units, viz. upland with steep slopes, strongly sloping land, valley land and the land in the vicinity of streams, in mid-shivalik ranges of Himachal Pradesh. The soils of upland with steep slopes had ochric epipedon, no subsurface diagnostic horizon, thermic soil temperature, udic moisture regimes and hence have been classified as Typic Udorthent. Soils of strongly sloping land had ochric epipedon underlain by an argillic horizon, high base saturation have been classified as Typic Hapludalts. Soils of valley land are quite deep, free infiltration and percolation of water, medium textured, level terraces, ochric epipedon underlain by the argillic horizon, higher clay content, presence of iron and manganese concretions and classified as Typic Hapludalts. Soils of the land in the vicinity of streams had ochric epipedon underlain by stratified layers with preponderance of coarse fragments and have been classified as Typic Udifluvents.

Singh et al. (1991) conducted a detailed soil survey to characterise and classify the mid altitude soils of outer Himalayas in order to generate and transfer agrotechnology to other areas having comparable soil site characteristics.

The soils have been developed on Shimla group of rocks under monsoon climate as conditioned by undulating topography and peculiar natural drainage system. Soils of high and low altitudes are Dystrochrepts and the mid-hill soils are Hapludults.

The pedochemical characterisation and genesis of soils in relation to altitude in Mizoram was studied by Singh et al. (1991), where he found that silica, the dominant constituent of all the soils decreased with depth paripassu with increase in sesquioxides. Also the K_2O and P_2O_5 decrease with decrease in altitude, whereas CaO and MgO contents increase with decreasing altitude. Soils of high altitude are Umbric Dystrochrepts, mid-hill soils are Typic Hapludults and low altitude soils are Umbric Dystrochrepts.

Four pedons from a lateritic zone and three pedons from a mixed red and black soil zone under subtropical monsoonic climate of Khurda district in a toposequence (Panigrahi 1991) indicated shallow profiles in the upper ridges and deep at the bottom region. Soil textural variation from sandy loam on the upper region to sandy clay loam down the slope was observed. There is increase in the clay content and CEC, and gradual decrease of organic matter down the profile could be observed. The upper ridge soils and mid upland soils are classified under Alfisols and the soils of mid low land are classified under Inceptisols.

Studies on the high level and low level laterites of Orissa (Sahu & Patnaik 1991) in the eastern ghat region indicated the high level laterites to be more clayey, higher CEC but are dominated by kaolinite type of clay mineral. The low level laterites are comparatively light textured, lower CEC and are of mixed mineralogy. The high level laterites are classified as Rhodic Paleustalfs and that of low level laterites as Plinthic Haplustults.

Bhattacharyya et al. (1992) studied the soils in part of western Maharashtra and configured into four major physiographic units viz. hills, plateau, pediment and piedmont plains. In hills, the entire landform is severely eroded, rugged with frequent rockout crops, steep to very steeply sloping, very shallow to shallow, gravelly fine loamy, reddish to reddish brown, noncalcareous are grouped into Lithic Ustorthents. In plateau, these are gently sloping, shallow to moderately deep, silt clay to clay, brown to very dark greyish brown, non-calcareous soils with more than 0.5 cm cracks vertically extending to a depth of 30-80 cm, peds have pressure-faces, and/or slicken sides and are grouped into Typic Haplustalf, Typic Chromustert, Typic Ustropept. In pediment, the soils having moderately sloping, eroded, very shallow to shallow to the Lithic contact, gravelly and calcareous are grouped into Lithic Udorthents, and soils having moderately deep, gently sloping, gravelley clay loam to clay, dark brown, calcareous with 1-2 cm wide cracks extending

to a depth of 32-60 cm, peds exhibiting pressure faces are classified as Typic Ustropepts and Vertic Ustropepts. In piedmont plains, the area having very gently sloping, moderately deep, clay loam, dark brown, calcareous, very slightly to moderately eroded having peds with pressure faces and cracks of 1 cm wide and 30-50 cm deep are classified as vertic Ustropepts. Whereas the area having very gently sloping, deep to very deep, slightly clay to clay, very dark greyish brown, calcareous and very slightly eroded with well developed slickensides and 2-4 cm wide cracks vertically extending to a depth of 70-80 cm have been classified as Typic Chromusterts.

Kaistha and Gupta (1993) studied the soils of the subhumid temperate highlands of the central Himalayas. The soils formed on steep slopes over granite/gneiss parent material, having mixed vegetation (coniferous and deciduous), had ochric integrating to mollic epipedon. Contrary to this, the soils on mild slopes over similar parent materials and under potato cultivation, had mollic epipedon underlain by cambic¹ sub-surface horizon. The soils have been classified as Mollic Udorthents and Fluventic Hapludolls.

Shrikanta et al. (1993) studied different land forms in Raisen district of Madhya Pradesh. The depth of P₁ is only 15 cm, exists a lithic contact at depth shallower than 25 cm, fine loamy, hyperthermic have been classified as Lithic Ustorthent. Soils of P₂ are fine, mixed, hyperthermic

have been classified as Typic Ustochrept. Soils of P₃ having more than 1 cm wide cracks extending up to 50 cm depth, clay content more than 35%, classified as Vertic Ustochrept. Soils of P₄ are very deep, more than 35% clay, 1 cm or more wide cracks extending up to 50 cm, slicken sides close enough to intersect below 54 cm depth, have been classified as Typic Chromustert. Soils of P₅ are very deep, fine, montmorillonitic have been classified as Entic Chromustert. Soils of P₆ is also very deep, fine, mixed, calcareous have been classified as Typic Ustochrept.

Five pedons of the hill slope soils of Middle Andaman Island were characterized and classified taxonomically. (Bala & Sahu 1993). These are situated on a slightly sloping land terrain with undulating surfaces. Soils are strongly to extremely acidic and fairly high in organic matter. The value of CEC varied from 10.6 to 23.2 cmol (P⁺) kg⁻¹ and calcium dominates the exchange complex along with exchangeable Al³⁺. At sub-group level the soils have been classified as Typic Udifluent, Typic Ustifluent and Fluventic Dystrochrept.

CHAPTER III

MATERIALS AND METHODS

CHAPTER-III

MATERIALS AND METHODS

Location and extent

The district of Phulbani is one of the centrally located district of Orissa. It is drained by three major rivers namely the Mahanadi, the Vansadhara and the Rushikulya. The catchment area of these rivers have been delineated and codified upto mini watershed level. Each mini watershed forms the unit of any integrated developmental programme.

The hierarchy of the mini watershed (ORM 3-16-7-3) of Dhobakia Nala is as follows :

ORM (Mahanadi catchment)	-	(Primary river)
ORM-3 (Salki sub-catchment)	-	(Secondary river)
ORM-3-16 (Kakalbaki watershed)	-	(Tertiary stream)
ORM-3-16-7 (Siriki Nala sub-watershed)	-	(Quarternary stream)
ORM-3-16-7-3 (Dhobakia Nala mini watershed)	-	(Pentad streamlet)

The Dhobakia Nala mini watershed (ORM-3-16-7-3) located in watershed ORM-3-16 (Kakalbaki) and sub-watershed ORM-3-16-7

(Siriki Nala) in G.Udayagiri Block of Phulbani district lies in between $20^{\circ} 1'$ to $20^{\circ} 6'$ N latitude and $84^{\circ} 19'$ to $84^{\circ} 23'$ E longitude (Fig. 1). It includes eleven villages out of which the village Nilungia with the total geographical area of 67.438 ha has been taken for the present study (Fig.2).

The present land use pattern of the Nilungia village comprises of 13.324 ha of high land, 1.346 ha medium land, 42.360 ha hills, 5.100 ha 'gochar' and 3.762 ha of cultivable wasteland.

The mini watershed comes under Eastern ghat hill tract having folded topography of anticlinal ridges and Synclinal valleys. The entire land scape is sedentary origin with two broad categories.

1. Sedentary land scape in eroded phase with hill, hill slopes (Pedement) and ridges (upland) and
2. Sedentary land scape in depositional phase (valley).

For the present study, profile samples from upper pediment (P_1), ridge slope (P_2), valley top (P_3) and valley slope (P_4) were taken (Fig. 2) and characterised. P_1 and P_2 comes under upland, P_3 under medium land and P_4 under low land.

The climate of the project area is hot and moist subhumid and falls in the North eastern ghat agroclimatic zone of Orissa with an average rainfall of 1280.6 mm. The mean maximum

(Siriki Nala) in G.Udayagiri Block of Phulbani district lies in between $20^{\circ} 1'$ to $20^{\circ} 6'$ N latitude and $84^{\circ} 19'$ to $84^{\circ} 23'$ E longitude (Fig. 1). It includes eleven villages out of which the village Nilungia with the total geographical area of 67.438 ha has been taken for the present study (Fig.2).

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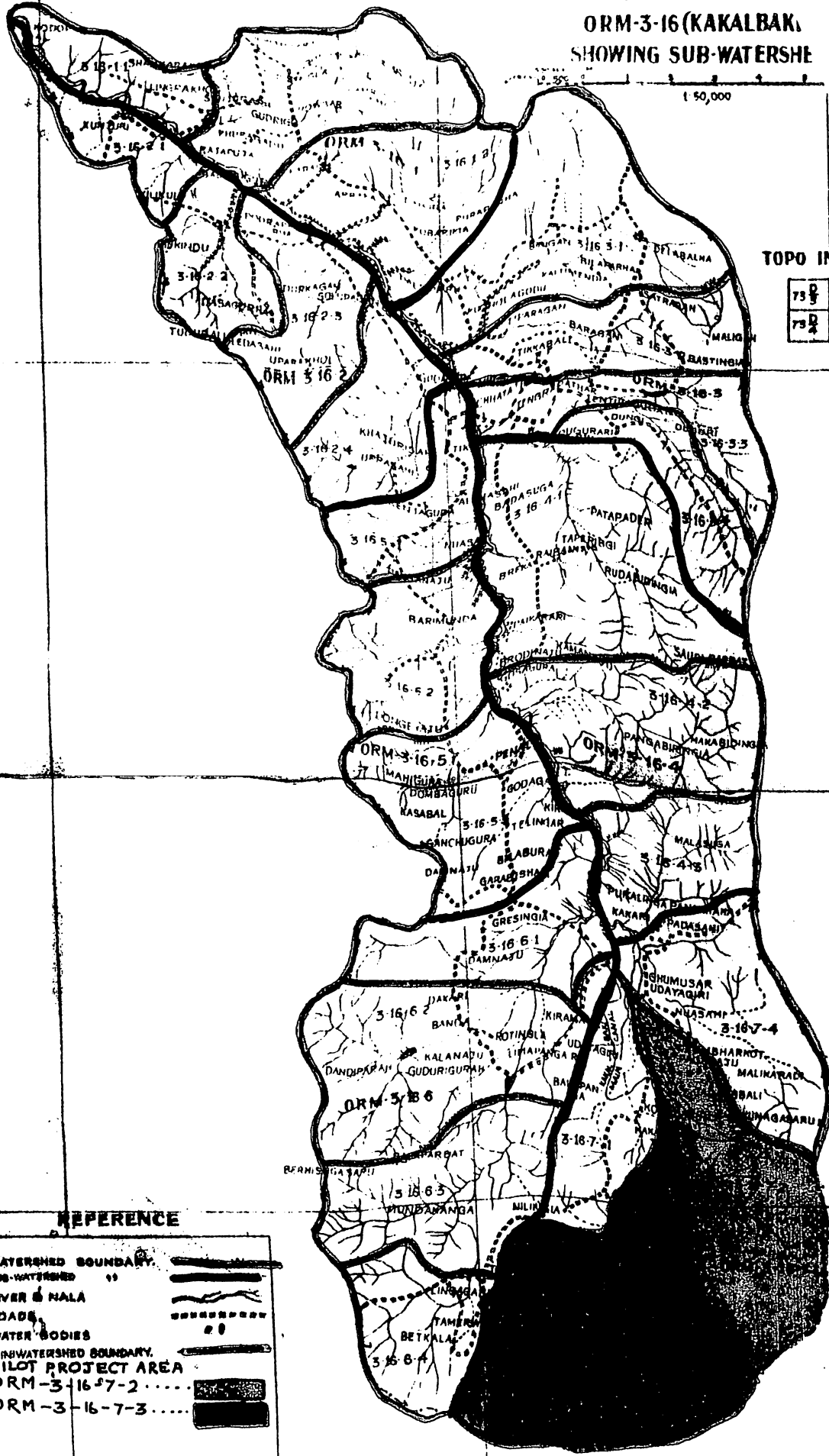
Fig. 1

