CHARACTERISTICS OF SOILS AND EVALUATION OF LAND IN THE SOUTHERN RARH PLAIN, WEST BENGAL

by

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ABSTRACT

This study reviews the nature and distribution of soils of the Southern Rarh Plain and evaluates the suitability of land for current and potential land use types, indicating the most suitable uses for each land unit. For this purpose, the region is classified into 29 land facets which are grouped into 6 land systems. The land facets form the units for studying the soils and for evaluating the suitability of land. The soils of this region, although associated with 'laterite' (plinthite and ironstone), are not extremely weathered. They belong to the Alfisol soil order. The soil conditions improve from the upper to the lower facets in the toposequential land systems, A - E. In the lower facets, the nutrient status improves increasingly from system A towards system E. Land system F is highest in nutrient status on account of flood deposition processes. There is no salt problem nor toxicity of sodium nor aluminium in any of the facets. The lower facets of systems A - E and the system F are obviously more suitable for cultivation. During the wet season, these areas are highly suitable for rice which is the main crop. A few millets are found to be equally suitable and are of significant potential. During winter and summer, these areas can support many crops if provided with irrigation. The upper facets, poor in soil conditions, are left to forests, but the forests are being severely disturbed by man. Therefore, such areas ought to be reafforested, mainly with native species and partly with other quick-growing trees. Some hardy crops of nutritive or cash value are also suited to these facets. They may be grown in small parcels. Natural pastures occur throughout all facets, but they are very poor. Some high-yielding and nutritious species have been found suitable for sowing the pastures. The pastures and the dykes of cultivated fields are potentially suitable for growing some species of multipurpose trees. Various facets are found to be suitable for growing a number of additional fruit trees of high nutritive value. The suitability of the land for the crops currently grown and those suggested in this thesis may be further improved by fertilization and irrigation.

DECLARATION

This thesis has been composed by myself and it has not been submitted in any previous application for a degree. The work reported within was executed by myself unless otherwise stated.

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INTRODUCTION: CONTEXT, AIMS AND OBJECTIVES.

Southern Rarh Plain is one of the economically backward regions of West Bengal, India. The economy is based mainly on traditional agriculture and forest products, but the output is too low to support the population of the region. Previously it was thought that this region consisted of "laterite and lateritic soils" of low fertility (Raychaudhuri *et al*., 1963; chapter 1). Few attempts have been made at regional development by the authorities. On the contrary, forests were destroyed for extension of agriculture into marginal lands and for construction purposes. This made the situation worse by depressing the income from forest products, disrupting the plant-soil nutrient cycle and increasing runoff, if not soil erosion.

Changing concepts concerning the nature of "laterite" and modern classification systems of soils based on their properties, justify an initial review of the soil resources of the area. The results of this review have been used to evaluate the degree of suitability of land for various uses. Recent attempts at afforest-:ation and irrigation, fertilizer additions and the use of improved seeds have led to a situation where it may be possible to re-shape the disturbed land use pattern by putting each unit of land to its most suitable use. In this way, the productivity of land can be used to its optimum level.

The Southern Rarh Plain is selected for this project for two reasons. Firstly, the common features of the so-called "laterite plains" are represented here within a relatively small area.

The methods and results of this study can be applied to similar regions such as Northern Rarh Plain and the Barind Plain. Secondly, more practically, this region is familiar to the writer and is relatively less expensive for field work.

The thesis has two aims:

(1) to prepare a survey and analysis of the soil profile characteristics and soil classification according to U.S.D.A. system (Soil Survey Staff, 1975) and

(2) to form an evaluation of the suitability for existing and alternative uses of land, based on land qualities according to F.A.O. framework (Food and Agricultural Organization, 1976 and Beek, 1978).

No previous soil survey existed for this area at a scale larger than 1: 1000 000. But a detailed survey of an area of 5000 sq. km is beyond the scope of this project. A two-stage method was applied instead:

(a) reconnaissance survey of land resources of the whole area and classification of land;

(b) intensive study of a representative area for each class of land.

The reconnaissance survey was made following the principle of "Land Systems Approach", i.e. taking into consideration both physical and biological elements. Other methods such as "terrain evaluation" or more ecologically inclined surveys were not used because these focus predominantly on either physical or biological criteria (Dent and Young, 1981). Certain deviations were made from the theme of "Land Systems Approach" to suit the purpose of the study. Firstly, the survey was carried out by field exploration instead of interpretation of air-photographs, because the latter were unavailable. Secondly, classifications of "land facets" and "land systems" were made on the basis of detailed variations in hydrology, land forms, soil and vegetation.

Six land systems are recognized in this area where they occur recurrently. Each system has been studied in a representative area at the scale of 1: 3960. Soil profiles are examined and other data on "land qualities" are collected for each "facet", which forms the unit of land evaluation. Since the genetically related facets form a regular pattern across the slope in each system, the soil profiles are mapped within "catenas" (Milne, 1935). These concepts are defined more clearly in chapter 3.

The essential pedological character of the region is the increase of clay in the profile with depth and the high base saturation. Among other features of interest are the occurrences of "plinthite", "ironstone" (see SECTION 1.1) and "calcium carbonate concretions". Plinthite is found in the zone of groundwater fluctuation of a profile, particularly in the footslope, whilst ironstone occurs in the freely drained profiles at the summit and shoulder of a slope. Plinthites do not turn into massive ironstone upon excavation, but the prominent mottles harden into nodules. Calcium carbonate concretions are present in the toeslopes of poorly drained systems. The relevance of these features to soil development and their significance to plant growth will be given special attention in the following chapters.

The thesis consists of six chapters. Following this introduction, there is a critical review of published works concern:ing the laterite problem in general and its significance upon the soils of the Southern Rarh Plain in particular. In chapter 2, the role of physical and biological factors on the development of soil characteristics and land use pattern is discussed. These two chapters set up the background of the present study. The tech:niques of field and laboratory studies are then explained in chapter 3. The methods of identifying the land facets and land systems, survey of slopes, studies of soils in the field, analyses of soil samples in the laboratory and the processes of land evaluation are described in this chapter. The results of these investigations are described and discussed in the following two chapters. The morphological, physical and chemical properties of soils are dealt with in chapter 4. The soil profiles are classified and a catenary soil map is also included in this chapter. A note has been made of the local cases of very severe gully erosion. In chapter 5 a suitability evaluation of each land unit is proposed for both the current and potential land use types, followed by a discussion of the results. Finally, chapter 6 is devoted to a summary of the main conclusions and recommendations for management and development of the area.

This study is meant to be of practical value in the under:standing of the soil resources and in the formulation of land use plan of the region. However, a greater number of similar intensive studies over the area of the Southern Rarh Plain would be desirable in order to ascertain the precise variations within each land system. Furthermore, a few land qualities (e.g. availability of water) need to be substantiated by more extended field experimental data to improve the land suitability evaluation. Moreover, the evaluation has, of necessity, been a theoretical exercise. A new crop requires to be tested by field trials before introduction. Finally, it is necessary to add that the social and economic factors are beyond the scope of the present study, but it is appreciated that, without them, no development plan is complete. It is the intention of the writer to continue the project to cover these fields at a later date.

CHAPTER I

REVIEW OF LITERATURE

The soils of the Southern Rarh Plain have been conventionally identified as "laterite soils" by the Indian Council of Agricultural Research (Raychaudhuri et al., 1963). The diagnostic feature of these soils has been defined as "the presence of hard vesicular laterite in the soil profile". Such emphasis is placed on the presence of laterite because the latter is believed to be an integral and the most significant horizon of the soil profile. The processes responsible for the formation of these soils and laterite are believed to be genetically related and are referred to as "lateritisation". Since these processes are held to be those of extreme weathering, the soils are also described as extremely weathered and hence poor in mineral nutrients and in their reserves of weatherable minerals.

However, according to current research, laterites do not necessarily form by the same processes as those operating on the soils in which they are found (Alexander and Cady, 1962; Sivarajasingham et al., 1962; Maignien, 1966). The soil profile may well have a different weathering status and corresponding grade of fertility. The importance placed upon laterite, particularly the hard form, by the I.C.A.R. in characterizing the soils is questionable. Moreover, there still remains a lot of confusion around the definition and meaning of the term "laterite". It is, therefore, necessary to resolve the following questions:

(1) what is laterite?

(2) how does it form?

(3) what is its significance in soil classification?

These issues are discussed in the following sections showing the historical development of the ideas concerning laterite.

1.1 WHAT IS LATERITE

Laterite was first described by Buchanan in 1807 as an iron-rich clay which, when fresh in the quarry, was soft enough to be cut by an iron instrument but became as hard as brick when exposed to the air. He assumed the presence of iron from the ochre-like red and yellow colour of the clay. He further observed that laterite could be exposed by erosion of the top soil and become hard. He described massive outcrops of hard laterite, black in colour and full of pores and cavities resting over granite at many places in Southern India. But he was puzzled to see the same laterite already hardened beneath a soil cover in Eastern India (Oldham, 1930).

At first, the property of "irreversible hardening on exposure" was used as the diagnostic criterion of laterite. However, it was soon found in India and elsewhere that the soft clay form was rather infrequent while most of the occurrences, either above or beneath the soil, were already hard. A wide range of colour and structure was also recognized. Newbold (1844), also working in Southern India, listed purple, red, brown and black colours in the hard laterite and variegated patches of white, yellow, lilac, purple and red in the soft clay. He also pointed out that the cavities of a hard laterite might be filled or empty. Oldham (1859) described nodular, cemented nodular, conglomeratic and platy laterites in addition to the massive varieties. All these forms - soft and hard, massive and nodular, were brought within the connotation of laterite by the Geological Survey of India (Medlicott and Blanford, 1879). The Survey recognized that laterite could be eroded and deposited elsewhere where they might be recemented into laterite. These were called "low-level" laterites in contrast to the "high-level" laterites from which they were derived. The laterites of the Southern Rarh Plain were described as low-level laterites.

Starting with the works of Bauer (1898) and continued by Holland (1903), Harrison (1910, 1933), Campbell (1917) and others, the chemical composition of laterites came to be understood. It was found that laterite occurred over different types of rocks - from granite, basalt, gneiss and schist to sandstone and shale. But, in comparison to the underlying rock, it was richer in the sesquioxides of iron or aluminium or both but poorer in silica and almost devoid of bases. Mineralogically, iron was found in the form of goethite, haematite and as amorphous oxides. Free alumina was present as gibbsite, boehmite and as amorphous hydroxides. Free silica was mostly in the form of inherited quartz. Colloidal silica, chalcedony and opal were also noted. Silica and alumina frequently occurred combined as kaolinite in crystalline or sub-crystalline forms. Manganese was commonly detected. Resistant minerals like magnetite, ilmenite, rutile, anatase, zircon and sphene occurred as residues (Harrison, 1910; Hardy, 1931; Humbert, 1948; Alexander _et al_., 1956; Bonifas, 1959).

The growing understanding of the chemical composition led to attempts at a chemical definition of laterite which was thought to be precise. But the proportions of silica, alumina and iron oxide were extremely variable in materials which might otherwise be called laterite (Sivarajasingham et al., 1962). Iron oxide ranged between 2% and 80% and alumina from less than 4% to over 60%. Silica ranged from traces to as high as 35%. There was, therefore, no consensus over the defining property.

Crook (1909) proposed to use the high proportion of alumina while Nestruev (Lacroix, 1913) was in favour of iron oxide. Evans (1910) and Fermor (1911), on the other hand, suggested using the low amount of silica for definition. Instead of employing only one property, Van Bemmelen (1904), Harrassowitz (1926) and Martin and Doyne (1927) brought the silica-alumina ratio into the definition. Joachim and Kandiah (1941), on the other hand, proposed to use a ratio of silica to alumina plus iron oxide. These two ratios became very popular for defining laterite and various critical values for them were suggested (Botelho da Costa, 1954; Aubert, 1954; Segalen, 1957; Camargo and Bennema, 1962).

In addition to the lack of general agreement, the use of such ratios alone gave rise to problems. The material, which should be called laterite from physical properties, was denied that by a chemical ratio definition and vice versa. Pendleton (1936), Robinson (1949) and others pointed out that the chemical ratios were the results of a combination of processes and were, therefore, indicative rather than absolute criteria.

Walther (1916), in the meantime, erroneously assumed that laterite signified red colour and employed the term for all red coloured earths in the tropics. This novel explanation became very popular and everything red in the tropics became laterite (Martin and Doyne, 1927). Talbott (Prescott, 1931) further complicated the connotation of laterite by including siliceous and travertine crusts.

The confusion over the term and its connotation has been apparent for a long time and many scientists sought a precise defini-:tion which could be universally accepted. Lamplugh (1907) proposed an altogether new term "ferricrete" to denote hard crusts of laterite. The French scientists created two terms: "carapace" for friable cemented material and "Cuirasse" for resistant and solid cemented material (Tricart, 1972). These terms covered the connotation of hard laterite only. Although they continued to be used, they could not replace the term laterite. Pendleton (1936) defended the term laterite and supported Buchanan's original usage. It was Kellogg (1949) who redefined laterite in clear language and confined it to four principal types of sesquioxide-rich material that are either hard or harden upon exposure:

(1) soft mottled clays that change irreversibly to hardpans or crusts when exposed,

(2) cellular and mottled hardpans and crusts,

(3) concretions or nodules in a matrix of unconsolidated material,

(4) consolidated masses of such concretions or nodules.

This definition corroborated the views of the Geological Survey of India. It was accepted by the U.S. Department of Agriculture and many others. Nevertheless the term "laterite" continued to be used in more than one sense and the U.S.D.A. finally abandoned it to avoid confusion. The U.S.D.A. adopted a new term "plinthite" (from the Greek, but having the same meaning as laterite, from Latin meaning brick) for what was essentially Kellogg's definition. Only the clause "hardening on exposure" was changed to "hardening on repeated wetting and drying". It implied that the hardening may not be immediate and that hardening may happen beneath a soil cover. Plinthite was formally defined as "the sesquioxide-rich, humus-poor, highly weathered mixture of clay with quartz and other diluents, which commonly occurs as red mottles, usually in platy, polygonal or reticulate patterns; plinthite changes irreversibly to hardpans or irregular aggregates on repeated wetting and drying, or it is the hardened relict of the soft red mottles" (Soil Survey Staff, 1960). Later the U.S.D.A. divided this connotation into two parts with a name each (Soil Survey Staff, 1975):

(1) the sesquioxide-rich soft mottled clay was called "plinthite", and

(2) the irreversibly hardened pans and irregular aggregates were called "ironstone".

The Food and Agricultural Organization supported this idea and used it to prepare soil maps of the world (F.A.O., 1974).

The value of the new terminology with precise definition is obvious. It avoids confusion with the many senses in which "laterite" is still used today. Moreover, the two terms highlight the different behaviour of soft and indurated forms from the view-point of land utilization. The U.S.D.A. terms and connotation are used in the subsequent chapters of this thesis. The term "laterite" is used in this chapter for historical purpose only, to denote both plinthite and ironstone.

1.2 THE FORMATION OF LATERITE

The development of the ideas on the genesis of laterite may be traced through three stages:

(1) the nineteenth century hypotheses, based mainly on morphological characteristics;

(2) the hypotheses of the first half of the twentieth century, attempting to explain the chemical composition;

(3) the recent developments through correlation of the exist:ing data, mineralogical and micromorphological analyses and experi:mentation.

STAGE 1: Hard laterite obviously looks like a rock. This fact, together with its slag-like character and occurrence over basalt in some cases, led Voysey (1833) and Carter (1852) to propose a volcanic origin. Oldham (1893), on the other hand, emphasized the presence of laterite over different types of rocks and postulated a sedimentary origin in lake beds. Both these views were rejected, for laterite did not exhibit any volcanic or sedimentary structures. Maclaren (1906), Simpson (1912) and Jensen et al. (1915) suggested that laterite crusts were efflorescences. The evidence was lacking for this view also and process of capillary rise was generally considered to be inadequate for laterite formation (Keen, 1942; Baver, 1956).

None of these hypotheses tried to explain how the soft laterite formed in the first place. This soft laterite was found only beneath a soil cover and over many kinds of rocks from which it was separated by a weathering zone. This led Babington (1821), Benza (1836), Clark (1838), Wingate (1852), Kelaart (1853), McGee (1880) and others to advocate that laterite was a residual product of weathering *in situ*. They ascribed the subsequent hardening to exposure by quarrymen or by erosion of the top soil. Cole (1838), Blanford (1859), King and Foote (1865), Wynne (1872), Theobald (1873) and Lake (1890) pointed out that the hard laterite itself could be eroded and deposited elsewhere where it might be recemented to form detrital laterite. Both the residual and detrital hypotheses were accepted as official views of the Geological Survey of India and were correlated with the "high-level" and "low-level" laterites respectively (SECTION 1.1; Medlicott and Blanford, 1879).

STAGE 2: The processes by which different types of rocks could be weathered into soft laterite and the processes of change into hard laterite were not understood until the chemical composition of laterite came to be known (SECTION 1.1). Two opposite views arose to explain the concentration of sesquioxides in laterite. Holland (1903), Harrison (1910), Hanlon (1944), Humbert (1948), Mohr and Van Baren (1954) and others suggested that the sesquioxide concentration in laterite was due to the removal of silica and bases from the original rock. Holland and Hanlon envisaged a simple process leaving behind the sesquioxides by differential leaching and subsequent hardening by dehydration. Mohr and Van Baren believed that silica was leached downwards to a zone where it formed an impermeable pan. Above this pan, a saturated zone developed where kaolinised mottled clay accumulated. Sesquioxides remained above the saturated zone. Humbert, from the studies of thin sections, suggested that local movement of iron towards nuclei and subsequent crystallization in dense aggregates were necessary for induration.

Campbell (1917), Harrassowitz (1926), Whitehouse (1940), Prescott and Pendleton (1952) and others maintained that the sesquioxide came from other parts of the profile into the laterite horizon - from above, below or sides. The groundwater was believed to be the chief medium of sesquioxide transport and the zone of concentration was in the range of water-table fluctuation. But there was no consensus of opinion as to the provenance of the sesquioxides. Harrassowitz suggested that they came from below. Campbell and Whitehouse contended that there were contributions from both above and below. Prescott and Pendleton pointed out the significance of lateral transport at the foot of the slopes.

Each of these ideas provided partial explanation for the concentration of sesquioxides at a particular horizon in a profile. But none of them could describe the complete sequence of events. Moreover, the processes suggested were not adequate in their original description. Questions such as why the silica should be leached out and not the sesquioxides, or how sesquioxides could be concentrated at the upper layer of the water table which is poorest in dissolved material (Wentworth, 1955), on why aluminium also would be precipitated, amongst others, were not satisfactorily answered. In the absence of detailed understanding of the processes, the environmental factors were emphasized so much so that laterite was described as a product of hot and humid, preferably wet and dry, climate. Ultimately, it was identified as the typical product of the tropical climate.

STAGE 3: Current understanding of the origin of laterite is based on a synthesis of the existing data and ideas together with mineralogical analyses using modern techniques, micromorphological studies and experimentation of the processes involved (D'Hoore, 1954; Alexander and Cady, 1962; Sivarajasingham et al., 1962; Maignien, 1966; and others). It is now clear that there are three phases in laterite formation: (a) weathering, (b) accumulation and (c) indur:ation, often followed by (d) degradation. It is also established that one phase does not necessarily lead to or follow another.

(a) WEATHERING: "Lateritic weathering" implies total decomposition of rocks, almost complete loss of bases and partial loss of silica so that proportion of iron and aluminium becomes relatively higher. Iron and aluminium remain, not because they are unaffected by weathering but, because they are transformed from original combinations to more resistant lateritic minerals (SECTION 1.1). Such transformations may be obtained from the same mineral by different processes as well as from different minerals by similar processes.

(b) ACCUMULATION: As indicated above, iron and aluminium may accumulate as a result of removal of bases and some silica. This is known as "relative accumulation". The quantities of sesqui-:oxides, in such cases, depend on the amount originally present in the parent material.

The iron and some aluminium may also migrate and accumulate elsewhere. This is referred to as "absolute accumulation". The source may be either lateritically weathered material or degraded hard laterite. The reception zone may or may not be lateritically weathered.

The mechanism of migration involves mobilization, transport and immobilization. Iron may be mobilized as complexes or chelates of organic substances and as ferrous ions. To a limited extent, aluminium may also move as complexes and chelates. Transport depends on the availability of water. Groundwater as well as a saturated horizon may serve the purpose. Immobilization occurs following destruction of organic complexing or chelating agents and oxidation or adsorption of ferrous ions by changes in pH, Eh and dissolved ions.

Migration may be upwards, downwards or lateral. Upward move-:ment by capillarity is restricted to a narrow zone. Downward move-:ment is more common, but considering the low amount of organic matter available in a profile for complexing or chelation and the difficulty of oxidizing ferrous ions at depth, it may not be a major process of accumulation. Lateral movement down a slope is the easiest mode of migration because it derives the organic complexing or chelating agents as well as the iron and aluminium from a wider area. It probably accounts for the greater proportion of lateritic accumulation (Sivarajasingham _et al._, 1962; Maignien, 1966).

A fluctuating water table favours the segregation of iron and aluminium and increases the loss of other minerals.

These processes of accumulation operate in various combinations depending on local conditions. There are few examples where only one process is responsible.

(c) INDURATION: High levels of sesquioxide accumulation alone do not ensure induration. A minimum amount is of course necessary but it varies according to the total specific surface of the mass. Induration is a function of greater degree of crystallinity and more significantly, greater continuity of the crystalline phase. These processes are promoted by alternate wetting and drying which encourage crystal growth and local movements through voids to accrete on to the nuclei or to permeate the matrix. It may involve only a small proportion of the sesquioxides and may affect only a small part of the mass resulting in discrete concretions whereas with greater proportions and a larger mass, massive ironstone can develop. Iron is more significant in this regard because it causes induration more repidly with smaller concentrations than aluminium. Induration can take place without exposure or after exposure - providing there are right conditions for the necessary growth of the crystalline phase.

At present the mode of origin of laterite is understood so far as to separate it from soil formation. But some of the processes, particularly those of induration, require more detailed investigation.

(d) DEGRADATION: Thick and hard laterites are probably more resistant than most rocks. But they do degrade in time and in several ways:- (1) they may disintegrate physically and they are then distributed by normal processes of erosion and deposition; (2) the iron may be further segregated resulting in hard nodules in a more friable matrix; (3) growth of vegetation may contribute humus chelators which significantly mobilize iron. The mobilized iron may accumulate elsewhere.