WATERSHED MAP ORM-3-16 (KAKALBAK) SHOWING SUB-WATERSHE

1:50,000

TOPO INDEX

73 8	73 9
73 4	73 8

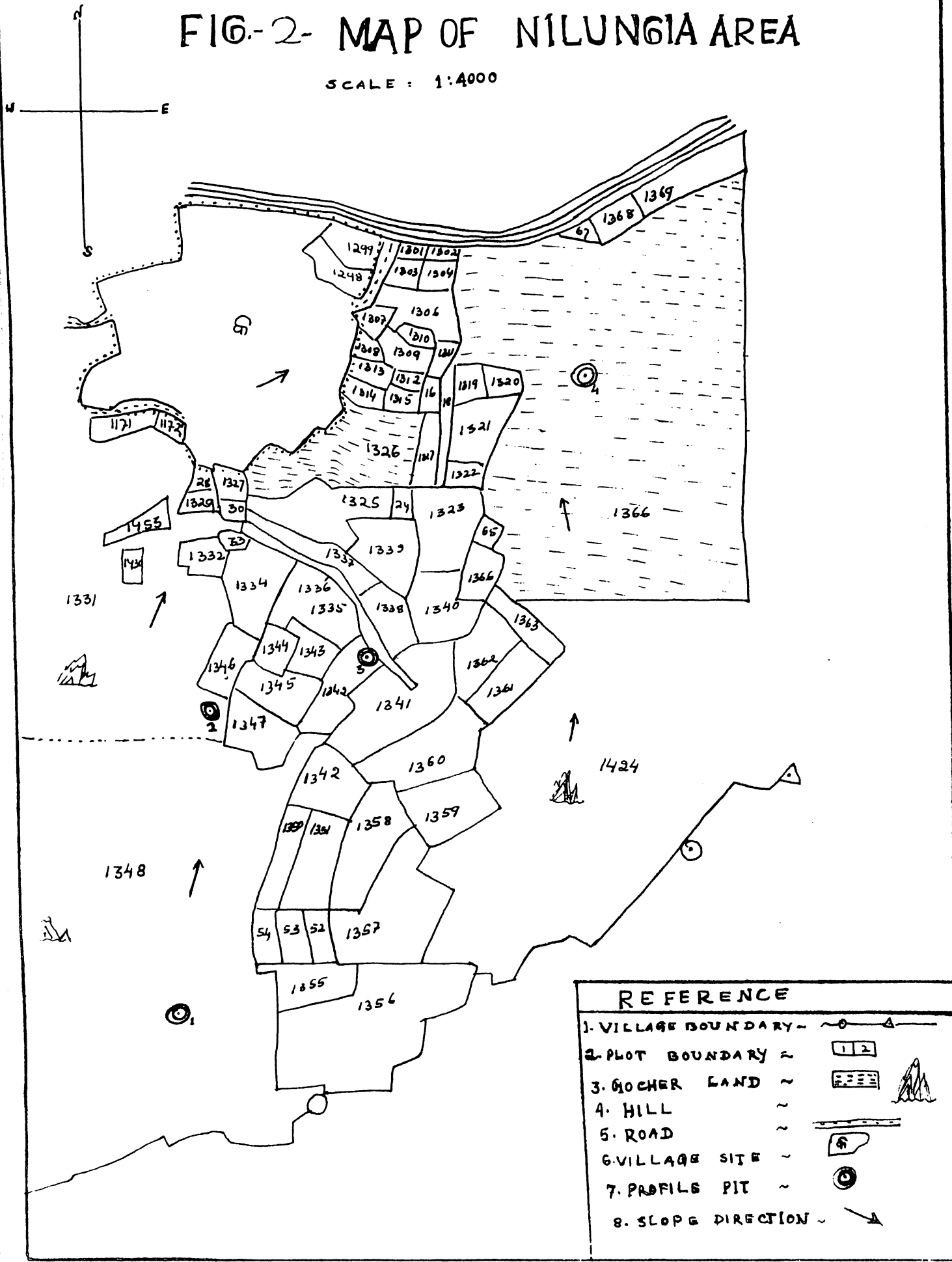


REFERENCE

- WATERSHED BOUNDARY
- SUB-WATERSHED
- RIVER & KALA
- ROADS
- WATER BODIES
- INTERWATERSHED BOUNDARY
- PILOT PROJECT AREA
- ORM-3-16-7-2
- ORM-3-16-7-3

FIG.-2- MAP OF NILUNGIA AREA

SCALE : 1:4000



REFERENCE	
1. VILLAGE BOUNDARY ~	
2. PLOT BOUNDARY ~	
3. GOPHER LAND ~	
4. HILL ~	
5. ROAD ~	
6. VILLAGE SITE ~	
7. PROFILE PIT ~	
8. SLOPE DIRECTION ~	

temperature is 37° C (May) and the mean minimum temperature is 10.4° C (December). The relative humidity ranges from 64-80%.

The different catchment characteristics of the mini watershed area ORM-3-16-7-3 are presented below (Anonymous, 1989).

1. Name of the watershed : DHOBAKIA NALA MINI WATERSHED (ORM-3-16-7-3)
2. Drainage area : 2237 hectares
3. Location : 20°1' to 20°6' N latitude
84°19' to 84°23' E longitude
4. Shape : Fan shape
(Just like bottle vine leaf shape)
5. Shape index : 2.41

(shape index = $\frac{\text{Largest length of watershed}}{\text{Largest width of watershed}}$)
6. Drainage frequency : 17.43 Nos./1000 ha
(Drainage frequency = How many times, drainage can be done from a particular area)
7. Drainage pattern : Dendritic
(Dendritic drainage pattern means the drainage pattern in which the streams branch irregularly in all directions and at almost any angle usually less than 90° resembling in plan, the branching habit of certain trees such as oaks and apples).
8. Drainage density : 1.5422 km/km²
(Drainage density is the average length of streams per unit area within a basin)
9. Silt production rate : 3.4636 km/100² km/year
(It is the total distance travelled by the silt particle per unit area per unit time)
10. Stream grade : 3%
(Average slope of the stream)
11. Topo reference : 73 D/3

12. Time of concentration : 312 minutes

$$\text{(Time of conc. = } \frac{\text{Travelling distance (L)}}{\text{Velocity of flow (V)}} \text{)}$$

Travelling distance is the distance from starting point of the watershed to the end point of the watershed)

13. Orientation : North and South

METHODS OF ANALYSIS

Preparation of soil samples

Collection of representative soil samples from individual horizons of the profiles and also some surface samples were made. The samples were air dried, ground with a porcelain mortar and pestle and passed through a 2 mm sieve. The samples so obtained were preserved in stoppered bottles, labelled and stored in a dry place for further study. The materials remaining on the sieve were recorded as coarse fragments.

A. PHYSICAL METHODS

i) Soil colour

The colour of the air dried and moist soil samples were determined by matching the colour with Munsell's soil colour chart and was designated by the given notation i.e., hue, value and chroma.

ii) Mechanical analysis

Bouyoucos hydrometer method of particle size analysis was employed as described by Piper (1950) after removal

of soluble salts and dispersing with 15 Ml of 5 per cent sodium hexametaphosphate solution. Textural classes were determined using international textural triangular diagram.

iii) Bulk density, particle density and pore space

Bulk density, particle density and total pore space were determined by adopting the procedures outlined by Lal Singh (1988). In this method 30 gm of air dried soil was taken in a 100 Ml measuring cylinder and the volume was noted to find out the bulk density. Then to the same cylinder, water was added in 5 Ml lots at a time from a burette and stirred by a glass rod until complete saturation. From the data, volume of water added and the volume of soil water mixed, the particle density and total pore space of soil was calculated.

iv) Water holding capacity

It was determined by adopting the procedure outlined by Chopra and Kanwar (1976).

B. CHEMICAL METHODS

i) Soil pH

The pH of the soil samples were determined in 1:2 soil:water suspension after equilibrating for half an hour with intermittent stirring by the systronics digital pH meter No. 335.

ii) Electrical conductivity

The electrical conductivity of soil samples were determined in 1:2.5 soil water suspension after equilibrating for half an hour by using ELICO conductivity bridge type CM 82 T.

iii) Organic carbon

The organic carbon content of the soil samples were determined by Walkley and Black's wet digestion method as described by Jackson (1973).

iv) Cation exchange capacity (CEC)

The CEC of soil samples were determined by the procedure of Chapman (1930). Ten grams of soil was shaken with 150 ml of neutral ^{normal} ammonium acetate solution and was kept overnight. After filtering and washing the contents with Ammonium chloride and then with ethyl alcohol until the soil was free of chloride, the adsorbed NH_4^+ was determined by distillation procedure and the CEC of soil was determined.

v) Exchangeable cations **Na^+ and K^+**

Standard curves were prepared and Na^+ , K^+ were determined from the 1N NH_4OAc (pH = 7.0) extract directly making dilutions wherever necessary. Digital flame photometer (ELICO) model Cl 22D was used for the determination.

Ca⁺⁺ and Mg⁺⁺

Ammonium acetate leachate obtained during CEC determination was evaporated to dryness on waterbath, treated with aquaregia (3:1 conc. HCl: conc. HNO₃) and again dried on sand bath. The residue was dissolved by adding 10 ml of 0.1 N HCl followed by slow digestion in a hot water bath and then diluted to 100 ml with distilled water. Any insoluble material present was filtered off. Calcium and magnesium in suitable aliquots were determined by versenate titration method of Chapman (1930).

vi) Available nitrogen

It was determined by alkaline permanganate method by distilling 20 g of soil with 100 ml of 0.32% potassium permanganate and 100 ml of 2.5% NaOH as described by Jackson (1973).

vii) Available phosphorus

Available phosphorus was determined by Olsen's method by taking 2 g of soil in 40 ml Olsen reagent (1N NaHCO₃). A filtrate of 19 ml was mixed with 20 ml chloromolybdic acid and 1 ml of SnCl₂ and the volume was made upto 50 ml and reading was taken colorimetrically (Jackson, 1973) using Bausch and Lomb (340) calorimeter.

viii) Available K₂O

It was determined by equilibrating 5 g of soil in 25 ml neutral normal ammonium acetate (Jackson, 1973) and

the reading of extract was taken in a Elico digital flame photometer model Cl 22 D.

ix) Exchange acidity

Exchange acidity was determined by leaching the soil with 1N KCl and titrating the leachate with standard NaOH as described by Coleman et al. (1958). Exchangeable Al^{+++} was determined by adding NaF and back titrating with standard HCl. Exchangeable H^+ was calculated from differences of total exchange acidity and exchangeable Al^{+++} .

x) Lime requirement

It was determined by Woodruff's buffer method as described by Mitra et al. (1980). In this method, the pHs of the soils were determined by using 1 M $CaCl_2$ solution. Following the measurement of pHs, ten cc of Woodruff's buffer solution was mixed thoroughly and the pH measurement were taken after half an hour. The lime requirement upto pH 6.0 was calculated from the difference between pHs and pH buffer.

CHAPTER IV

RESULTS AND DISCUSSION

CHAPTER-IV

RESULTS AND DISCUSSIONS

In this chapter, the results of this investigation together with appropriate discussion are presented in the following broad heads for convenience :

1. Morphological characteristics of the soil profiles.
 2. Physical characteristics including mechanical composition, densities and water holding capacities etc.
 3. Chemical characteristics with regard to pH, E.C., organic carbon, CEC and exchange compositions, exchange acidity etc.
 4. Available nutrient status of the soil
 5. Lime requirement of the soil
 6. Classification of soils as per soil taxonomy.
-
1. **Morphological characteristics of the soil profiles**

After traversing the Nilungia area of Dhobakia nala mini watershed, G.Udayagiri block of Phulbani district, four profiles were exposed one day before study. Morphological characteristics of the four profiles were made (Soil Survey Manual, 1970) on 25th June 1993 and have been presented below. Photographs of different profiles have been taken and are presented in appropriate pages.

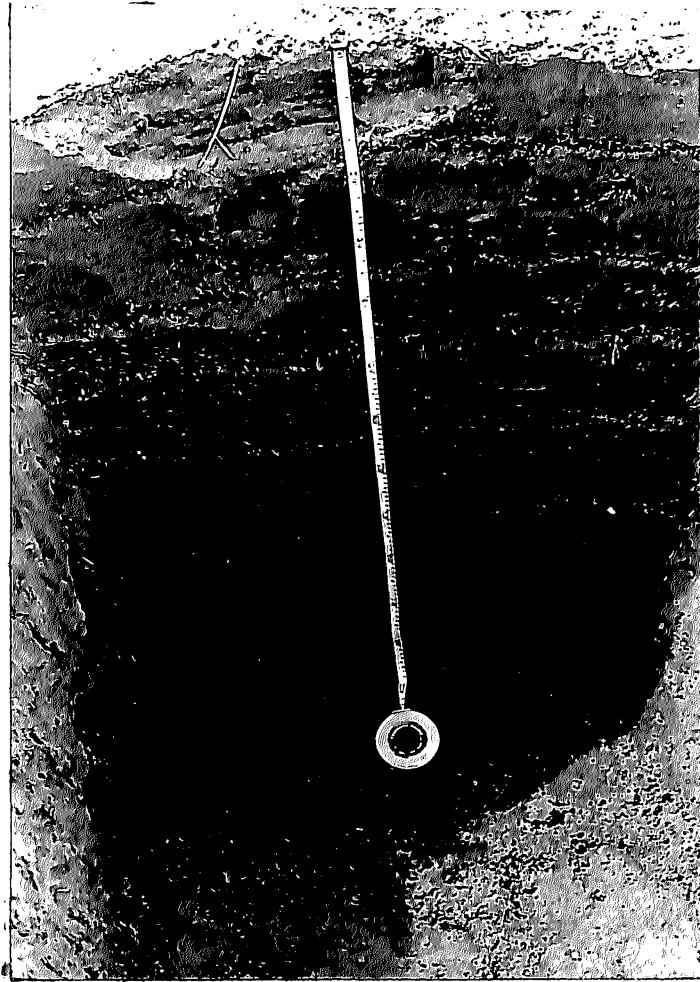


PHOTO PLATE - 1. Soils of upper pediment (P_1)

Genetic horizon	Depth (cm)	Description
B 21 t	24-56	Red (2.5 YR 5/6), red (10 R 4/6 m); sandy clay; moderate, fine, subangular blocky; slightly hard, firm, non-sticky; thin patchy clay cutans on ped faces; many fibrous very fine roots; moderate permeability; medium acid few, fine, spherical pores (imped); diffuse smooth boundry;
B 22 t	56-80	Red (2.5 YR 5/8); red (10R 4/6 m); sandy clay; weak, fine, subangular blocky; soft, friable, slightly sticky, thin patchy clay cutans on ped faces; very few; very fine roots; moderate permeability; medium acid; few, fine, irregular pores (imped); diffuse smooth boundry;
C	80-130	Red (2.5 YR 5/8), red (10 R 4/8 m); sandy clay loam; moderate, fine, subangular blocky; soft, firm, slightly sticky; very few, very fine roots; slow permeability; medium acidic; common, medium irregular pores; broken stones of 15 to 30 cm size and higher.