From this discussion it is manifest that laterites form by the various combinations of many processes. Some of the occurrences may be the result, quite simply, of "relative accumulation". A few may be entirely enriched from outside sources. But most of them are the results of both relative and absolute accumulations (Sivarajasingham et al., 1962). The processes of laterite formation may be favoured in a tropical climate with a humid phase, but the laterite can not be called the typical product of the tropics because the largest proportion of the land area is covered by non-lateritic materials.

1.3 SIGNIFICANCE OF LATERITE IN SOIL CLASSIFICATION

Laterite often occurs as a horizon in a soil profile. It was believed that laterite and the other horizons of the profile were formed by genetically related processes. This idea led to many attempts to classify soils by the presence of laterites, particularly the hard laterites. For example, Raychaudhuri (1941) classified:-

"laterite soils" = with hard vesicular laterite;
"red earths" = with many iron concretions;
"red loams" = with a few iron concretions.

This classification is used by the Indian Council of Agricultural Research (Raychaudhuri *et al*., 1963).

Pendleton and Sharasuvana (1946) classified:-

"laterite soils" = with a well developed 'laterite horizon';
"lateritic soils" = with an immature 'laterite horizon'.

Baldwin, Kellog and Thorp (1938) recognized:-

"laterite soils" = strongly weathered, iron-rich, sometimes with iron concretions but no indurated horizon;
"lateritic soils" = less weathered, clayey but friable;
"groundwater laterite soils" = with indurated laterite under hydromorphic conditions.

Later Kellog (1949) replaced the words laterite and lateritic by "latosol" to avoid confusion with hard laterite and distinguished the types by prefixing soil colour names.

In contrast to these views, Martin and Doyne (1927, 1930) proposed using the silica/alumina ratio of the clay fraction as an indicator of the degree of weathering:-

"laterite soils" = ratio below 1.33;
"lateritic soils" = ratio between 2.0 and 1.33;
"non-lateritic soils" = ratio above 2.0.

Prescott and Pendleton (1952) criticised the ratio as an inadequate and non-essential criterion. It is, however, used by the French (Comm. Ped. Cart. Sols, 1967), Belgian (Sys *et al*., 1961) and S.P.I. - C.C.T.A. (D'Hoore, 1964) as one of the criteria in soil classification.

The confusion about the position of laterite in soil classi-:fication is obvious from the above definitions. Since the origin of laterite was differently understood, the early authors were impressed by the presence of laterite in a soil profile, but could not successfully relate the material to soils at various stages of weathering. The present views on the genesis of laterite (SECTION 1.2) make it clear that the processes of lateritic accumulation are not necessarily genetically linked with the process operating on the other horizons of the profile. Commonly, the lateritic material is received, at least in part, from outside the profile by lateral migration. Whatever may be the mode of accumulation, once it becomes irreversibly indurated, the hard laterite is nothing but a hardpan or concretion like those of silica and calcium carbonate. Such hard laterites should be used, like the latter, in the lower levels of soil classification only.

When the lateritic accumulation is soft and dominates the soil profile, it can be used as the diagnostic criterion for the "extremely" weathered soils". These soils are called "Oxisol" in the U.S.D.A. classification (Soil Survey Staff, 1975) and "Ferralsol" in the F.A.O. system (F.A.O., 1974). The mode of accumulation may be relative or absolute or any combination of the two. Although the other soil horizons are not genetically related to the soft laterite in case of absolute accumulation, the profile virtually appears "extremely weathered" when lateritic materials are predominant.

It is, therefore, the degree of accumulation of soft laterite which is significant in soil classification, for it reflects the fact that the profile consists of extremely weathered material. The hard laterite, when massive or abundant in concretions, only determines the depth of the soil as far as classification is concerned. A soil profile containing hard laterite may nevertheless be classified as an "Oxisol" or "Ferralsol" if the soil horizons are dominated by soft lateritic accumulation. Many modern soil classification systems, in addition to the U.S.D.A. and F.A.O., support these views (Comm. Ped. Cart. Sols, 1967; Sys et al., 1961; D'Hoore, 1964). In this project, the U.S.D.A. system is employed for its detailed and quanti:tative nature. It will be seen in chapter 4 whether the soils of the Southern Rarh Plain containing hard laterite are Oxisols.

1.4 CONCLUSIONS

On the basis of the review of the nature, formation and signi:ficance of laterite, the following conclusions are drawn regarding the relationship of "laterite" to the soils of the Southern Rarh Plain.

The soils of this region have been identified so far by the presence of hard laterite. This criterion should be abandoned. The soils should be classified according to the status of weathering, extent of lateritic accumulation in the soft form and other features. For this purpose, the "Soil Taxonomy" (Soil Survey Staff, 1975) is ideal, for it recognizes the above ideas in full detail.

Secondly, the soils of this region should not be called a product of "lateritisation" process just because of the presence of hard laterite. The parent material of these soils is Pleistocene and Recent alluvium (SECTION 2.2). This alluvium is derived from the erosion of a wide variety of rocks, including hard laterite. The lateritic portion of the alluvium has been segregated and then indurated in certain parts of the landscape. But the soils are nowhere extremely weathered nor are the profiles dominated by soft lateritic accumulation. The hard laterites themselves occupy only 10% of the region according to my estimate which compares with the 7% estimate of Sanchez and Buol (1975). Most of the occurrences are beneath soil cover. Therefore, even in I.C.A.R. classification, only 10% of the soils of this region could be called "laterite soils".

Lastly, the soils should not be described as poor simply because of the presence of hard laterite within certain parts of the landscape. The soil properties themselves must be examined and then they can be judged on their merits and demerits. This is one of the main purposes of the present study. The nature of the soils is described in chapter 4. Their suitability for plant growth is analysed in chapter 5.

CHAPTER 2

PHYSICAL AND BIOLOGICAL FACTORS AFFECTING SOILS AND LAND USE IN THE SOUTHERN RARH PLAIN

The Rarh Plain is a gently undulating plain between the Ganges delta to the east and the Chotanagpur plateau to the west. It is divided into north and south sections by the Damodar river. The Southern Rarh Plain is an area of about 5000 sq. km between latitudes 21 degrees, 45 minutes north and 23 degrees, 15 minutes north and between longitudes 86 degrees, 45 minutes east and 87 degrees, 30 minutes east. It comprises the western halves of Midnapore and Bankura districts of West Bengal, India (Figs. 2.1 and 2.2).

In this chapter, the features of topography, hydrology, geology, climate and vegetation are described in so far as they influence soil characteristics and the land use patterns in this area.

2.1 TOPOGRAPHY AND HYDROLOGY

The region lies between 30 and 135 m above mean sea level, sloping south-east at an average gradient of 1 in 600. The streams may be classified according to Strahler's method (Strahler, 1952). The main rivers developing flood plains in the region are fourth order such as Darakeswar, Silai, Kasai and Subarnarekha. They originate in Chotanagpur plateau and subsequently flow south-eastwards in approximately parallel sets of level flood plains, 2-10 km in width.

Apart from these flood plains, the region consists of gentle undulations of low relief drained by first, second and third order

Figure 2.1 Situation of the Southern Rarh Plain (after Survey of India and National Atlas Organization maps).

1. International boundary; 2. State boundary; 3. District boundary; 4. Approximate boundary of the Southern Rarh Plain; 5. Contours and heights in metres.

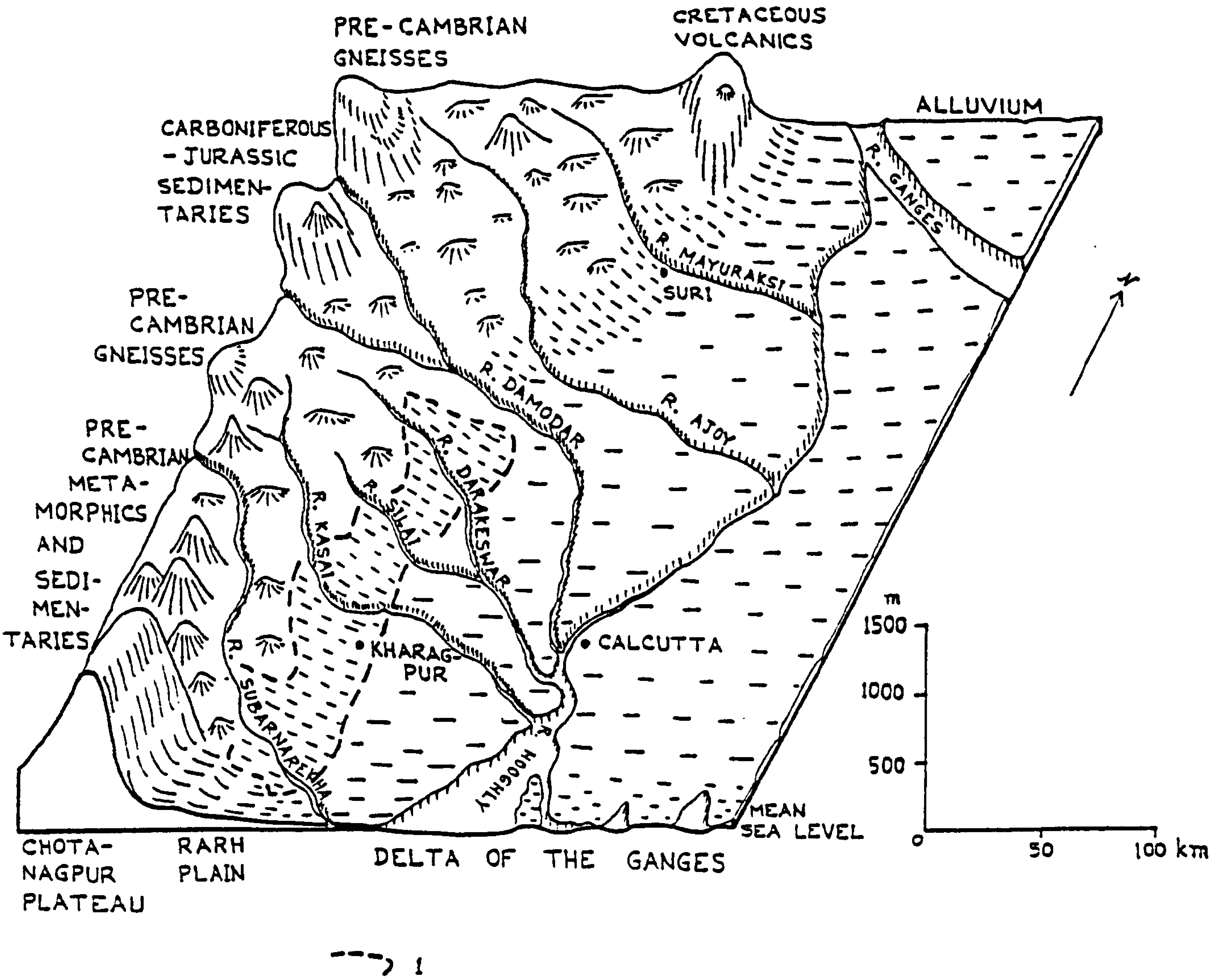


Figure 2.2 Block diagram showing the regional setting of the Southern Rarh Plain (after Survey of India and National Atlas Organization maps).

1. Approximate boundary of the Southern Rarh Plain.

streams. Some of the basins are without a stream. The slope length is between 1000 and 1500 m and the average slope angle is between 30 minutes and 1 degree, 30 minutes. The relief amplitude ranges from 10 to 25 m. The profile form is, in general, convex-rectilinear-concave but the proportion of each segment varies according to drainage basin hierarchy. The concave portion is greatest in the valley of a third order stream. The size decreases with lower order streams and is smallest in a basin lacking a perm:anent stream. In some streamless basins, the concave segment contains earth mounds or multi-convexities, 1.0 - 1.5 m in relief. Although the origin of these features is not understood, they stand out because of their slightly different moisture regime and hence, special soil characteristics (see SECTION 4.5).

The maximum amount of slope angle is found at the junction of convex and rectilinear segments. The mean value ranges from 3 degrees in third order stream basins to 1 degree or less in streamless basins. The maximum station value obtained in the surveyed profiles is 10 degrees.

The convex segment is very gently rounded. It is only 400 - 600 m on average in lateral extent across the interfluves, but longitudinally it runs as long ridge between valleys on either side.

In this thesis, the convex segment is referred to as the "summit" and the zone of maximum slope angle as the "shoulder". The rectilinear portion is designated as the "footslope". The concave segment is divided into two parts; that below the footslope is called the "toeslope" whilst the part beside a stream or occupying the centre of a streamless basin is identified as the "base". This five-fold division of the slope profile is not only topographical but characterized by soil drainage and colour pattern of the soils as well.

The angle and length of slope are the main determinants of water movement along a slope. The nature of rainfall, slope material and vegetation cover have modifying influences which are elaborated in the subsequent sections. In a gently undulating landform, overland flow and throughflow are slow while deep percolation depends upon the position of water-table (FIG. 2.3). On the summits, the greater proportion of rainwater infiltrates and percolates down to the water-table which is deep even in the wet season. The dominant pedological processes here are weathering and leaching under free drainage. The solum is in relatively advanced stage of development. In some places, however, a perched water-table may form over local beds of clay in the sub-:surface. Here the lower horizons of the profile develop under seasonally reducing conditions.

In the shoulder area, the overland flow and throughflow are maximum on account of the maximum angle of slope. The shoulder is the zone of greater relative removal. Since there are few rills or gullies, overland flow occurs as laminar flow. Sheet erosion is slight to moderate depending upon the degree of slope. Stoniness also appears to be positively correlated to the degree of slope. Since the soil drainage is free, the development of the solum is comparable to that of the summit area.

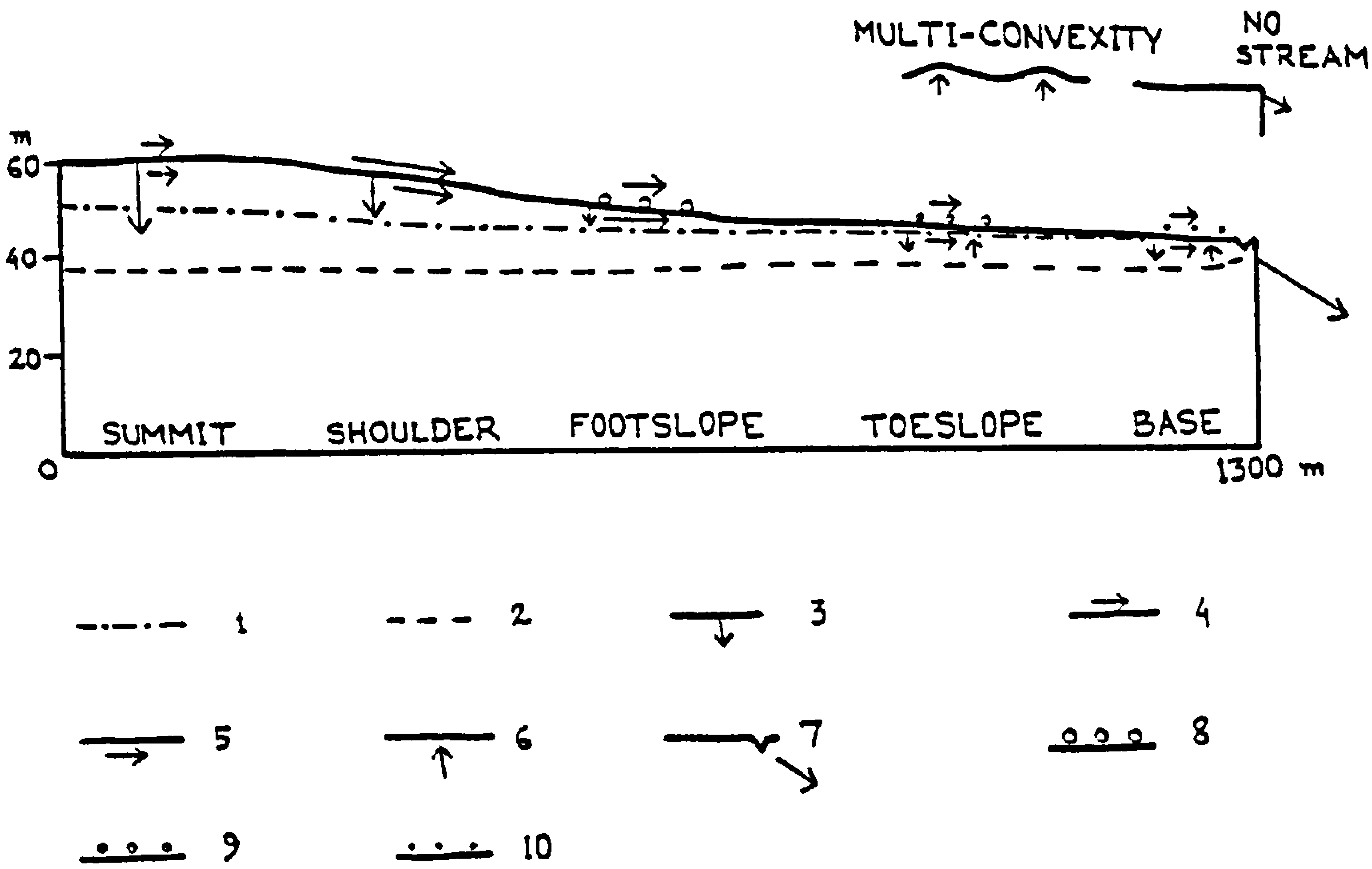


Figure 2.3 Model of the movement of water across an idealized slope in the study area.

1. Wet season water-table; 2. Summer water-table; 3. Infiltration and deep percolation; 4. Overland flow; 5. Throughflow; 6. Capillary movement; 7. Stream-flow; 8. Surface deposition of coarse particles; 9. Surface deposition of medium particles; 10. Surface deposition of fine particles.
Length of arrow indicates intensity.
See text for further explanations.

At the footslope the overland flow coming down from the summit and shoulder areas is checked on the surface by the break of slope and by the terraces and dykes of the cultivated fields. Nevertheless the overland flow continues to move relatively slowly towards the base area. The movement of the throughflow is also continued until the shallow water-table is met with. For these reasons, the lower parts of the slopes receive water and with it, organic matter, soil particles, salts and bases from the upper segments. The quantity received becomes progressively higher towards the base area. Parts of these additions are ultimately drained into the stream or the bottom of a streamless basin and are lost by stream flow or sheet flow. The loss is maximum in higher order stream basins and minimum in a streamless basin.

Because of the presence of shallow water-table in the lower parts of the slopes, soil forming processes operate under seasonally oxidizing and reducing conditions. At the base area, whole profiles are reduced in the wet season, but the depth to the reduced horizon becomes progressively greater towards the footslope. The intensity of reducing conditions is greatest in streamless basins.

Capillary movement of water, upward from the water-table, is significant in the lower parts of the slopes during the dry season. In the streamless basins, where the groundwater is relatively richer in salts and bases, calcium carbonate and bicar-:bonate are deposited as concretions at the capillary front. The earth mounds or multi-convexities over the lower slopes of some streamless basins, referred to earlier, are particularly associated with these concretions. It is likely that the concretions have imparted resistance to erosion to these mounds.

The drainage conditions are clearly reflected in soil colour. The red colour of freely drained soils of the summit and shoulder areas changes through yellow colour of the footslope area to grey colour at the toeslope and base with increasing water-logging. The thoroughly oxidized summit and shoulder soils are red throughout the profile. In the footslope, only the lower horizons are reduced and show prominent mottles. The toeslope and base profiles are totally reduced and very low in chroma.

The position of the water-table is not only significant in soil development but influences the agricultural pattern as well. The water-table generally follows the surface form but fluctuates greatly because of seasonal rainfall. During the wet season it comes to the surface of the lower slope areas but remains below 5 m at the summit. In the dry season, the water-table at the lower slopes is within 2 m in streamless basins but may be 4 m deep in basins of third order streams. It lies between 10 and 20 m depth at the summit areas during the dry season. The wet season shallow water-table in the lower slopes restricts the choice of crops to rice. In the dry season, however, a variety of crops may be grown utilizing the groundwater. This is significant in the flood plains of the main rivers where the yield of water is higher. The upper slope areas, on the other hand, are well drained throughout the year but poorer in plant available moisture.

Apart from the groundwater resources in water-table conditions, there are deep aquifers which may be exploited for irrigation (TABLE 2.1). The yield in tubewells ranges from 20 to 80 cubic metres per hour. In the flood plains, there are aquifers within 200 m which yield 80 - 250 cubic metres per hour in tubewells.

All the streams of this region are non-perennial (TABLE 2.2). Their flow is very low during the dry season when irrigation water is necessary to grow crops. In winter (November to February), limited water is available from third and fourth order streams by direct lift irrigation technique. Second order streams also yield limited irrigation when dammed, but no irrigation is possible in summer (March to May) either by direct lift or by local damming. Recently the West Bengal Government has started a project to provide irrigation water for the Southern Rarh Plain by damming the rivers Kasai, Silai and their main tributaries beyond the western limit of the region and by constructing a fine network of canals from the reservoirs. The project is nearing completion and the supply of irrigation will start soon. Its success will enable more land to be brought under winter and summer crops and will allow a greater flexibility in the choice of crops.

It has been pointed out earlier in this section that soil erosion is not severe in the gently undulating landforms. However, severe to very severe gully erosion occurs in very localized areas on the cliffs of fourth order streams and also in some head stream areas (FIG. 2.4). A case study has been made in a very severely

TABLE 2.1 GROUND WATER POTENTIAL

(Million cubic metres per year)

DISTRICT	GROUNDWATER RECHARGE	CURRENTLY USED	BALANCE
Bankura	1534	255	1279
Midnapore	2790	778	2012

source: Adyalkar and Banerjee, 1981 .

TABLE 2.2 STREAM FLOW

NAME OF STREAM	STREAM ORDER	ANNUAL FLOW IN MILLION CUBIC METRES	SEASONAL FLOW AS % OF THE ANNUAL		
			June-Oct.	Nov.-Feb.	March-May
Kasai	4	1505	78	19	3
Subarnarekha	4	1653	81	17	2

source: Ministry of Irrigation and Power, West Bengal, 1972 (quoted in Adyalkar and Banerjee, 1981).