* m denotes moist condition

Profile-II

Setting - Vill. Nilungia, Tahasil-G.Udayagiri, Dist. Phulbani.

Site characteristics (Photo plate-2)

Location - About 200 m right of G.Udayagiri - Nilungia road

Land form - Slopy, slope - 3-5% (W-E)

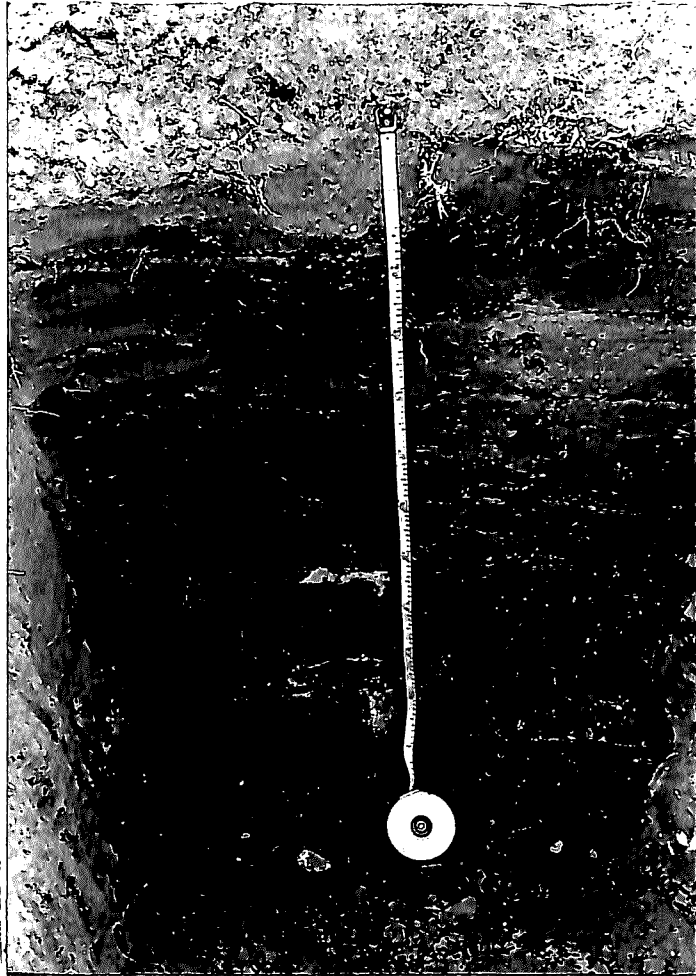


PHOTO PLATE-2. Soils of ridge slope (P_2)

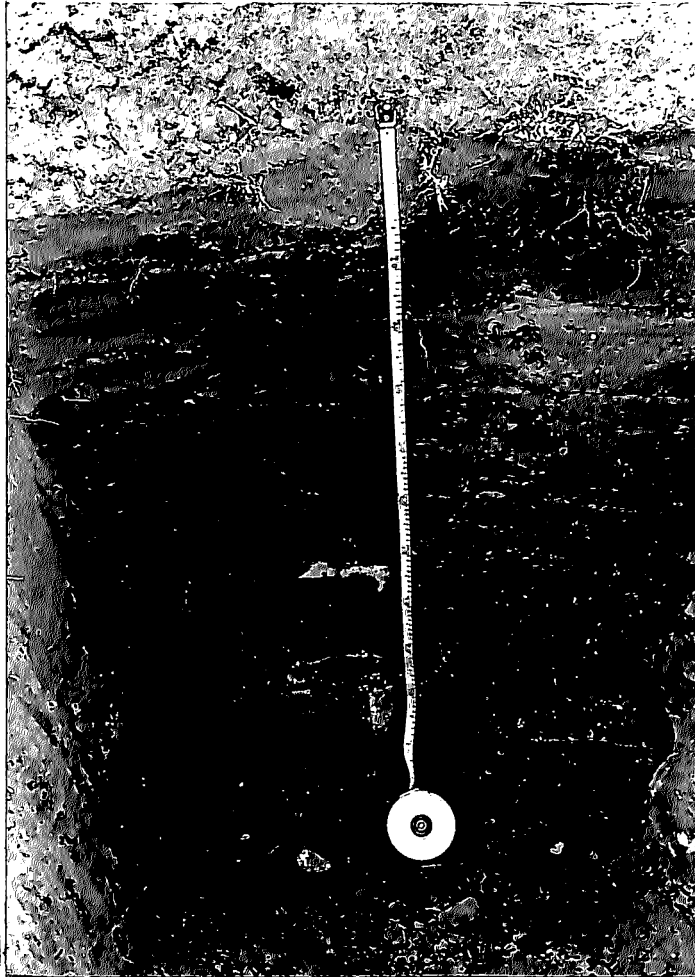


PHOTO PLATE-2. Soils of ridge slope (P_2)

Surface condition - Barren

Parent material - Laterite

Ground water table - Nil

Natural; vegetation - Forest trees like Shorea robusta, Mangifera indica, Madhuca latifolia, Tamarindus indica etc.

Erosion - e₂

Surface drainage - Well drained

Land use - Fallow

Genetic horizon	Depth (cm)	Description
A11	0-14	Yellowish red (5 YR 5/6), red (10 R 4/6 m); sandy clay loam; moderate, fine, subangular blocky; slightly hard, friable, slightly sticky; common, very fine roots, rapid permeability medium acid; many, medium, vesicular pores; diffuse smooth boundary;
A12	14-42	Reddish brown (5 YR 5/4), weak red (10 R 4/4 m); sandy clay loam; weak, fine, subangular blocky; slightly hard, friable, slightly sticky; common, very fine roots; rapid permeability; medium acid; common, fine, vesicular pores; clear wavy boundary;
B21t	42-76	Yellowish red (5 YR 5/6), red (10 R 5/6 m); clay loam; moderate, fine, subangular blocky; hard, firm, sticky; few, very fine roots; moderate permeability; medium acid; many fine irregular pores; thin, patchy, clay cutans; diffuse smooth boundary.
B22t	76-153	Yellowish red (5 YR 4/8), red (10 R 4/6 m); sandy clay; strong, fine, subangular blocky; hard, very firm, sticky; plenty

clay cutans; inceptient manganese concretions; few, very fine roots; moderate permeability; medium acid; many, very fine, irregular pores.

Profile-III

Setting - Vill. Nilungia, Tahasil-G.Udayagiri, Dist. Phulbani

Site characteristics (PHoto plate-3)

Location - About 150 m right of G.Udayagiri - Nilungia road

Land form - Slopy, slope - 3-5% (W-E)

Surface condition - Barren

Parent material - Laterite

Ground water table - Nil

Natural vegetation - Forest trees like *Shorea robusta*, *Mangifera indica*, *Madhuca latifolia*, *Tamarindus indica* etc.

Erosion - θ_2

Surface drainage - Well drained

Land use - Fallow

Genetic horizon	Depth (cm)	Description
A11	0-9	Reddish yellow (7.5 YR 6/6), weak red (10 R 5/3 m); sandy loam; weak, fine, granular, hard, very friable, slightly sticky; many fibrous fine roots; rapid permeability; medium acid; many, fine, vesicular pores; cracks in summer; clear smooth boundary;
A12	9-38	Light reddish brown (5 YR 6/4), red (10 R 4/6 m); clay; moderate, fine, subangular

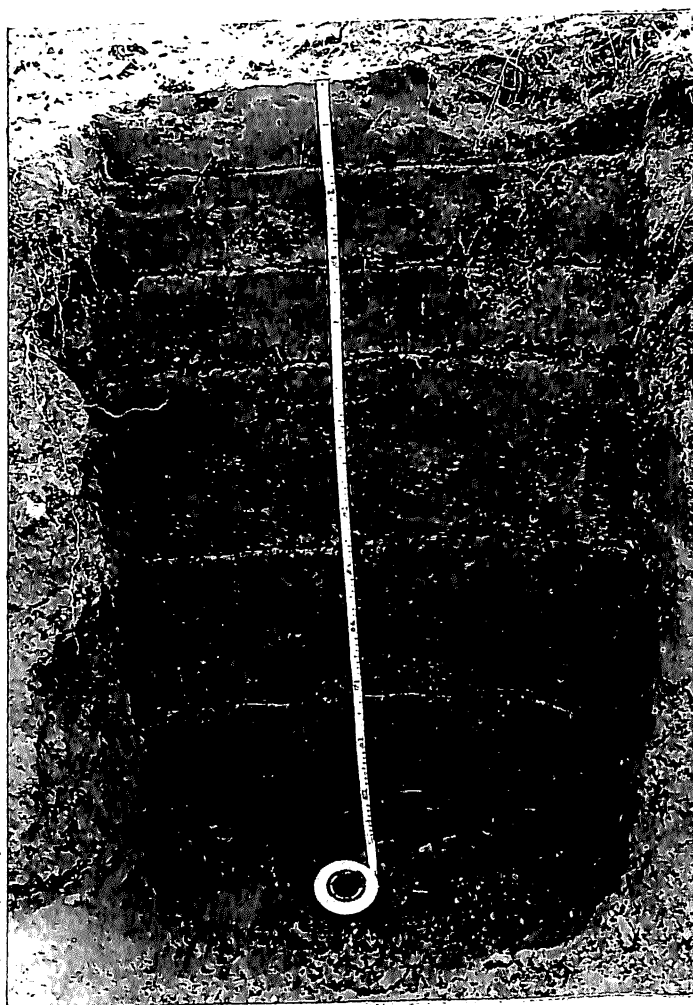


PHOTO PLATE-3 Soils of valley top (P_3)

		blocky; hard, firm, sticky; many fibrous fine roots; rapid permeability; medium acid; many, fine, vesicular pores; gradual wavy boundary;
B21t	38-100	Yellowish red (5 YR 5/6), light red (10 R 6/6 m); clay; moderate, fine, subangular blocky; hard, firm, sticky; few very fine roots; thin patchy clay cutans; plenty, semi rounded concretions (20%); few fine vesicular pores; rapid permeability; medium acid; gradual wavy boundary;
B22t	100-139	Reddish yellow (5 YR 6/6), red (10 R 4/6 m); clay; moderate, fine, subangular blocky; hard, firm, sticky; few very fine roots; thin patchy clay cutans; plenty, semi rounded concretions (10%); few, very fine irregular pores; rapid permeability; slightly acid; gradual broken boundary;
B23	139-150	Yellowish red (5 YR 5/6), weak red (10 R 5/4 m); clay; moderate, fine, subangular blocky; hard, firm, sticky; few very fine roots; inceptient concretions; few very fine irregular pores; rapid permeability; medium acid.

Profile-IV

Setting - Vill. Nilungia, Tahasil-G.Udayagiri, Dist. Phulbani

Site characteristics (Photo plate-4)

Location - About 50 m right of G.Udayagiri-Nilungia road

Land form - slightly slopy, slope 1-3% (NE-SW)

Surface condition - Barren

Parent material - Laterite

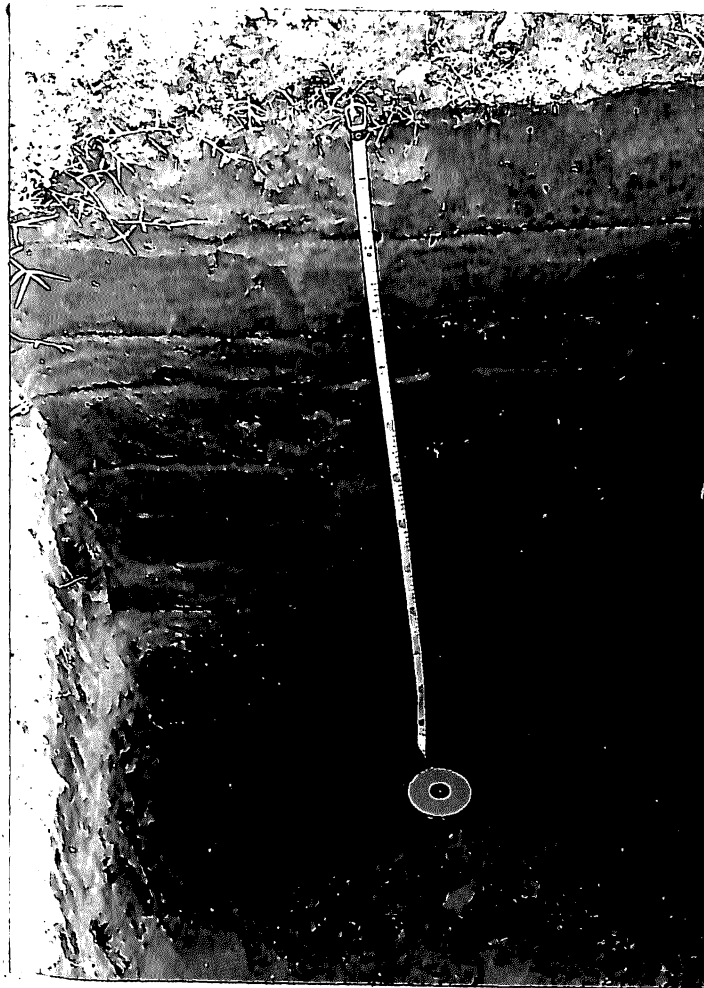


PHOTO PLATE-4. Soils of valley slope (P_4)

Ground water table - Nil

Natural vegetation - Forest trees like Shorea robusta, Mangifera indica, Madhuca latifolia, Tamarindus indica etc.