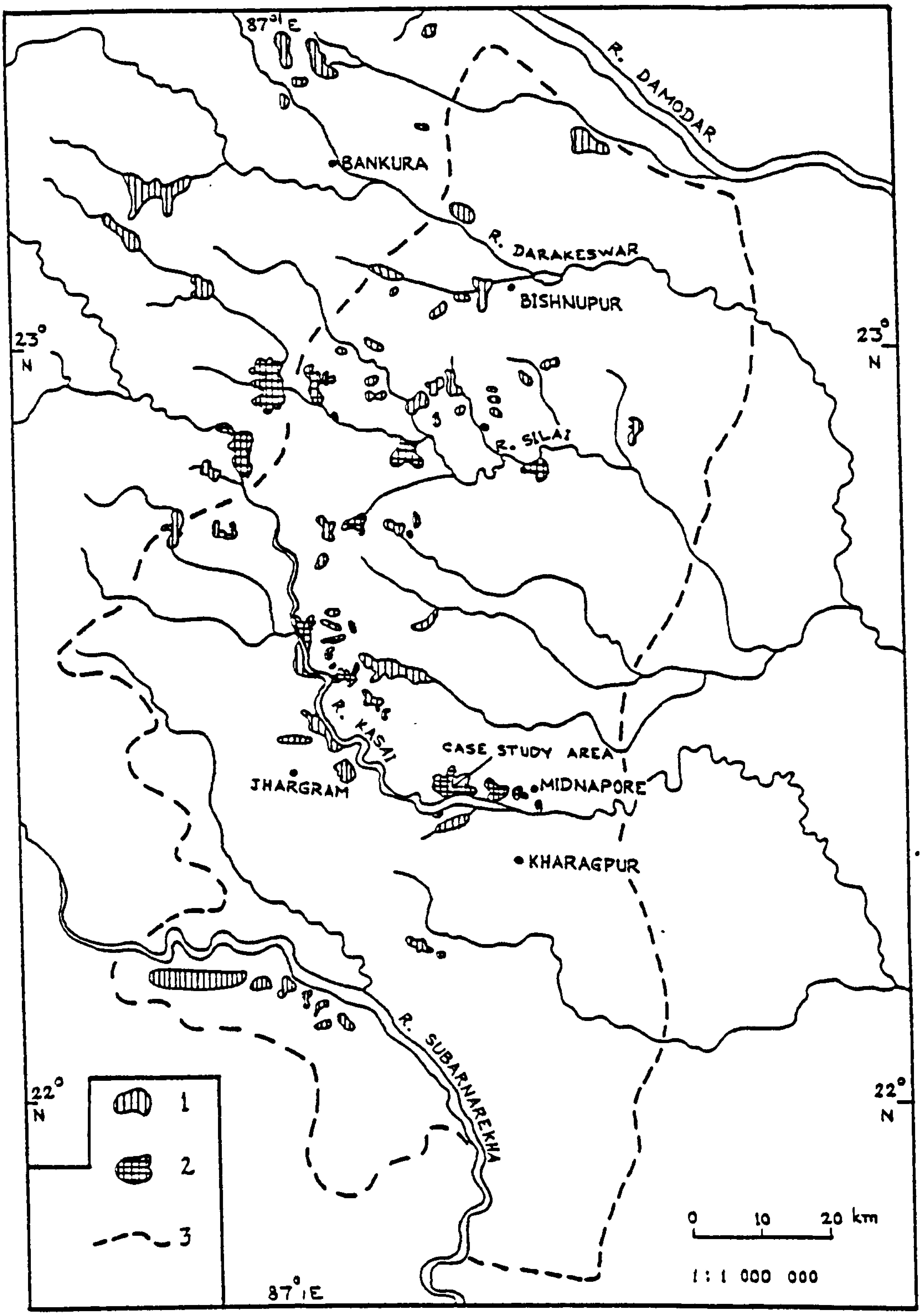


Figure 2.4 Soil erosion in the Southern Rarh Plain (source: field work, 1976-82).

1. Severe gully erosion; 2. Very severe gully erosion;
3. Approximate boundary of the Southern Rarh Plain.

severely eroded area to investigate the nature and cause of erosion. The results are discussed in SECTION 4.7.

In conclusion to this section, it may be emphasized that topography and hydrology are the major determinants of the soil characteristics and of the land use pattern of this region. Success of low cost land use plans based on soil survey will depend upon an understanding of these two factors.

2.2 GEOLOGY

The Southern Rarh Plain is composed of loose and semi-consolidated sedimentary materials. These are derived from the hills and plateaus of Chotanagpur by fluvial erosion and deposited from Upper Tertiary onwards. The TABLE 2.3 shows the stratigraphic succession of rocks.

The Chotanagpur plateau was the scene of intense tectonic activity during the Pre-Cambrian period. Huge thicknesses of sedi:ments were folded and thrusted upon the basement complex accompanied by igneous intrusions and eruptions of lava. The result was a complex of metamorphic, igneous and sedimentary rocks like gneiss, schist, phyllite, slate, quartzite, granite, dolerite, basalt, shale, sand:stone and limestone, which make up the plateau. The earth movements gradually came to a close towards the end of Pre-Cambrian. Since then, the region has remained relatively stable, except for vertical block movements, and it has been subjected to deep weathering and sub-aerial denudation (Dunn and Dey, 1942).

During the Tertiary period, the Southern Rarh Plain was the western margin of Bengal Basin where marine conditions prevailed.

TABLE 2.3 STRATIGRAPHY

SYSTEM	FORMATION	LITHOLOGY
Quaternary (Recent	New Alluvium	sand, silt and clay
Quaternary (Pleistocene	Old Alluvium	sand, silt and clay
Tertiary: Mio-Pliocene	Unclassified Upper Tertiaries	gravel, sand, silt clay, siltstone and coarse ferruginous sandstone

source: Geological Survey of India, 1974

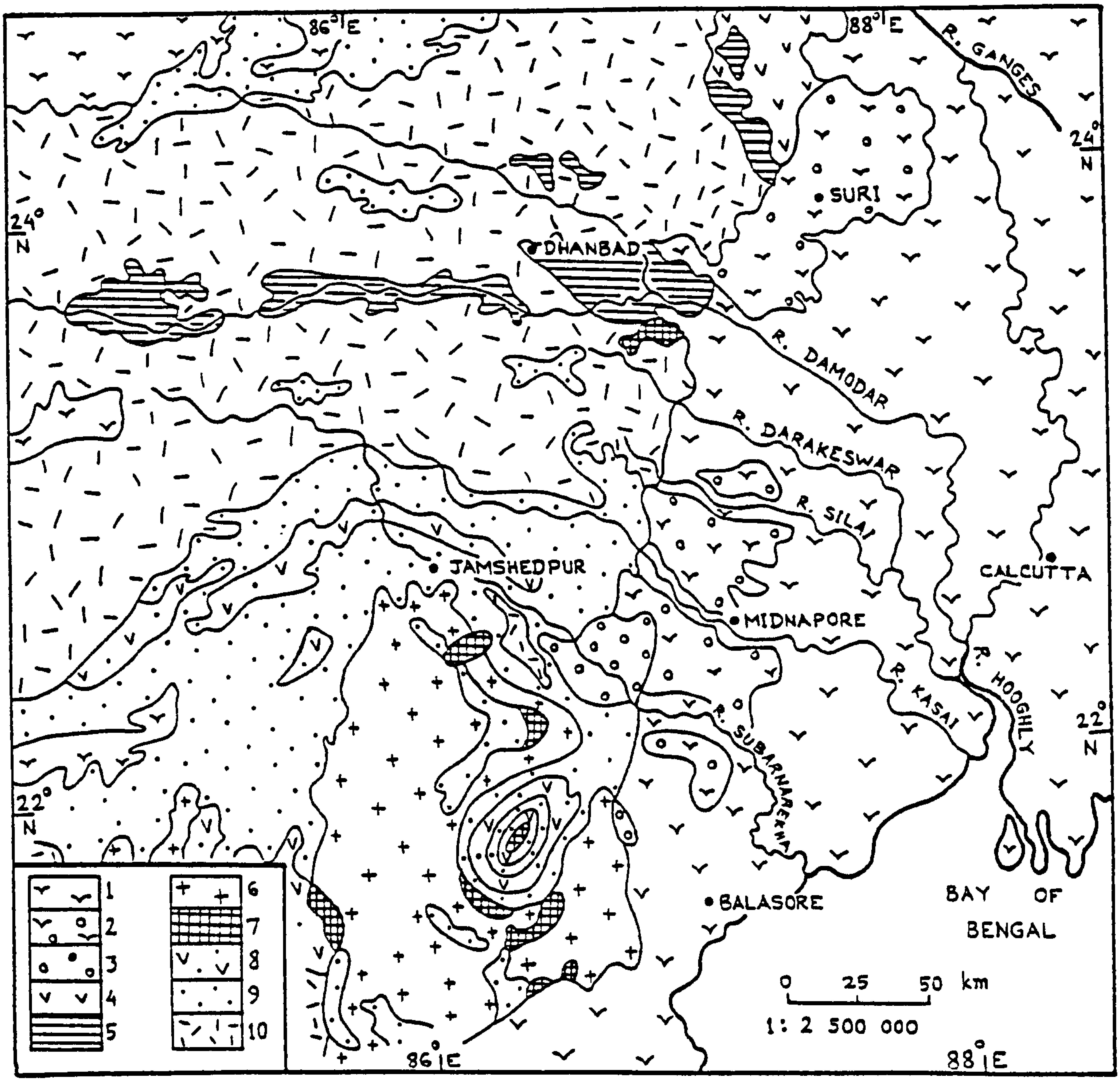


Figure 2.5 Geology of the Southern Rarh Plain and surrounding areas (after U.N. E.C.A.F.E. & U.N.E.S.C.O., 1971).

1. New Alluvium (Recent); 2. Old Alluvium (Pleistocene); 3. Semi-consolidated sedimentaries (Upper Tertiary); 4. Rajmahal volcanics (Jurassic-Cretaceous); 5. Gondwana sedimentaries with coal (Carboniferous-Jurassic); 6. Granites (Pre-Cambrian); 7. Basic and ultrabasic intrusives (Pre-Cambrian); 8. Dharwar volcanics (Pre-Cambrian: Huronian); 9. Dharwar metamorphics and sedimentaries (Pre-Cambrian: Huronian); 10. Basement complex of gneisses (Pre-Cambrian: Lewisian).

The boundary between Southern Rarh Plain and Chotanagpur plateau formed the coastline. Sengupta (1966) suggested on the basis of geophysical data that the Pre-Cambrian formations continue beneath the Rarh Plain as buried ridges before finally disappearing near its eastern boundary in a series of normal faults into the deeper part of Bengal Basin. The top of the buried ridges is about 450 m below surface (FIG. 2.6).

During the Mio-Pliocene period, a series of streams from the Chotanagpur plateau deposited alluvial sediments of heterogeneous composition across what was a hilly coastline into this shallow marginal sea. False bedding is a common feature of these sediments. Their outcrops are few and limited in extent because these are usually covered by Quaternary sediments. Exploratory drilling in several places has revealed the presence of large thicknesses of semi-consolidated sand and clay of Upper Tertiary age beneath the Quaternary alluvial cover (FIG. 2.7). These sediments contain the main aquifers of this region, yielding 20 - 250 cubic metres of water per hour in tubewells (Sinharoy and Dutt, 1972).