Erosion - e_2

Surface drainage - Well drained

Land use - Fallow

Genetic horizon	Depth (cm)	Description
A11	0-16	Light reddish brown (5 YR 6/4), weak red (10 R 5/4 m); sandy loam; weak, coarse, subangular blocky; soft, friable, slightly sticky; many fibrous fine roots; rapid permeability; medium acid; many fine vesicular pores; gradual wavy boundary;
A12	16-50	Reddish yellow (5 YR 6/6), red (10 R 4/6 m); loamy sand; structureless, fine, single grain; slightly hard, loose, slightly sticky; few fine roots; rapid permeability; slightly acid; many fine vesicular pores; gradual wavy boundary;
A13	50-70	Light reddish brown (5 YR 6/4), weak red (10 R 5/4 m); sandy clay loam; weak, coarse subangular blocky; soft, friable, slightly sticky; few very fine roots; moderate permeability; medium acid; many fine vesicular pores; gradual wavy boundary;
AC	70-78	Reddish brown (5 YR 5/4), weak red (10R 4/4 m); sandy clayloam; structureless, fine, single grain; hard, loose, slightly sticky; moderate permeability; medium acid; common very fine vesicular pores; gradual wavy boundary;

C	78-150	Reddish yellow (5 YR 6/6), pale red (10 R 6/4 m); clay; strong, medium angular blocky; hard, extremely firm, sticky; very slow permeability; medium acid; few very fine vesicular pores.
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General morphological features

Village Nilungia under the Dhobakia mini-watershed is a sloping terrain with 5-8% slope with moderate soil erosion. There is good surface drainage and the land is fallow. The soil colour varies from red through reddish yellow to yellowish red throughout the profile in different altitudes. Coarse fragments ranging from 6-15% are observed in different horizons of the profiles. Light textured soils are observed in the surface in different altitudes with gradual changes to heavy textured down the profiles. Soil structure on the surface is weak, fine, granular which gradually changes to moderate, coarse, subangular blocky structure (Sinha *et al.*, 1962). Consistency is soft to hard, friable to firm, non-sticky to sticky. Boulders of 15-30 cm or more size are observed in the last two horizons of profile-I (upland). Thin patchy clay cutans are observed in the subsurface horizons of profile I, II and III. The soils are almost acidic and slight variation could be observed in different horizons of the profiles.

2. Physical characteristics

Data on mechanical composition and other physical properties of the different horizons of the profiles are presented

C	78-150	Reddish yellow (5 YR 6/6), pale red (10 R 6/4 m); clay; strong, medium angular blocky; hard, extremely firm, sticky; very slow permeability; medium acid; few very fine vesicular pores.
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General morphological features

Village Nilungia under the Dhobakia mini-watershed is a sloping terrain with 5-8% slope with moderate soil erosion. There is good surface drainage and the land is fallow. The soil colour varies from red through reddish yellow to yellowish red throughout the profile in different altitudes. Coarse fragments ranging from 6-15% are observed in different horizons of the profiles. Light textured soils are observed in the surface in different altitudes with gradual changes to heavy textured down the profiles. Soil structure on the surface is weak, fine, granular which gradually changes to moderate, coarse, subangular blocky structure (Sinha et al., 1962). Consistency is soft to hard, friable to firm, non-sticky to sticky. Boulders of 15-30 cm or more size are observed in the last two horizons of profile-I (upland). Thin patchy clay cutans are observed in the subsurface horizons of profile I, II and III. The soils are almost acidic and slight variation could be observed in different horizons of the profiles.

2. Physical characteristics

Data on mechanical composition and other physical properties of the different horizons of the profiles are presented

in table 1. In P_1 , the clay content is 16% on the surface which gradually increases down the profile, with a maximum value of 38% (Fig. 3). Concurrently the content of sand decreases from 74% to 48% and the silt content varies from 10-14%. The increase in clay from surface downwards could be attributed to translocation of clay from the surface due to heavy rainfall (Zouzou and Furley, 1975).

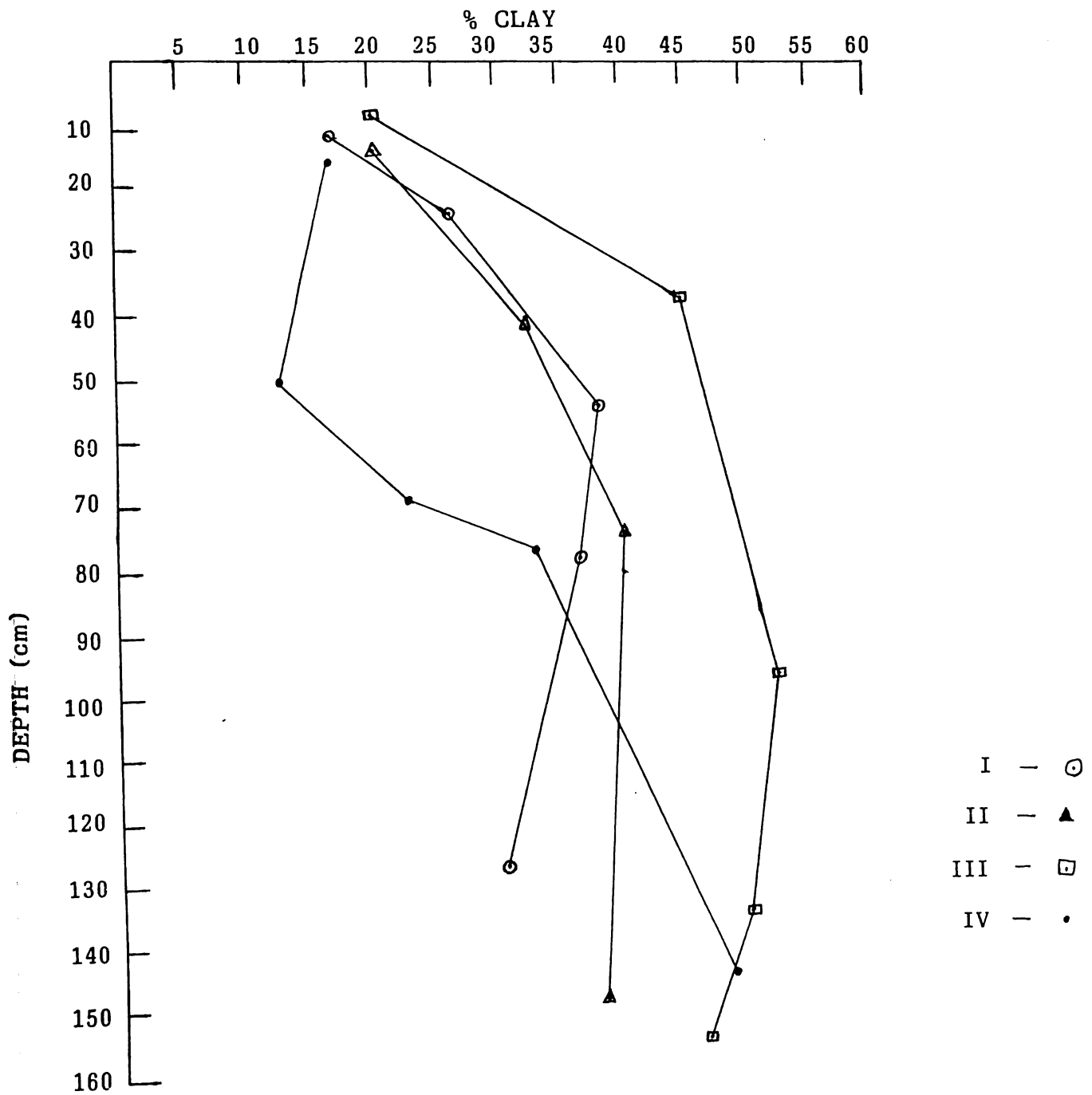
In profile -II, the clay content varies from 20-40% and it increases from the surface downwards. The opposite trend is observed with regard to sand content in different horizons of the same profile. Clay content upto 53% in the B2t horizon of profile-III could be observed although the surface soil contains only 20% clay. This is attributed to translocation and deposition of the finer particles in the lower pediment situations.

No distinct horizons could be observed in profile-IV which is also reflected in the mechanical composition of the soil separates. No trend could be observed in sand or clay content from the surface downwards in this profile although higher clay content and lower sand content could be observed in the lowest layers of the profile. The textural class in all the profiles are almost sandyloam on the surface which gradually changed to sandy clay and clay down below. Taking the altitude into consideration, it may be seen that higher clay content is therein lower pediment profile than the upper pediment profile (Datta et al., 1990). The bulk

Table 1. Physical properties and mechanical composition of the profile soil samples

Pedon	Depth (cm)	Mechanical composition			Textural class	Bulk density Mg m ⁻³	Particle density Mg m ⁻³	Water holding capacity (%)	Coarse fragments (%)
		Sand %	Silt %	Clay %					
P ₁	0-11	74	10	16	Sandy loam	1.27	2.40	35.38	10
	11-24	60	14	26	Sandy clay loam	1.32	2.27	44.50	8
	24-56	48	14	38	Sandy clay	1.32	2.31	44.63	6
	56-80	54	10	36	Sandy clay	1.31	2.31	43.37	25
	80-130	64	6	30	Sandy clay loam	1.33	2.30	43.18	30
P ₂	0-14	66	14	20	Sandy clay loam	1.26	2.45	39.97	8
	14-42	50	18	32	Sandy clay loam	1.33	2.25	44.66	7
	42-76	40	20	40	Clay loam	1.34	2.30	45.16	8
	76-153	56	6	38	Sandy clay	1.35	2.27	50.00	15
P ₃	0-9	54	26	20	Sandy loam	1.34	2.39	38.81	7
	9-38	33	22	45	Clay	1.33	2.22	43.42	10
	38-100	27	20	53	Clay	1.33	2.22	43.70	14
	100-139	31	18	51	Clay	1.36	2.22	40.69	7
	139-150	35	18	47	Clay	1.33	2.40	41.30	7
P ₄	0-16	73	10	17	Sandy loam	1.30	2.50	31.34	11
	16-50	83	4	13	Loamy sand	1.30	2.40	39.44	8
	50-70	61	16	23	Sandy clay loam	1.33	2.40	38.00	6
	70-78	51	16	33	Sandy clay loam	1.30	2.40	38.43	25
	78-150	35	16	49	Clay	1.33	2.50	46.37	22

Fig. 3. % clay vs depth of the profile



density values in general lower on the surface ranging from 1.26 to 1.34 Mg m^{-3} . Higher bulk density values are observed in the subsurface horizons. This may be attributed to higher content of organic matter on the surface. The value of particle density varies from 2.22 to 2.50 Mg m^{-3} and the water holding capacity varies from 31.34 to 50.00%.

Physical properties and mechanical composition of surface soil samples presented in table 2 indicated the soils to be sandy loam through loam to sandy clay loam in texture; clay content varies from 5.7 to 21.7 per cent, silt from 2.0 to 14.0 per cent and sand from 62.3 to 84.3 per cent. Bulk density values vary from 1.38 to 1.56 Mg m^{-3} , particle density from 2.40 to 2.52 Mg m^{-3} and water holding capacity from 32.84 to 40.22 per cent. Invariably in all the surface samples, there is presence of coarse fragments ranging from 7.0-14.0 per cent.

3. Chemical characteristics

The chemical properties of the profile soil samples are presented in table 3. Soil reaction is almost medium acidic, in different horizons of all the profiles (Fig. 4). As the soils are highly weathered and leached and devoid of basic cations, the trend in pH down the profile does not occur and the pH in different horizons are almost similar varying from 5.41 to 6.11 (Hakimian, 1978). The electrical conductivity values are very low ranging from 0.03 to 0.13 dsm^{-1} indicating the soils to be devoid of soluble salts.