During the early Pleistocene, the sea retreated from the Southern Rarh Plain eastwards, possibly in response to change of sea-level related to glaciation (Niyogi and Mallick, 1973). The new coastline took a position along the eastern boundary of the region. The streams continued to bring sediments from the Chotanagpur plateau and deposited them under estuarine conditions over the Upper Tertiaries. These sediments are known as Old Alluvium. They were gradually exposed and formed the surface of the Southern Rarh Plain with the progressive retreat of the sea. The coastline has receded probably by three

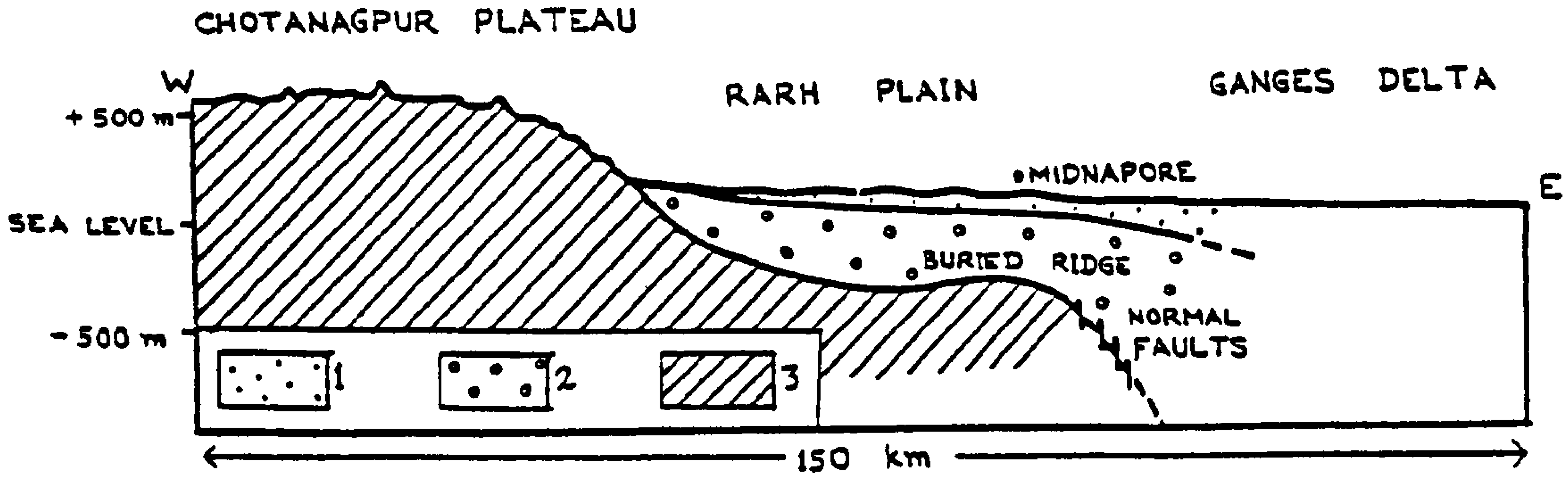


Figure 2.6 Sub-surface geology of the Southern Rarh Plain (adapted from Sengupta, 1966).

1. New and Old Aluvium; 2. Upper Tertiary formation; 3. Pre-Cambrian formations.

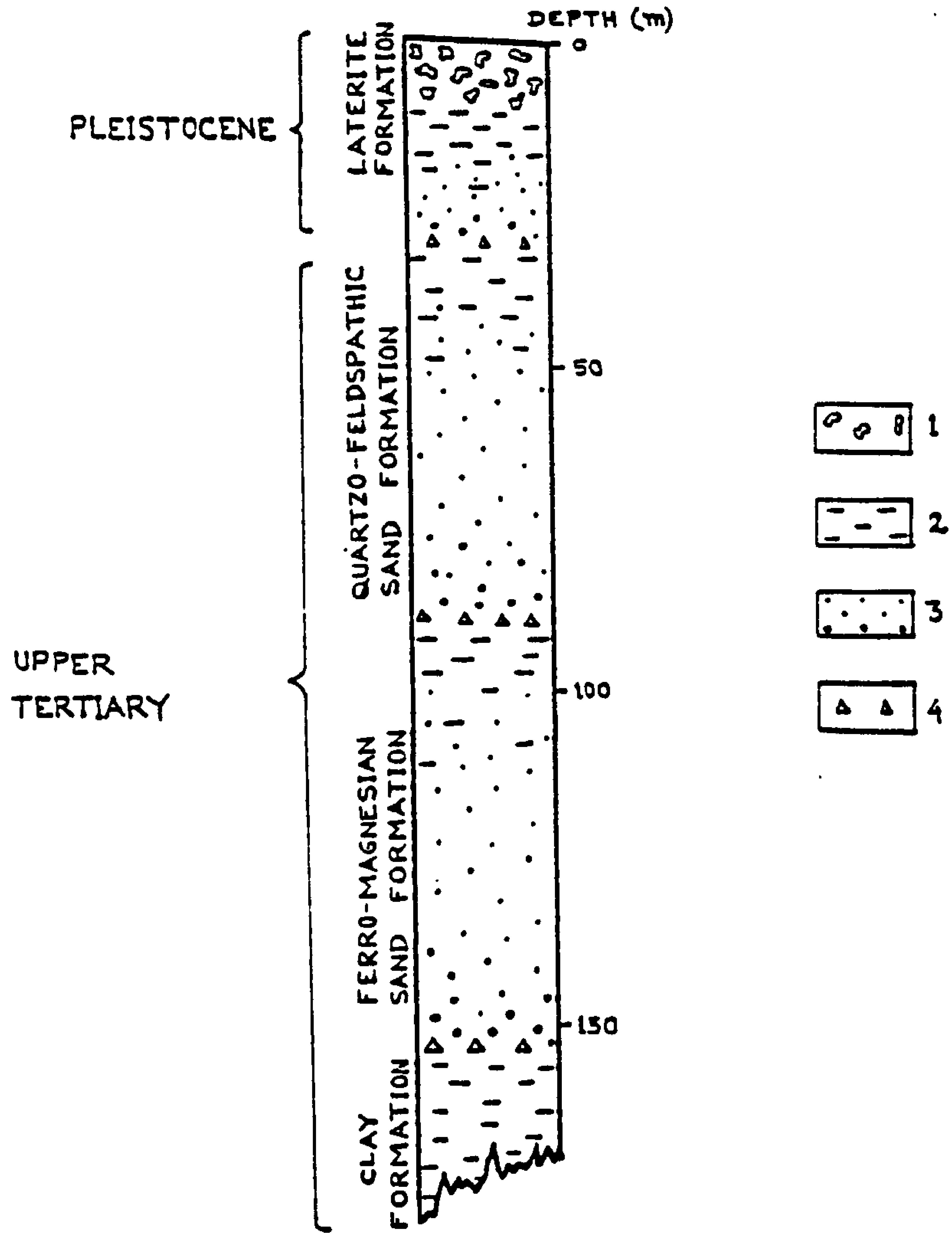


Figure 2.7 Bore-hole data from Midnapore (after Sinharoy and Dutt, 1972).

1. Laterite (Ironstone); 2. Clay; 3. Sand; 4. Gravel.

principal stages to its present position, leaving the Southern Rarh Plain at its present height relative to the sea-level (Niyogi and Mallick, 1973). The gently undulating relief has resulted from subsequent incision and broadening of the valleys. The rivers are still depositing sediments, particularly in the major flood plains, derived from the rocks of Chotanagpur plateau as well as the Old Alluvium. These deposits are known as New Alluvium.

Old Alluvium, therefore, is the material derived from the Chotanagpur plateau by erosion of a great variety of rocks. It is a complex mixture of ferruginous, calcareous, siliceous and aluminous materials. New Alluvium consists of more recent flood plain deposits laid down by the present rivers. It is also variable in composition. The Old and New Alluvium together form the parent materials of soils of the Southern Rarh Plain.

The particle size distribution, state of consolidation and complex composition of the parent materials have markedly influenced the soil characteristics of the area. Originally, in each phase of deposition, the parent materials were graded in particle size i.e. fine particles were at the top and the size became progressively coarser with depth (FIG. 2.7). Subsequently fine particles at the surface have moved with water laterally down the slope and also vertic-:ally down the profile. The less fine texture in the subsurface has encouraged downward movement of clay. Thus the lower parts of the slopes and the lower horizons of the profiles have become richer in clay.

Occasionally, very localized beds of clay are found in the original deposit. These are significant in forming perched water-tables. In an otherwise freely drained site, it leads to the development of a reduced subsurface horizon underlying an oxidized surface horizon.

The parent materials, being composed of already weathered substances, have been relatively rapidly decomposed, releasing the salts and bases. The latter have moved with water, like the soil mineral particles, both along the slopes and down the profiles and have enriched the respective areas.

The mineralogical components of the parent materials have also been redistributed by water. The calcareous materials are dissolved and transported down the slope. When a stream is present, they are drained into it and are lost by stream flow. But, in streamless basins, they have accumulated, at least partly, in the form of second-:ary concretions.

The movements of ferruginous and aluminous materials are more complex (SECTION 1.2). Part of them may move down the slope with water. In the poorly drained areas, they occur mainly in the ferrous forms. But, at the footslope areas, they accumulate and segregate abundantly as prominent mottles or plinthites under the influence of fluctuating water-table. In course of time, the plinthites transform into nodular or massive ironstone, depending upon the degree and continuity of accumulation.

Part of the ferruginous and aluminous materials may be left behind at the upper slopes. These areas may become relatively richer in sesequioxide content, although low in actual amount, by the removal of bases and siliceous materials. The ironstones of the upper slopes may have formed from such accumulations. It is also likely that the present areas of the uplands were low plains and under the influence of fluctuating water-table, previous to development of the undulating relief. The sesquioxidic materials might have accumulated and segregated at that period and, subsequent to the formation of relief, have transformed into ironstone under conditions of free drainage. In essence, both relative and absolute enrichment by the redistribution of the sesquioxidic components of the parent materials are responsible for the formation of plinthite at the footslope areas and massive or nodular ironstone over the summit and shoulder areas.

The moderate amount of silt (30-40%), high base saturation (greater than 35%) and mottles at different stages of segregation and induration indicate that the processes of soil formation are far from complete, when viewed from the potential profile development likely under the present climatic and drainage environment.

2.3 CLIMATE

The climate of the Southern Rarh Plain is characterized by high temperature and seasonal rainfall under the influence of monsoon conditions. The average climatic conditions are calculated from the data for the five meteorological stations in and around the region (India Meteorological Department, 1967). The mean annual temperature is 26.7 degree C. The mean summer temperature (May) is 31.5 degree C and the mean winter temperature (January) is 19.8 degree C. The mean maximum temperature in summer is 37.0 degree C and the mean minimum winter temperature is 11.3 degree C. Intra-regional variation in temperature is slight. The northern parts of the region are hotter by 1 degree C in summer and cooler by the same amount in winter compared to the southern parts. The average annual rainfall for the region is 1500 mm. There is a decrease of rainfall from 1600 mm in the south to 1400 mm in the north (FIG. 2.8). The rain-:fall is not evenly distributed through the year; about 75% of the rains fall in four monsoon months from June to September. The driest month, December, receives less than 5 mm. Climatological data for the five meteorological stations are given in TABLES 2.4 - 2.8. Their locations are shown in FIG.2.8.

The data for soil climate are scarce. Soil temperature data are available for the Calcutta area which should not be very different from the Southern Rarh Plain for the air climate is similar (TABLE 2.9). The mean annual soil temperature at 50 cm depth is 26.96 degree C and the difference between summer and winter temperatures is 9.28 degree C. The soil temperature regime is, therefore, classified as "hyperthermic" according to U.S.D.A. Soil Taxonomy (Soil Survey Staff, 1975).

The precipitation-potential evapotranspiration balance diagram gives an approximate indication of the moisture regime in soils (FIG. 2.9). Potential evapotranspiration is computed using Penman's formula which is then used in the calculations of monthly water balance (Penman, 1963). Moisture deficits occur for about 150 days while 215 days are moist in a year. This suggests an "ustic" soil moisture regime (Soil Survey Staff, 1975). But this regime applies only to the upper parts of the slopes where precipitation alone is the source of water income. The lower slopes, where additional water accumulates and the water-table is shallow, have an "aquic" soil

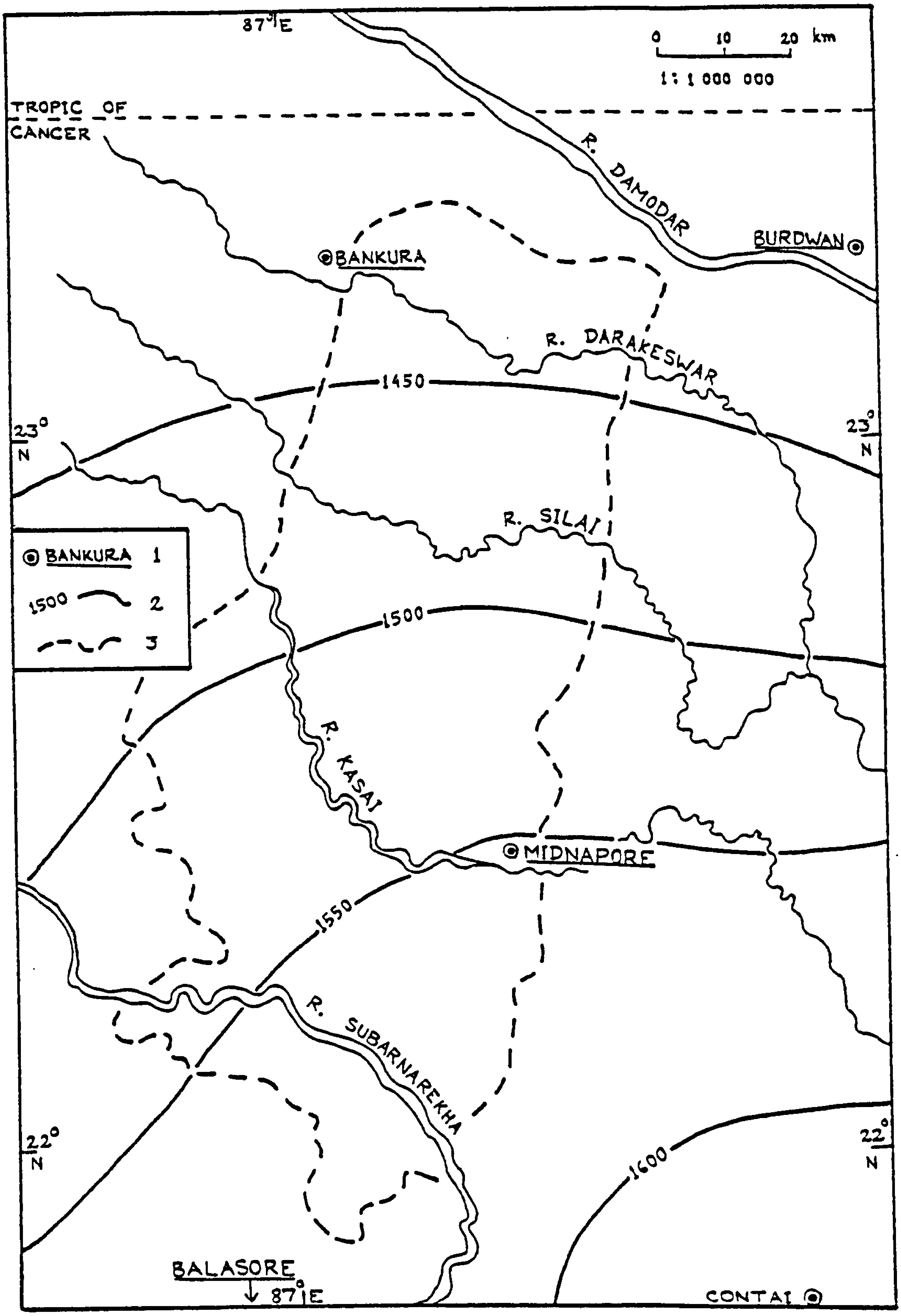


Figure 2.8 Annual rainfall in the Southern Rarh Plain (source of data: India Meteorological Department, 1967).

1. Meteorological station; 2. Isohyet in mm; 3. Approximate boundary of the Southern Rarh Plain.

TABLE 2.4 CLIMATIC TABLE FOR CONTAI

(Based on observations from 1951 to 1960)

MONTH	MEAN MAX. TEMP. DEGREE C	MEAN MIN. TEMP. DEGREE C	MEAN TEMP. DEGREE C	MEAN RAINFALL mm	No. OF RAINY DAYS	HAIL No. OF DAYS
January	26.6	14.5	20.5	16	1.2	0
February	29.4	17.6	23.5	13	0.8	0
March	32.5	22.3	27.4	17	1.6	0
April	33.9	25.9	29.9	19	1.4	0
May	33.6	27.3	30.4	127	4.4	0.3
June	32.5	26.5	29.5	269	11.6	0
July	30.8	26.3	28.5	314	14.7	0
August	31.2	26.2	28.6	384	16.5	0
September	31.1	25.9	28.5	368	14.3	0
October	31.1	24.7	27.9	272	8.9	0
November	29.2	18.8	24.0	38	1.6	0
December	27.1	14.8	20.9	6	0.3	0
total or mean annual	30.7	22.6	26.6	1843	77.3	0.3

source: India Meteorological Department, 1967

TABLE 2.5 CLIMATIC TABLE FOR MIDNAPORE

(Based on observations from 1931 to 1960)

MONTH	MEAN MAX. TEMP. DEGREE C	MEAN MIN. TEMP. DEGREE C	MEAN TEMP. DEGREE C	MEAN RAINFALL mm	No. OF RAINY DAYS	HAIL No. OF DAYS
January	26.9	13.1	20.0	14	1.0	0
February	29.6	15.9	22.7	30	2.1	0
March	35.1	20.8	27.9	34	2.2	0.1
April	38.4	24.6	31.5	44	2.7	0.1
May	38.2	26.3	32.2	109	6.1	0.1
June	35.3	26.5	30.9	232	11.3	0
July	31.9	25.8	28.8	322	16.8	0
August	31.9	25.8	28.8	336	16.8	0
September	32.1	25.6	28.8	262	12.5	0.2
October	31.4	23.0	27.2	132	5.9	0
November	29.0	17.0	23.0	36	1.5	0
December	26.7	13.3	20.0	3	0.2	0
total or mean annual	32.2	21.5	26.8	1554	79.1	0.5

source: India Meteorological Department, 1967

TABLE 2.6 CLIMATIC TABLE FOR BURDWAN

(Based on observations from 1931 to 1960)

MONTH	MEAN MAX. TEMP. DEGREE C	MEAN MIN. TEMP. DEGREE C	MEAN TEMP. DEGREE C	MEAN RAINFALL mm	No. OF RAINY DAYS	HAIL No. OF DAYS
January	26.2	12.7	19.4	11	0.9	0
February	28.6	14.9	21.7	25	1.8	0
March	34.1	20.1	27.1	25	1.7	0.1
April	37.5	24.3	30.9	46	3.0	0.1
May	37.2	25.8	31.5	115	6.5	0.7
June	34.8	26.1	30.4	196	10.6	0
July	32.0	25.8	28.9	314	15.9	0.6
August	31.9	25.8	28.8	301	16.3	0
September	32.2	25.7	28.9	236	11.5	0.1
October	31.4	23.7	27.5	107	5.2	0
November	28.7	17.8	23.2	23	1.1	0
December	26.2	13.6	19.9	4	0.2	0
total or mean annual	31.7	21.4	26.5	1403	74.7	1.6

source: India Meteorological Department, 1967

TABLE 2.7 CLIMATIC TABLE FOR BANKURA
(Based on observations from 1941 to 1960)

MONTH	MEAN MAX. TEMP. DEGREE C	MEAN MIN. TEMP. DEGREE C	MEAN TEMP. DEGREE C	MEAN RAINFALL mm	No. OF RAINY DAYS
January	28.0	13.3	20.6	13	1.2
February	29.6	14.8	22.2	24	1.1
March	33.9	19.8	26.8	26	1.7
April	38.5	23.7	31.1	38	2.6
May	37.6	25.7	31.6	102	4.9
June	36.1	25.5	30.8	219	10.4
July	32.2	25.9	29.0	326	17.4
August	31.7	25.4	28.5	314	16.9
September	33.0	25.2	29.1	234	11.7
October	32.4	22.8	27.6	102	5.5
November	29.8	16.7	23.2	20	1.1
December	26.7	12.0	19.3	4	0.3
total or mean annual	32.5	20.9	26.7	1422	74.8

source: India Meteorological Department, 1967

TABLE 2.8 CLIMATIC TABLE FOR BALSORE

(Based on observations from 1931 to 1960)

MONTH	MEAN RAINFALL mm	No. OF RAINY DAYS
January	15	1.0
February	19	1.5
March	28	1.9
April	42	2.6
May	108	6.1
June	220	11.2
July	336	17.0
August	347	16.8
September	272	13.0
October	168	6.1
November	26	1.6
December	5	0.3
total or mean annual	1586	79.1

source: India Meteorological Department, 1967

TABLE 2.9 SOIL TEMPERATURE AT CALCUTTA

MONTHS	AIR TEMP. DEGREE C	SOIL TEMP. DEGREE C		
		50cm DEPTH	100cm DEPTH	150cm DEPTH
January	20.2	21.33	23.09	24.27
February	23.0	23.32	23.81	24.16
March	27.9	27.31	26.48	25.86
April	30.7	30.61	29.44	28.24
May	31.1	32.47	31.31	30.01
June	30.4	31.88	31.51	30.91
November	23.9	26.32	27.88	28.85
December	21.6	22.45	24.90	26.47
mean annual	26.1	26.96	27.30	27.35
difference between summer (April, May June) and winter (Dec., Jan.,Feb.)	9.13	9.28	6.82	4.75

source: data (unpublished)by courtesy of Director of Agricultural Meteorology, India Meteorological Department.