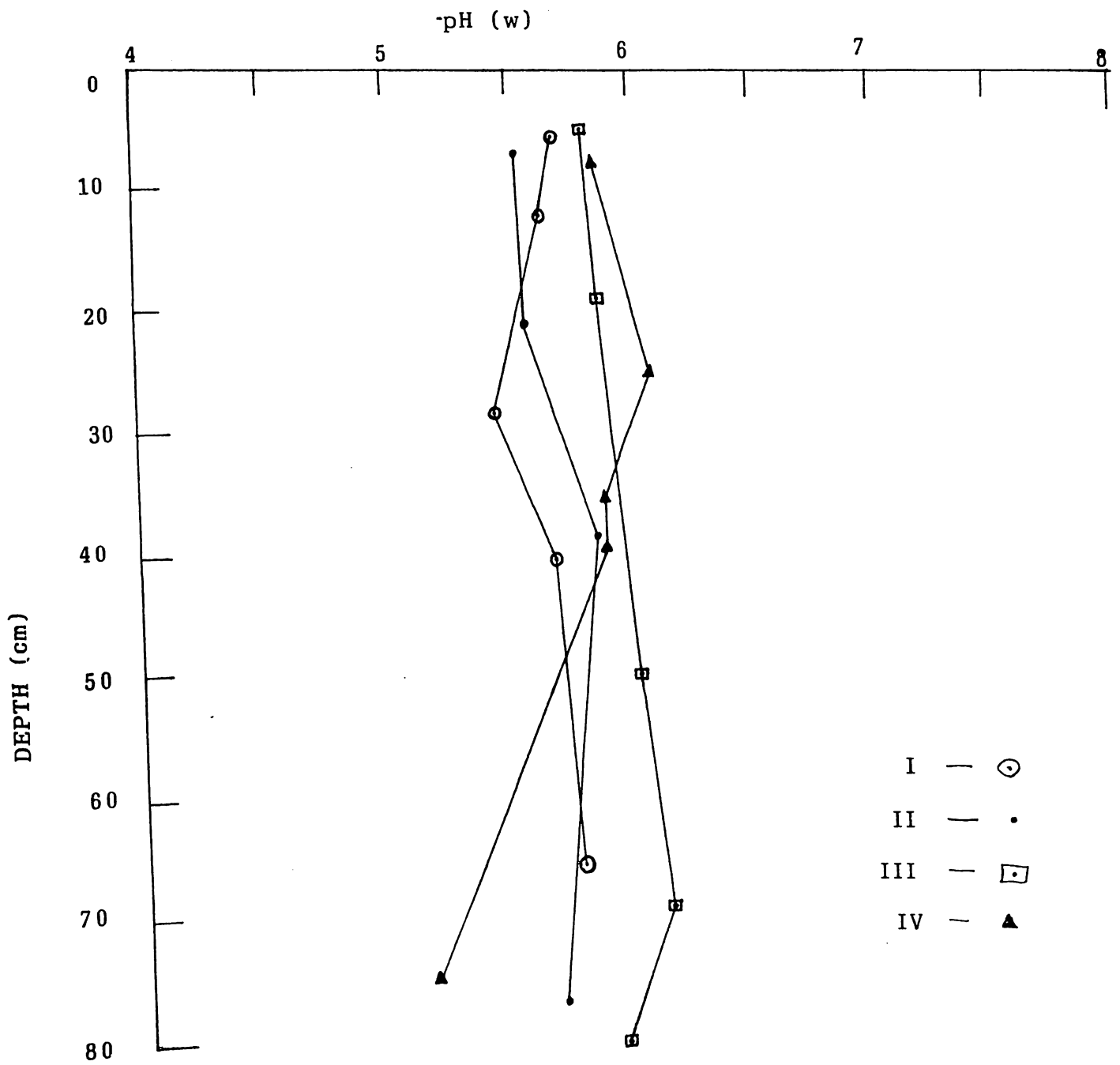
Table 2. Physical properties and mechanical composition of the surface soil samples

Sl. No.	Depth (cm)	Mechanical composition			Textural class	Bulk density MG m ⁻³	Particle density MG m ⁻³	Water holding capacity (%)	Coarse fragments (%)
		Sand %	Silt %	Clay %					
1.	0-15	70.8	14.0	15.2	Loam	1.44	2.40	36.48	8
2.	0-15	76.3	4.0	19.7	Sandy loam	1.48	2.48	34.82	10
3.	0-15	62.3	18.0	19.7	Loam	1.54	2.52	40.22	11
4.	0-15	70.8	8.0	21.2	Sandy clay loam	1.42	2.42	32.84	12
5.	0-15	74.0	6.0	20.0	Sandy clay loam	1.56	2.45	38.22	8
6.	0-15	80.8	11.0	8.2	Loamy sand	1.47	2.48	39.44	10
7.	0-15	65.8	14.0	20.2	Sandy clay loam	1.42	2.52	37.84	7
8.	0-15	81.8	5.0	13.2	Sandy loam	1.38	2.40	34.62	11
9.	0-15	76.3	2.0	21.7	Sandy clay loam	1.52	2.46	39.24	9
10.	0-15	81.3	3.0	15.7	Sandy loam	1.54	2.42	36.74	11
11.	0-15	68.8	8.0	23.2	Sandy clay loam	1.47	2.50	35.62	12
12.	0-15	74.8	10.0	15.2	Sandy loam	1.47	2.48	34.78	14
13.	0-15	72.8	10.0	17.2	Sandy loam	1.51	2.46	38.24	12
14.	0-15	78.8	8.0	13.2	Sandy loam	1.53	2.42	37.52	12
15.	0-15	80.8	6.0	13.2	Sandy loam	1.48	2.48	36.76	14
16.	0-15	84.3	10.0	5.7	Loamy sand	1.47	2.50	38.36	13

Table 3. Chemical properties of the profile soil samples

Pedon	Depth (cm)	pH(w)(1:2)	Electrical conductivity (d sm^{-1})	Organic carbon (%)	KCl acidity ($\text{cmol(p}^+)\text{kg}^{-1}$)	Exch. Al^{3+} ($\text{cmol(p}^+)\text{kg}^{-1}$)	Exch. H^+ ($\text{cmol(p}^+)\text{kg}^{-1}$)
P ₁	0-11	5.71	0.12	0.63	0.43	0.22	0.21
	11-24	5.63	0.07	0.43	0.43	0.22	0.21
	24-86	5.41	0.08	0.48	0.33	0.22	0.11
	56-80	5.65	0.06	0.36	0.33	0.11	0.21
	80-130	5.73	0.06	0.19	0.21	0.11	0.11
P ₂	0-14	5.52	0.09	0.44	0.43	0.22	0.21
	14-42	5.55	0.10	0.38	0.43	0.22	0.21
	42-76	5.83	0.03	0.19	0.33	0.22	0.11
	76-153	5.65	0.03	0.18	0.21	0.11	0.11
P ₃	0-9	5.79	0.13	0.74	0.43	0.22	0.21
	9-38	5.84	0.08	0.31	0.43	0.22	0.21
	38-100	6.00	0.08	0.22	0.43	0.22	0.21
	100-139	6.11	0.09	0.20	0.33	0.11	0.22
	139-150	5.91	0.09	0.21	0.33	0.11	0.22
P ₄	0-16	5.82	0.11	0.41	0.43	0.22	0.21
	16-50	6.05	0.12	0.17	0.33	0.22	0.11
	50-70	5.87	0.09	0.36	0.43	0.22	0.21
	70-78	5.85	0.10	0.19	0.33	0.11	0.22
	78-150	5.14	0.08	0.20	0.33	0.11	0.22

Fig. 4. pH(w) vs. Depth of the profile



There is a definite organic carbon profile in all the pedons except P_4 in which the value is more on the surface and decreases gradually downwards (Fig.5), (Nair and Chamuah, 1988). The organic carbon content is low to medium on the surface soils in P_1 , P_2 and P_3 , the value varying from 0.44 to 0.74 per cent. No definite trend is observed in case of P_4 and there is fluctuation of organic carbon content in different horizons of the profile indicating fluvial depositions in the profile. The total acidity in different horizons of the profiles varies from 0.43 to 0.28, the value almost decreasing gradually from the surface downwards. The value of exchangeable Al^{+++} and exchangeable H^+ are almost similar; the value varying from 0.22 to 0.11 c mol (P^+) kg^{-1} .

Chemical properties of the surface soil samples have been presented in table 4. In majority of the samples, the soil reaction is medium acidic. The pH value ranging from 5.35 to 6.59. Electrical conductivity values are low. Out of sixteen surface samples studied, the organic carbon content is low in ten samples and the rest are almost high. Total acidity varies from 0.33 to 0.65 c mol (p^+) kg^{-1} .

Cation exchange capacity and composition of the exchange complex in different horizons of the profiles are presented in table 5. The CEC values vary from 1.8 to 9.84 c mol (p^+) kg^{-1} . The values are comparatively less on the surface and it increases gradually with depth (Fig. 6). In general, the CEC values increase from the surface downwards and

Fig. 5. Organic carbon vs Depth of the profile

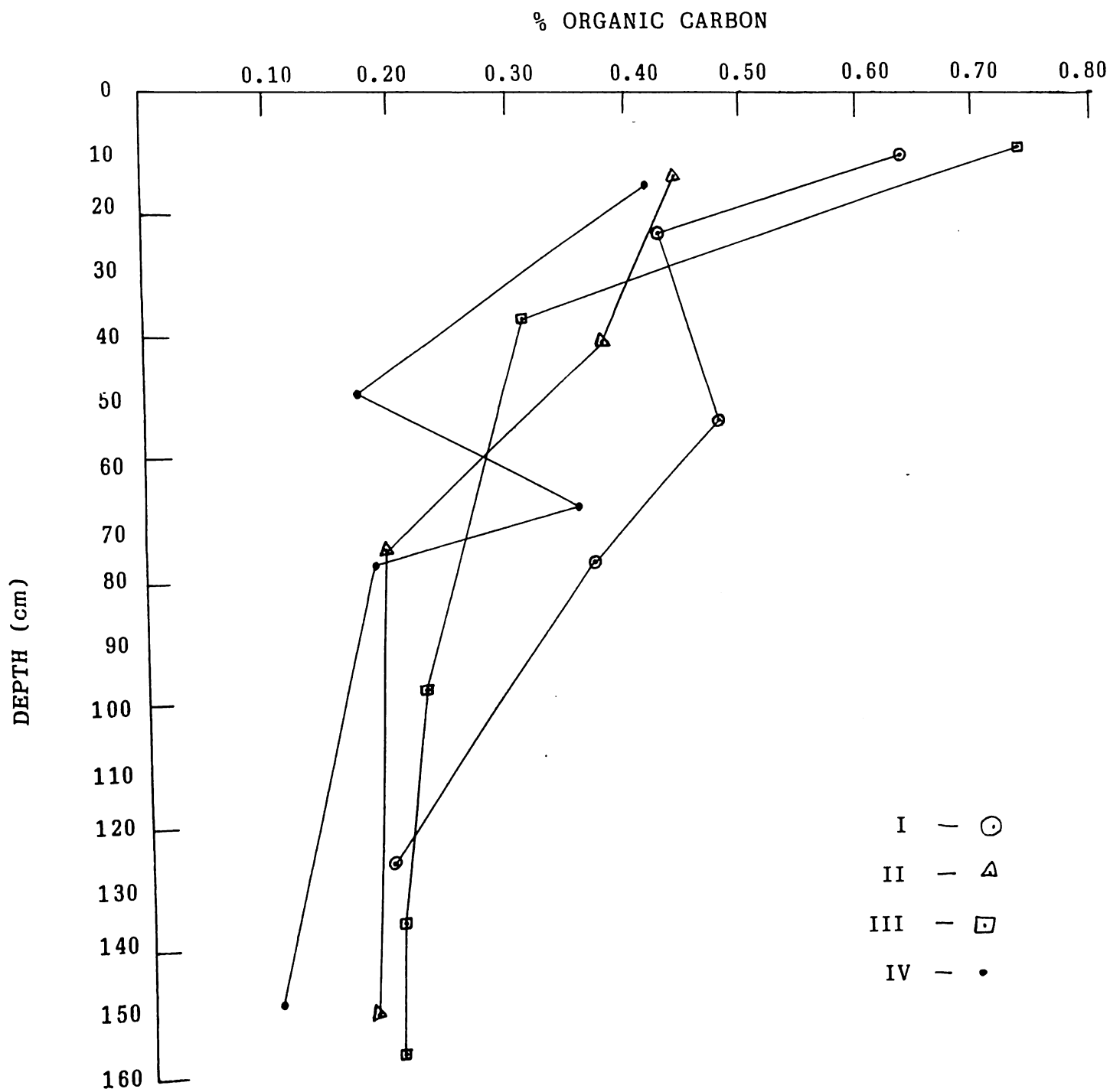


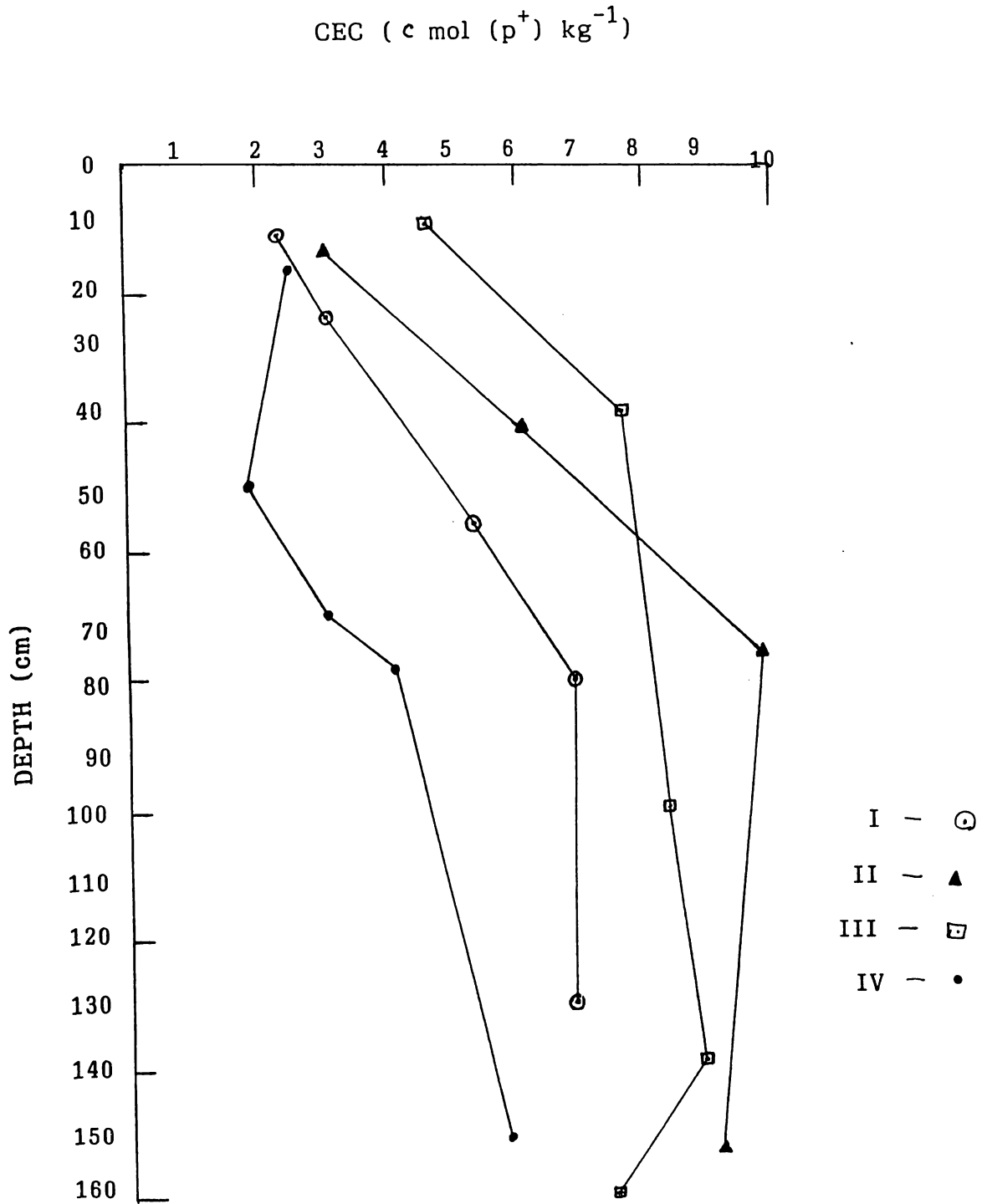
Table 4. Chemical properties of the surface soil samples

Sl. No.	Depth (cm)	pH(w)(1:2)	Electrical conductivity (d sm ⁻¹)	Organic carbon (%)	KCl acidity c mol (P ⁺) kg ⁻¹	Exch. Al c mol (P ⁺)kg ⁻¹	Exch. H c mol (P ⁺) kg ⁻¹
1.	0-15	5.5	0.11	0.84	0.43	0.22	0.21
2.	0-15	6.15	0.06	0.50	0.43	0.22	0.21
3.	0-15	6.20	0.12	1.03	0.43	0.22	0.21
4.	0-15	5.91	0.05	0.18	0.33	0.11	0.21
5.	0-15	5.82	0.11	0.51	0.33	0.22	0.11
6.	0-15	6.33	0.22	0.92	0.43	0.22	0.21
7.	0-15	5.98	0.04	0.40	0.33	0.11	0.22
8.	0-15	5.80	0.07	0.37	0.54	0.33	0.21
9.	0-15	6.59	0.22	0.68	0.65	0.33	0.32
10.	0-15	5.81	0.07	0.89	0.43	0.22	0.21
11.	0-15	6.44	0.07	0.33	0.54	0.33	0.21
12.	0-15	5.35	0.09	0.43	0.54	0.33	0.21
13.	0-15	6.06	0.07	0.49	0.65	0.33	0.32
14.	0-15	6.55	0.08	0.45	0.43	0.22	0.21
15.	0-15	5.80	0.06	0.26	0.33	0.22	0.11
16.	0-15	5.83	0.09	0.48	0.43	0.22	0.21

Table 5. Cation exchange capacity and composition of the exchange complex of the profile soil samples

Pedon	Depth (cm)	CEC c mol(p ⁺)kg ⁻¹	Exch. cations C mol(p ⁺)kg ⁻¹				Total basic cations c mol(p ⁺)kg ⁻¹	Base saturation (%)	CEC Clay (%)
			Ca ⁺⁺	Mg ⁺⁺	Na ⁺	K ⁺			
P ₁	0-11	2.28	0.64	0.21	0.15	0.23	1.23	53.9	14.2
	11-24	3.04	1.03	0.39	0.75	0.24	2.41	79.3	11.7
	24-56	5.32	1.37	0.96	0.20	0.24	2.77	52.1	14.0
	56-80	6.89	2.55	0.98	0.02	0.05	3.60	52.3	19.1
	80-130	6.84	2.89	0.61	0.03	0.07	3.60	52.6	22.8
P ₂	0-14	3.04	0.93	0.58	0.05	0.12	1.68	55.3	15.2
	14-42	6.12	2.23	1.12	0.02	0.08	3.45	56.3	19.1
	42-76	9.84	2.42	2.37	0.14	0.25	5.18	53.1	24.6
	76-13	9.12	3.25	2.17	0.23	0.33	5.98	65.6	24.0
P ₃	0-9	4.56	1.11	0.70	0.14	0.56	2.51	55.0	22.8
	9-38	7.6	2.57	1.19	0.06	0.09	3.91	51.4	17.0
	38-100	8.36	2.70	1.38	0.27	0.35	4.70	56.2	15.9
	100-139	9.08	2.90	1.08	0.27	0.38	4.63	51.0	17.8
	139-150	7.6	2.56	1.22	0.37	0.40	4.55	59.9	16.3
P ₄	0-16	2.52	0.92	0.31	0.16	0.19	1.58	62.6	14.8
	16-50	1.82	0.55	0.33	0.28	0.15	1.31	71.8	14.0
	50-70	3.04	1.09	0.42	0.38	0.26	2.15	70.7	13.4
	70-78	4.04	1.69	0.63	0.15	0.27	2.74	67.8	12.2
	78-150	5.8	2.38	0.65	0.19	0.43	3.65	63.0	11.8

Fig. 6. CEC vs Depth of the profile



have a linear correlation with the clay content ($y = -0.0095 + 0.171 x$, $r = 0.837$ Fig. 7). As the organic carbon content is not appreciable in these soils, the CEC values could be attributed to the nature and the quantity of clay minerals. The CEC/clay % values in different profiles vary from 11.7 to 24.6 indicating the nature of clay minerals to be a mixture of kaolinite and illite. The percentage base saturation values in general, increases from the surface downwards the value ranging from 51.0 to 79.3. The correlation between pH and base saturation percentage is nonsignificant (Fig. 8). Ca^{++} dominates the exchange complex followed by Mg^{++} , K^+ and Na^+ . Ca^{++} along with Mg^{++} constitutes 90-95 per cent of the total basic cations (Singh and Chamuah, 1991).

The cation exchange capacities values and the composition of the exchange complex of the surface soil samples have been presented in table 6. The CEC values are very low ranging from 2.14 to 4.84 $\text{cmol (p}^+) \text{ kg}^{-1}$. As the organic carbon content is almost low, the lower value of CEC of soil indicated the clay minerals to be dominated by kaolinitic type of clay minerals.

Ca^{++} dominates the exchange complex followed by Mg^{++} , K^+ and Na^+ . Percentage base saturation values vary from 51.5 to 73.98.

Correlation among soil properties

From the analytical data of soil profiles taken together, two correlations among the soil properties have been statistically worked out and the results are discussed as follows:

Fig.7. RELATIONSHIP BETWEEN % OF CLAY AND CEC OF SOIL.

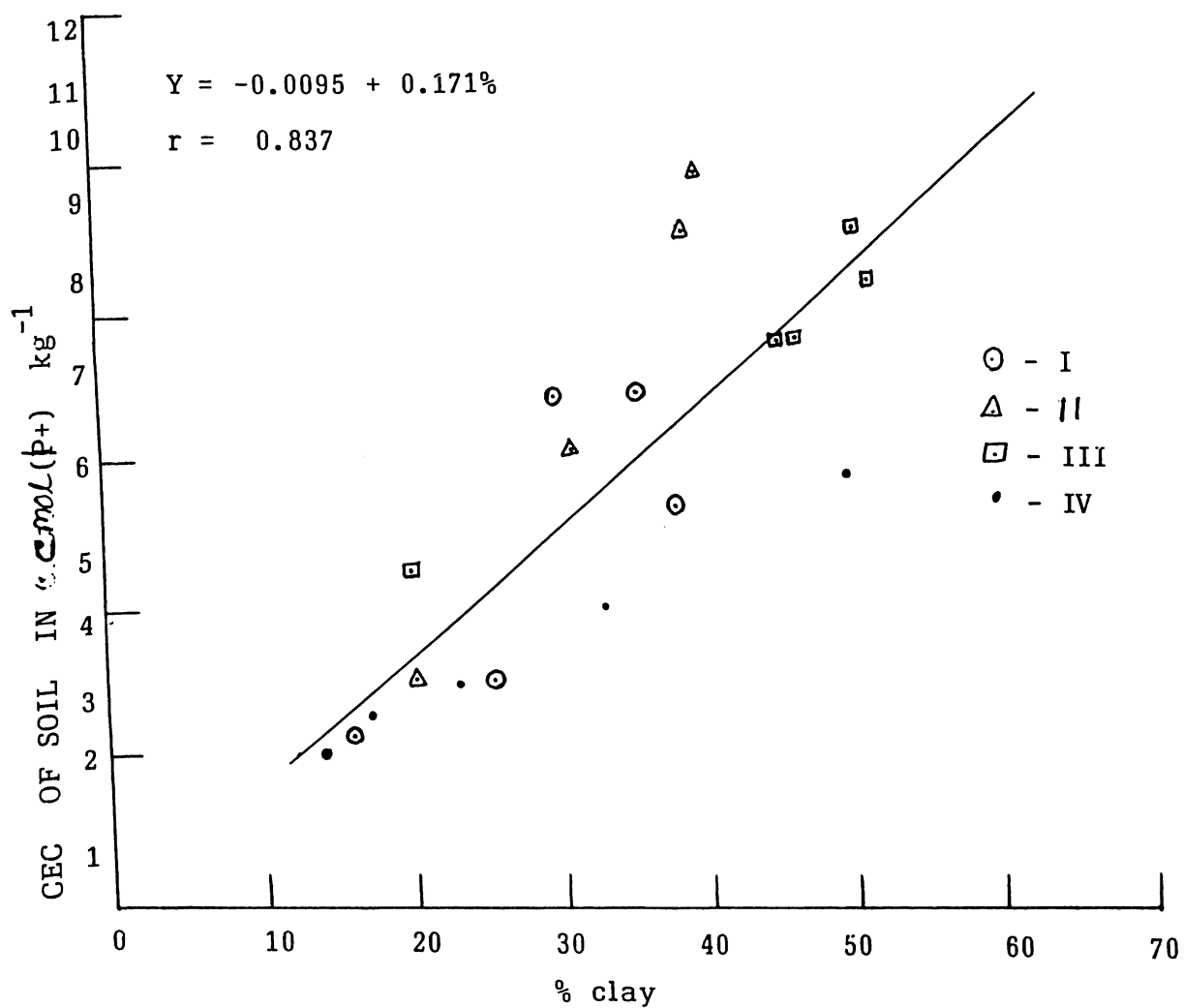


Fig.8. RELATIONSHIP BETWEEN pH AND % BASE SATURATION.

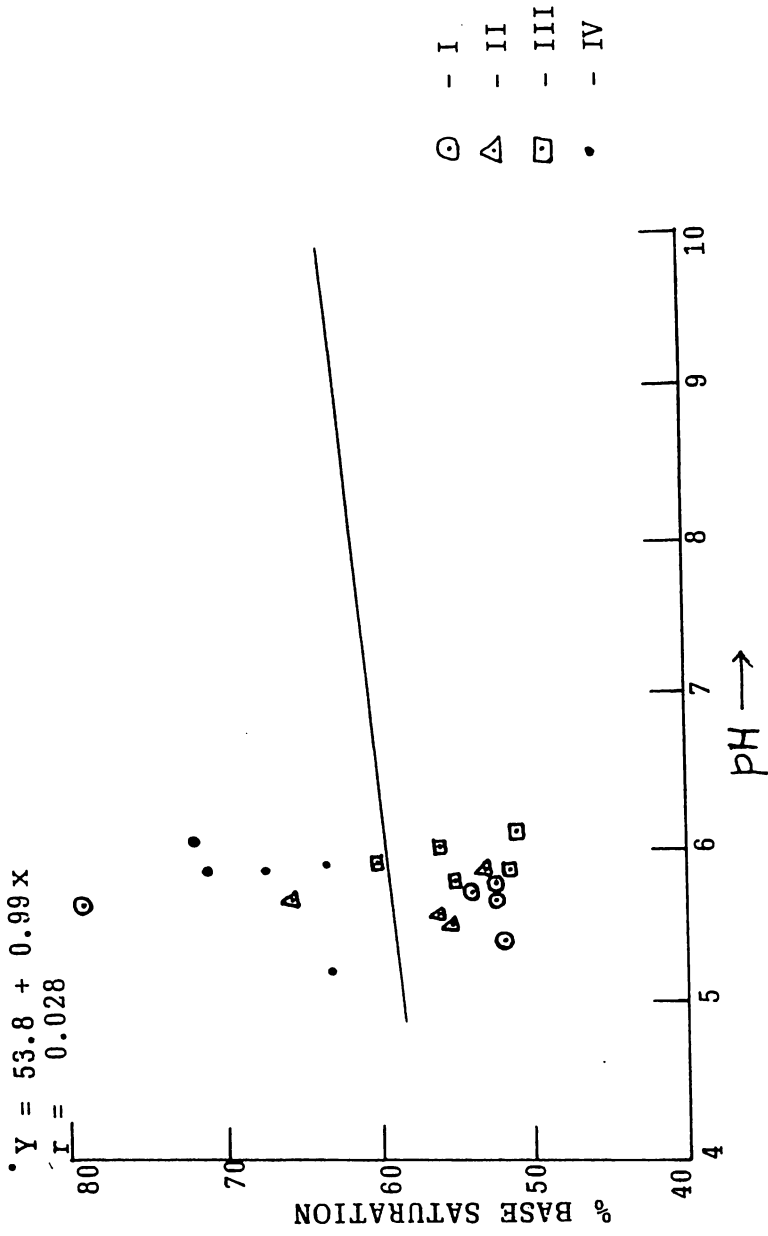


Table 6. Cation exchange capacity and composition of the exchange complex of the surface soil samples

Sl. No.	Depth (cm)	CEC ($\text{cmol}(\text{p}^+)\text{kg}^{-1}$)	Exch. cations ($\text{cmol}(\text{p}^+)\text{kg}^{-1}$)				Total basic cations ($\text{cmol}(\text{p}^+)\text{kg}^{-1}$)	Base saturation (%)	CEC/Clay (%)
			Ca^{++}	Mg^{++}	Na^+	K^+			
1.	0-15	2.42	0.62	0.24	0.18	0.24	1.28	52.69	15.9
2.	0-15	3.28	0.92	0.32	0.17	0.28	1.69	51.52	16.6
3.	0-15	3.46	1.62	0.28	0.32	0.34	2.56	73.98	17.5
4.	0-15	3.64	0.72	0.34	0.47	0.52	2.05	56.31	17.1
5.	0-15	3.58	0.68	0.52	0.23	0.46	1.89	52.79	17.9
6.	0-15	2.22	0.58	0.32	0.19	0.26	1.37	61.71	27.0
7.	0-15	3.62	0.69	0.48	0.29	0.48	1.94	53.59	17.9
8.	0-15	2.38	0.62	0.32	0.24	0.22	1.4	58.82	18.0
9.	0-15	4.56	1.12	0.62	0.38	0.48	2.6	57.01	21.0
10.	0-15	4.24	1.28	0.50	0.27	0.39	2.44	57.54	27.0
11.	0-15	4.84	1.34	0.48	0.34	0.56	2.72	56.19	20.8
12.	0-15	4.28	1.19	0.39	0.34	0.54	2.46	57.47	28.1
13.	0-15	3.92	1.15	0.68	0.38	0.48	2.69	68.62	22.7
14.	0-15	2.48	0.82	0.42	0.15	0.28	1.67	67.33	18.7
15.	0-15	2.56	0.98	0.39	0.23	0.26	1.86	72.65	19.3
16.	0-15	2.14	0.68	0.21	0.15	0.24	1.28	59.81	37.5

(i) CEC vs. % clay

The relationship between percentage of clay and CEC in $\text{c mol (p}^+) \text{ kg}^{-1}$ have been presented in Fig. 7. It is observed that these properties are positively correlated having 'r' value = 0.837, significant at 1% level. The regression equation fitted is

$$Y = -0.0095 + 0.171x$$

Where, $Y = \text{CEC in c mol (p}^+) \text{ kg}^{-1}$

$x = \text{Percentage of clay in soil.}$

This direct relationship is explained by the fact that the clays, being negatively charged, are the seats of exchange phenomena taking place in soil. Thus the amount of cations adsorbed depends on quantity of clays present.

(ii) % Base saturation vs. pH

A positive correlation as shown in Fig. 8 is found to exist between percentage base saturation and pH. The 'r' value is worked out to be +0.028 which is nonsignificant. The regression equation has been worked out to be as follows:

$$Y = 53.8 + 0.99x$$

Where, $Y = \% \text{ Base saturation}$

$x = \text{pH.}$

The explanation to such relationship is that the pH is governed by electrostatically bound H^+ and Al^{+++} of the

exchange complex that is in equilibrium with soil solution. With increase in pH, there is decrease in H^+ and Al^{+++} in the exchange complex with consequent increase in basic cations such as Ca^{++} , Mg^{++} , Na^+ and K^+ which results in higher base saturation.

4. Available nutrient status

For genesis and characterization of soil, usually soil profiles are exposed, morphologically described and their physical properties, chemical composition and mineralogy are determined. But to know the fertility status of a particular area, available N, P_2O_5 , K_2O and pH of the surface soils are determined and fertiliser recommendations are done for different crops. Accordingly surface and subsurface samples from the four profiles and sixteen composite surface samples (0-15 cm) from the entire tract were collected, analysed for their available nutrient status. Available nutrient status of the surface and subsurface samples has been presented in table 7 and that of the adjoining composite surface samples have been presented in table 8. Data presented in table 7 indicated that the surface soil of P_1 and P_3 are medium in available N and all other samples have low available N status. Available P_2O_5 content in the surface samples of the profiles are medium but on the subsurface is low. The available K_2O content in the subsurface and subsoil samples, in general are medium ranging from 120-410 kg/ha. In general, the values of available N, P, K are higher on

Table 7. Available nutrient status of the profile soil samples (kg ha⁻¹)

Pedon	Depth (cm)	Available 'N'	Available 'P ₂ O ₅ '	Available 'K ₂ O'	pH
P ₁	0-11	328.8	16.0	190	5.71
	11-24	214.6	9.6	160	5.63
P ₂	0-14	228.3	25.6	200	5.52
	14-42	182.2	8.0	170	5.55
P ₃	0-9	351.4	24.0	410	5.79
	9-38	192.6	8.8	240	5.84
P ₄	0-16	212.8	27.2	170	5.82
	16-50	78.4	8.0	120	6.05

Table 8. Available nutrient status of the surface soil samples (kg ha⁻¹)

Sl. No.	Depth (cm)	Available 'N'	Available 'P ₂ O ₅ '	Available 'K ₂ O'	pH
1.	0-15	320.4	2.8	280	5.5
2.	0-15	280.6	1.0	560	6.15
3.	0-15	260.2	2.4	440	6.20
4.	0-15	316.4	10.2	580	5.91
5.	0-15	220.6	12.6	290	5.82
6.	0-15	284.2	20.0	700	6.33
7.	0-15	274.6	10.8	320	5.98
8.	0-15	312.2	3.4	420	5.80
9.	0-15	318.4	5.2	740	6.59
10.	0-15	282.6	1.1	200	5.81
11.	0-15	264.2	3.1	720	6.4 ^a
12.	0-15	228.4	4.2	220	5.35
13.	0-15	248.6	4.7	780	6.06
14.	0-15	242.2	3.2	660	6.55
15.	0-15	268.2	4.8	320	5.80
16.	0-15	282.6	20.6	440	5.83

the surface samples which may be attributed to the higher organic matter content and which after decomposition releases these nutrients (Singh and Datta, 1988).

The available nutrient status of the composite surface samples (table 8) indicated the available nitrogen status to be medium, the value ranging from 220.6-320.4 kg/ha. Out of sixteen surface samples analysed, the available phosphorus content is low in seven samples and the rest are under medium availability. But the available potash content is medium in only two samples and the rest have available potash content high, the value ranging from 280 to 780 kg/ha. From this analysis, it may be indicated that the soils of Nilungia village are of medium nutrient status.

5. Lime requirement

It has been stated that soil pH may indicate the need for lime, but the value alone gives no indication relative to amounts of lime required unless other soil factors are known. The lime requirement of soil is normally considered to be that amount of lime (CaCO_3 or equivalent amounts of other liming materials) required to raise the soil pH to some pre-determined value. It is believed that the major components of acidity in soils that must be neutralised by liming are exchangeable Al^{+++} , H^+ and possibly Mn^{++} . Extensively used Woodruff's buffer method involves measuring the change in pH which occurs when a given quantity of a calibrated buffer solution is allowed to react with a given quantity of soil.

The change in pH of the mixture is directly proportional to the quantity of acidity in the soil and may be expressed directly in meq (wts)/100 gm of soil.

The lime requirement values of profile soil samples and composite surface soil samples have been presented in table 9 and 10 respectively. Taking the desired salt pH value of 6.0 in these soils (Sahoo, 1987), the lime requirement have been calculated.

Considering the data in table 9, it may be seen that higher lime requirement is there for the soils of the upper ridges than for the valley bottom lands. The value ranging from 3.0 to 5.0 tons/ha for P_1 and 1.5 to 3.6 tons/ha for P_4 . Considering the salt pH in different horizons of P_1 , P_2 and P_3 it may be seen that the pH is slightly more on the surface (4.74 to 5.31) which normally decreases in the sub-soil region and again increases down the profile. Accordingly the lime requirement of the soil is 3.7 to 4.2 tons/ha for the surface soils; slightly higher value in the sub surface and lower value in the bottom regions. The lime requirement in P_4 gradually increases from surface downwards with a concurrent decrease in salt pH values. Lime requirement for composite surface samples (table 10) varies from 0.8 to 5.1 tons/ha.

General characteristics of the soil

The soils are formed in Easternghat region in a sloping terrain. The lithology of the tract indicated presence of Khondalite

Table 9. Lime requirement of the profile soil samples

Pedon	Depth(cm)	pH(w) 1:2	pH(s) or salt pH	pH of soil (buffer suspension)	Meq(wts)/ 100 gm of soil	Lime requirement of CaCO_3 in tons/ha to maintain desi- red salt pH of 6.0
1	0-11	5.71	4.88	6.30	0.70	3.7
	11-24	5.63	4.62	6.15	0.85	4.9
	24-56	5.41	4.73	6.10	0.90	5.0
	56-80	5.65	5.06	6.20	0.80	3.9
	80-130	5.73	5.24	6.30	0.70	3.0
2	0-14	5.52	4.74	6.25	0.75	4.2
	14-42	5.55	4.86	6.16	0.84	4.5
	42-76	5.83	5.23	6.25	0.75	3.3
	76-153	5.65	5.09	6.16	0.84	4.0
3	0-9	5.79	5.31	6.27	0.73	3.0
	9-38	5.84	5.25	6.24	0.76	3.3
	38-100	6.00	5.29	6.24	0.76	3.2
	100-139	6.11	5.37	6.27	0.73	2.8
	139-150	5.91	5.38	6.29	0.71	2.7
4	0-16	5.82	5.61	6.39	0.61	1.7
	16-50	6.05	5.60	6.48	0.52	1.5
	50-70	5.87	5.53	6.32	0.68	1.2
	70-78	5.85	5.30	6.28	0.72	3.0
	78-150	5.14	5.03	6.27	0.73	3.6

Table 10. Lime requirement of the surface soil samples

Sample No.	Depth(cm)	pH(w) 1:2	pH(s) or salt pH	pH of soil (buffer suspension)	Meg(wts)/ 100 gm of soil	Lime requirement CaCO ₃ in tons/ha to maintain desi- red salt pH of 6.0
1.	0-15	5.50	4.76	6.22	0.78	4.3
2	0-15	6.15	5.38	6.28	0.72	2.8
3	0-15	6.20	5.44	6.38	0.62	2.2
4	0-15	5.91	5.36	6.27	0.73	2.8
5	0-15	5.82	5.24	6.22	0.78	3.4
6	0-15	6.33	5.54	6.46	0.54	1.7
7	0-15	5.98	5.39	6.32	0.68	2.6
8	0-15	5.80	5.21	2.20	0.80	3.5
9	0-15	6.59	5.62	6.71	0.29	0.8
10	0-15	5.81	5.60	6.37	0.63	1.8
11	0-15	6.44	5.56	6.49	0.51	1.6
12	0-15	5.35	4.71	6.10	0.90	5.1
13	0-15	6.06	5.12	6.23	0.77	3.6
14	0-15	6.55	5.57	6.60	0.40	1.2
15	0-15	5.80	5.20	6.20	0.80	3.6
16	0-15	5.83	5.21	6.22	0.78	3.4

suite of rocks comprising the metamorphosed sediments of argillaceous, arenaceous and granite gneisses. Much higher precipitation coupled with permeability of the substratum, leaching away of bases in a warm humid climate with deciduous forest, vegetation are congenial for acidic reaction in soil. Higher precipitation is also instrumental for eluviation of finer particles and illuviation in the B horizon conforming the presence of argillic horizon in the profiles of the upper ridges. The soils of the valley slope and are subjected to accumulation and deposition of runoff sediment from the hillocks and upper pediments resulting in no genetic horizon differentiation and hence forming Entisols.

6. Classification of the soils (Soil Taxonomy)

An attempt has been made in the present investigation to classify the soils as per the Soil Taxonomy (1978) and keys to Soil Taxonomy (1987) (Table 11).

Profile-1

These soils are placed under Alfisols because they

- i) have an argillic horizon
- ii) have percentage base saturation more than 35% in the entire argillic horizon and a colour value moist of 4.
- iii) an ustic moisture regime
- iv) no cracks are seen on the surface
- v) do not have mollic epipedon.

These soils are placed under the suborder Ustalfs and great group Kandiustalfs because they:

Table 11. Classification of soils according to Soil Taxonomy

Profile No.	Order	Sub-order	Great group	Sub group	Family
I	<u>Alfisols</u>	<u>Ustalfs</u>	<u>Kandiustalfs</u>	<u>Aridic-Rhodic-Kandiustalfs</u>	Fine loamy, mixed, hyperthermic
II	<u>Alfisols</u>	<u>Ustalfs</u>	<u>Paleustalfs</u>	<u>Ultic Paleustalfs</u>	Fine loamy, mixed, hyperthermic
III	<u>Alfisols</u>	<u>Ustalfs</u>	<u>Paleustalfs</u>	<u>Kandic Paleustalfs</u>	Fine loamy, mixed, hyperthermic
IV	<u>Entisols</u>	<u>Fluvents</u>	<u>Ustifluvents</u>	<u>Typic Ustifluvents</u>	Fine loamy, mixed, hyperthermic

- i) have ustic moisture regime
- ii) have a CEC ≤ 16 c mol (p⁺) kg⁻¹ clay (by 1 M NH₄ OAc pH 7) and ECEC ≤ 12 c mol (p⁺) kg⁻¹ clay in the major part of the upper 100 cm of the argillic horizon.
- iii) do not have a lithic, paralithic or petroferric contact within 150 cm of the soil surface.
- iv) have a clay distribution that increases gradually with depth and meet all the requirement of argillic horizon.

These soils are placed under the subgroup Aridic-Rhodic-Kandiustalfs because they :

- i) do not have mottles
- ii) do not have an epipedon that is 50 cm to 100 cm thick if the particle size class is sandy throughout
- iii) do not have a horizon within 150 cm of the soil surface that has > 5 per cent plinthite by volume
- iv) The soil temperature regime is hyperthermic and the soils are dry in some or all parts of the moisture control section for more than 90 days.
- v) The soil temperature regime is hyperthermic and are not moist in some or all parts of the moisture control section for 180 or more days.
- vi) have an argillic horizon that has a colour hue of 2.5 YR (not 5 YR or yellower).

Considering the findings of soil survey staff (Anonymous, 1989) for that area, these soils could be placed under fine loamy, mixed, hyperthermic family classes.

- i) have ustic moisture regime
- ii) have a CEC ≤ 16 c mol (p⁺) kg⁻¹ clay (by 1 M NH₄ OAc pH 7) and ECEC ≤ 12 c mol (p⁺) kg⁻¹ clay in the major part of the upper 100 cm of the argillic horizon.
- iii) do not have a lithic, paralithic or petroferric contact within 150 cm of the soil surface.
- iv) have a clay distribution that increases gradually with depth and meet all the requirement of argillic horizon.

These soils are placed under the subgroup Aridic-Rhodic-Kandiustalfs because they :

- i) do not have mottles
- ii) do not have an epipedon that is 50 cm to 100 cm thick if the particle size class is sandy throughout
- iii) do not have a horizon within 150 cm of the soil surface that has > 5 per cent plinthite by volume
- iv) The soil temperature regime is hyperthermic and the soils are dry in some or all parts of the moisture control section for more than 90 days.
- v) The soil temperature regime is hyperthermic and are not moist in some or all parts of the moisture control section for 180 or more days.
- vi) have an argillic horizon that has a colour hue of 2.5 YR (not 5 YR or yellower).

Considering the findings of soil survey staff (Anonymous, 1989) for that area, these soils could be placed under fine loamy, mixed, hyperthermic family classes.

Profile II and III

Profile II and III are placed under the order Alfisol and suborder Ustalfs as they meet all the requirements of that suborder. Both profile II and III are placed under the great group Paleustalfs because -

- i) they do not have lithic or paralithic contact within 1.5 meters of the surface
- ii) have clay distribution such that the percentage of clay increase from the surface downwards, hues redder than 10 YR (5 YR) and chroma of > 4 in the matrix.
- iii) they do not have lithic or paralithic contact within 50 cm of the soil surface and there is an increase of at least 20% clay downwards.

Profile-II is placed under subgroup Ultic Paleustalfs as -

- i) they meet all the requirements of typic paleustalfs except that they have an argillic horizon that has base saturation (by sum of cations) is less than 75 per cent in all parts.

In the family level they are placed under fine loamy, mixed, hyperthermic.

Profile-III is placed under subgroup Kandic Paleustalfs as:

they meet all the requirements of typic paleustalfs excepting that they have CEC of < 24 c mol (p⁺) kg⁻¹ clay by (1 M NH₄OAc pH 7) in the major part of the argillic horizon.

In the family level they are placed under fine loamy, mixed hyperthermic.

Profile-IV

Profile-IV are placed under order Entisols as :

- i) they have no evidence of development of pedozonic horizons.
- ii) the soil temperature regime is hyperthermic and no cracks are seen on the surface.
- iii) have an ochric epipedon

These soils are placed under the suborder Fluvents because they -

- i) have a texture of loamy, very fine sand or finer in all sub-horizon below the AP horizon
- ii) do not have fragments of diagnostic horizons that can be identified
- iii) have slope of $\leq 25\%$
- iv) have an organic carbon content that decreases irregularly with increase in depth and remains of 0.2 per cent at 1.5 m depth.
- v) are not permanently saturated with water and do not have characteristics associated with wetness
- vi) have a mean annual soil temperature of $> 22^{\circ}$ C.

In the family level they are placed under fine loamy, mixed hyperthermic.

Profile-IV

Profile-IV are placed under order Entisols as :

- i) they have no evidence of development of pedozonic horizons.
- ii) the soil temperature regime is hyperthermic and no cracks are seen on the surface.
- iii) have an ochric epipedon

These soils are placed under the suborder Fluvents because they -

- i) have a texture of loamy, very fine sand or finer in all sub-horizon below the AP horizon
- ii) do not have fragments of diagnostic horizons that can be identified
- iii) have slope of $\leq 25\%$
- iv) have an organic carbon content that decreases irregularly with increase in depth and remains of 0.2 per cent at 1.5 m depth.
- v) are not permanently saturated with water and do not have characteristics associated with wetness
- vi) have a mean annual soil temperature of $> 22^{\circ}$ C.

- vii) do not have a lithic or paralithic contact within 25 cm of the soil surface.

The soils are placed under great group Ustifluvents as :

- i) they have an ustic soil moisture regime
- ii) have a hyperthermic temperature regime

In the sub-group level they are placed under Typic Ustifluvents as they -

- i) do not have mottles in the entire profile
- ii) do not have cracks at same periods in most years
- iii) have an AP horizon that has a colour value moist of 4 or more.

In the family level they are placed under fine loamy, mixed, hyperthermic.

CHAPTER V

SUMMARY AND CONCLUSION

CHAPTER-V

SUMMARY AND CONCLUSION

Village Nilungia under the Dhobakia Nala Mini Watershed was surveyed in detail and four pedons from upper pediment (Pedon-I), ridge slope (Pedon-II), valley top (Pedon-III) and valley slope (Pedon-IV) were characterised. Besides, sixteen composite surface samples were also collected to know the fertility status of the area. It is a sloping terrain with 5-8% slope with moderate soil erosion and is situated in the foot hills of the Eastern ghat region.

The climate of the area is hot and moist subhumid and falls in the North eastern ghat agroclimatic zone of Orissa with an average rainfall of 1280.6 mm. The mean maximum temperature is 37° C (May) and the mean minimum temperature is 10.4° C (December). The relative humidity ranges from 64-80%.

Morphological characteristics were studied in the field on 25th June 1993. The laboratory estimation includes mechanical composition, physical characteristics, chemical characteristics consisting of pH, EC, organic carbon, CEC and exchange compositions, exchange acidity, lime requirement, available N, P, K. etc.

- (1) The soil colour is yellowish red on the upper pediment which gradually changes to light reddish brown along with sloping terrain.
- (2) The profiles are deep at the bottom region than upper pediment.
- (3) The surface soil texture varies from sandy loam to sandy clay loam whereas, it is sandy clay loam to clay down the profile. The coarse fragments are comparatively more in the lower horizons of the profile than surface.
- (4) In the upper region profiles the clay content increases down the depth with presence of thin, patchy clay cutans in the subsurface horizons qualifying for argillic horizon. This is attributed to the eluviation of finer particles from the surface because of well drained condition of the substratum. Although the content of clay increases downwards, no genetic horizon could be identified in the profile (P₄). But in the valley slope, moderately well drained condition prevails and there is possibility of deposition of materials from the upper ridges.
- (5) Soil reaction is almost medium acidic, in different horizons of all the profiles. As the soils are highly weathered and leached and devoid of basic cations, the trend in pH down the profile does not occur and the pH in different horizons are almost similar.
- (6) The organic carbon content is medium on the surface (0.42-0.74%) which decreases gradually (0.18-0.21%) down the depth in all the pedons.
- (7) The CEC values of soil are comparatively less on the surface and it increases gradually with depth. In general, the CEC values increase from the surface downwards and have a linear correlation with the clay content. As the organic carbon content is not

- appreciable in these soils, the CEC values could be attributed to the nature and the quantity of clay minerals. The exchange complex in all the profiles are dominated by Ca^{++} followed by Mg^{++} , K^+ and Na^+ .
- (8) The percentage base saturation values in general, increases from the surface downwards.
 - (9) The soils of this area are of medium nutrient status. The rating for available N, P and K are medium the values ranging from 220 to 320 kg/ha, 1.0 to 20.6 kg/ha and 280 to 780 kg/ha respectively.
 - (10) Lime requirement is higher for soils of the upper ridges than for the valley bottom lands. Lime requirement for ridges varies from 2.7 to 5.0 tons/ha and that of valley slope soils from 1.5 to 3.6 tons/ha, for composite surface soil samples the value varies from 0.8 to 5.1 tons/ha.
 - (11) The upper pediment, ridge slope, valley top soils of the area are classified under the order Alfisols, sub-order Ustalfs. The soils of upper pediment are classified under great group Kandiustalfs and sub-group Aridic-Rhodic-Kandiustalfs. Soils of ridge slope are classified under great group Paleustalfs and sub-group Utic Paleustalfs whereas soils of valley top are classified under great group Paleustalfs and sub-group Kandic Paleustalfs. The valley slope soils are classified under the order Entisols, sub-order Fluvents, great group Ustifluvents and sub-group Typic Ustifluvents. In the family level, soils of all the profiles are placed under fine loamy, mixed, hyperthermic.

CONCLUSION

From the present investigation the following treatments are suggested for integrated watershed development in the study area. In general the work involve fuel-fodder plantations

in the denuded catchments, construction of erosion control structures like check dams, graded bunds, construction of small water storage reservoirs, adoption of appropriate cropping systems, cultural methods and water management practices.

In the Dhobakianala mini watershed, two categories of land are there which are to be treated as follows :

1. **On farm land** - The on-farm land includes all agricultural lands such as upland (P_1 , P_2) medium land (P_3) and low land (P_4). As these lands belong to the local cultivators, the villagers are to be persuaded and their participation should be sought. The main conservation measures in the uplands would be (i) planting of vertivers on contours and existing earthen bunds, (ii) silvi-horticultural plantations.

The treatment for the medium land includes contour cultivation, terracing, adopting the cropping system like short duration paddy/ragi/millet in kharif and pulses/groundnut/tomato/vegetables in rabi. In all cases, application of lime as per full lime requirement or half-lime requirement should be done and the fertilisers should be applied as per recommended dose.

For low land the moisture storage capacity is more because of high clay content (49%) at a depth below 78 cm. The above recommendation should be followed with slight change in the cropping system, which may be medium duration rice/ragi/sugarcane in kharif and oilseeds/pulses/vegetables in rabi season. Water harvesting ponds may be constructed in between medium land and low land to collect the runoff water during rainy season and which is to be utilised for the crops at the time of need.

2. **Off-farm land** - It includes the hills, pediment, reserve forest, culturable waste land etc. For these type of land the following programme should be taken up.

- i) Plantation of timber species
- ii) Silvi-horticultural plantations

This type of study may be extended to different similar topographic situations in order to evolve a uniform management of watersheds in Orissa. Steps may be taken to study the climatic water balance of the entire mini watershed.

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