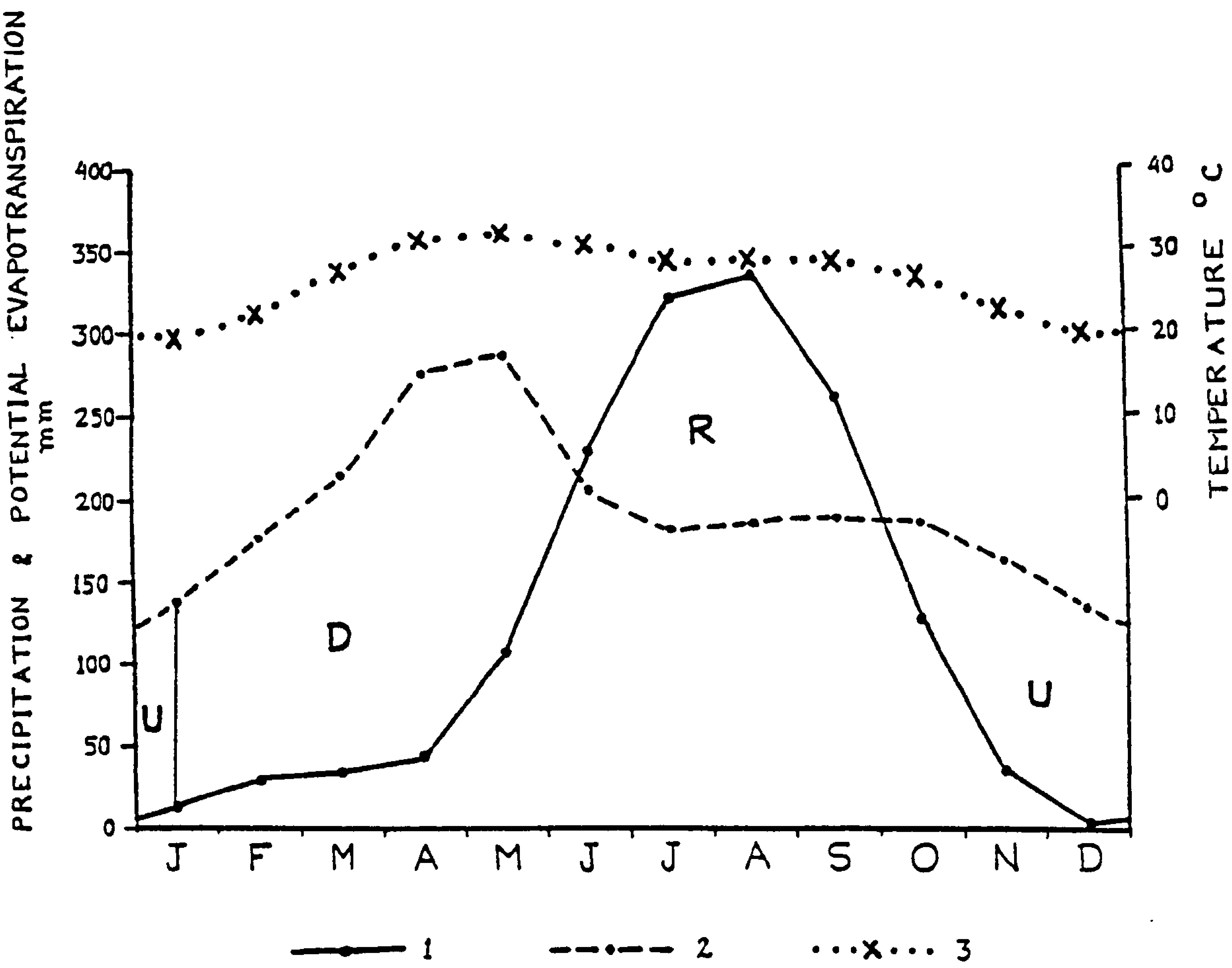


Figure 2.9 Monthly rainfall - evapotranspiration balance diagram for Midnapore (calculated from meteorological data using Penman's formula, 1963).

1. Precipitation; 2. Potential evapotranspiration (Penman, 1963); 3. Temperature.
R = Moisture recharge; U = Moisture utilization; D = Moisture deficit.
Moisture deficit = 150 days;
Moist (cumulative)= 215 days;
Moist (consecutive) = 95 days.

moisture regime. The zone of saturation occupies the whole profile at the base area and is found at progressively deeper levels towards the footslope. The length of the saturation period increases from third order stream basins to streamless valleys.

The difference between air climate and soil climate is clearly reflected in the slope-soil relationships. Soils on the upper slopes are deeply weathered and leached conforming to a climate with high temperature and seasonal rainfall. At the lower slopes, on the other hand, weathering occurs under reducing conditions and leaching is less advanced. These factors, together with the processes of removal and accumulation, contribute towards the decrease of organic matter, bases and salts over the upper slopes and their increase at the lower parts of the slopes.

The seasonality and intensity of rainfall should be conducive to overland flow and soil erosion. Rains come at the end of dry summer when soils are cracked and loose and are liable to be washed out. Insensity of rainfall often exceeds the hydraulic conductivity of the soil, starting overland flow. However, the gentle slopes, the coarse texture of the surface horizons and the vegetation cover all help to reduce excessive overland flow and encourage infiltration of water so that soil erosion is restricted to slight to moderate sheet erosion in the zone of maximum slope (shoulder area) only (SECTIONS 2.1, 2.2 and 2.4).

From the viewpoint of agriculture, the year may be divided into three seasons:

(1) hot and wet monsoon (June to October),
(2) cool and dry winter (November to February) and
(3) hot and dry summer (March to May).

The range of temperature is suitable for growing a great variety of crops at different seasons of the year. But seasonal rainfall limits the choice and growing season of rainfed crops. In the monsoon months, the lower slopes are too wet for any other crop than rice. The upper slopes can be used for other rainfed crops during the wet season, but these areas are usually under forest. During the dry winter and summer, few crops can be successfully grown without irriga-:tion. Obviously the need for irrigation is greater in summer when evapotranspiration is maximum (FIG. 2.9).

Variability of rainfall is also significant to the growing of crops. A 15% or more coefficient of variation for monsoon rains is disastrous for rice. In case of winter rainfall, it is the timing which is important. A slight rain or even cloudy weather during maturity of potato or wheat can seriously damage the crops by encour-:aging pests and diseases. Summer rains are sometimes associated with hail and often with lightning which are harmful to standing crops and forests (TABLES 2.4 - 2.6).

In conclusion, it may be said that although climatic elements set the boundary conditions for soil processes and influence agriculture and land use, their effects are significantly modified by relief and hydrology.

2.4 VEGETATION

The natural vegetation of the Southern Rarh Plain belongs to Champion's "Group 3b-C1, Tropical Moist Deciduous Forest" (Champion, 1936). The vegetation is conspicuous by the dominance of one species - <u>Shorea robusta</u> which constitutes 60-70% of the forest.

Although this is the climatic climax vegetation, its dominance is intensified by human activities. S. robusta is resistant to burning and has the capacity to regenerate after burning or under grazing or as coppice. It is adaptable to varying site conditions and is long-lived.

The common associates in this forest are Terminalia tomentosa, T. arjuna, T. bellerica, Pterocarpus marsupium, Lagerstroemia parviflora, Melia azadirachta, Bombax malabaricum, Bassia latifolia and Butea frondosa. S. robusta and its associates form a moderate canopy at 25-35 m in natural conditions, but in coppice, the canopy is open and reaches 3-8 m. There is a second storey of semi-evergreen shrubs, usually 1 m high, principally composed of Eugenia jambolana, Holarrhena antidysenterica, Diospyros melanoxylon and Zizyphus jujube.

Two palms are common in the landscape - Borassus flabellifer and Phoenix sylvestris. They grow outside the forest. Their distribution is, however, controlled by man, if not actually planted. Grasses are uncommon on the forest floor but grow abundantly in open land. Grasses of this region belong to "Sehima-Dichanthium" type (Dabadghao and Shankarnarayan, 1973). Bamboos, mainly Dendrocalamus strictus and Bambusa arundinacea, are grown in the open land around villages.

Forests cover about 36% of the surface of the Southern Rarh Plain (FIG. 2.10). They are more abundant in the north and west of the region where pressure on land for agriculture is lower. Nearer the towns and villages forests have degenerated into shrubland by cutting for fuel. Only in a few remote areas can traces of original

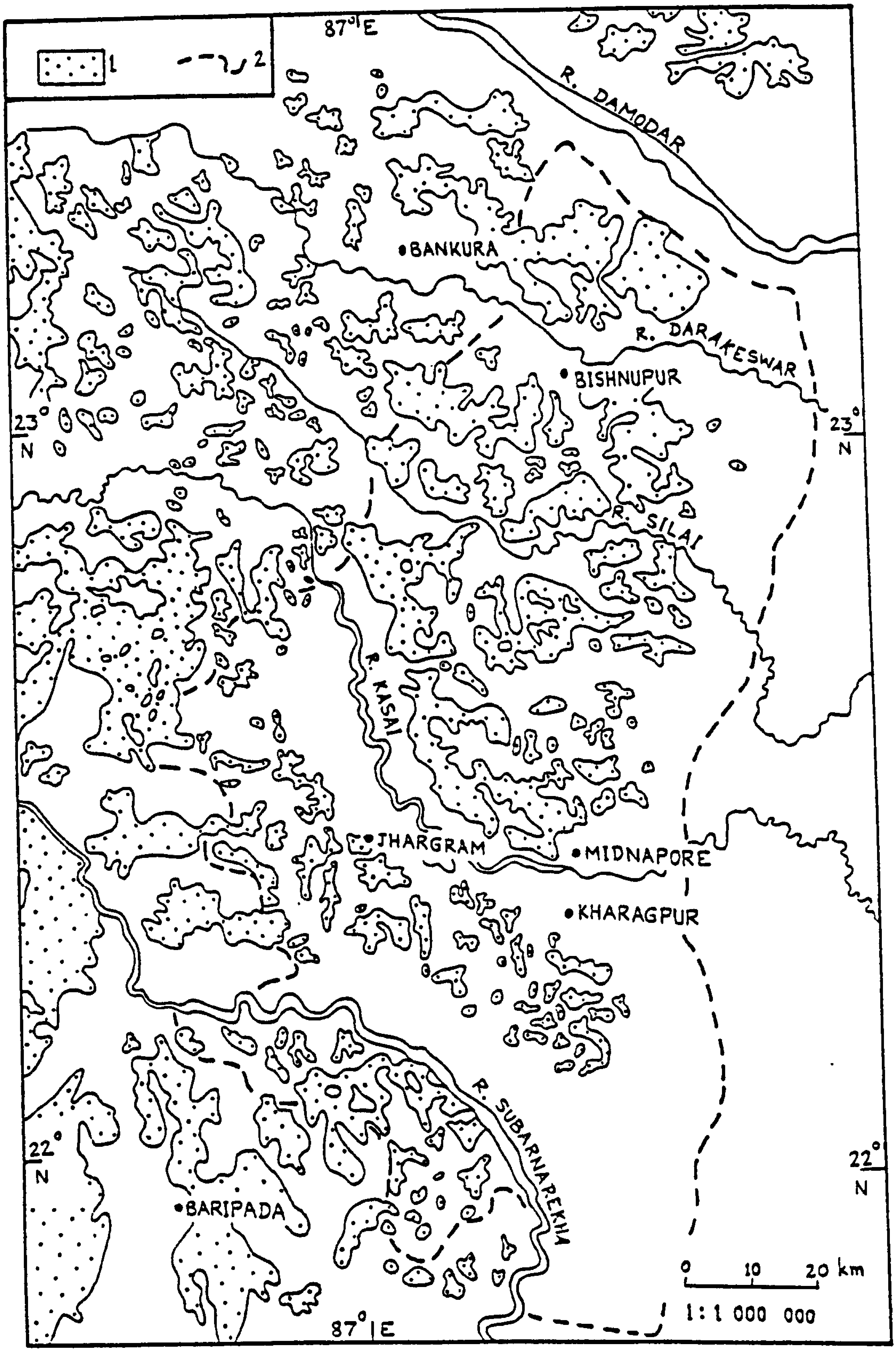


Figure 2.10 Forest cover of the Southern Rarh Plain (after National Atlas Organization, 1972).

1. Forest; 2. Approximate boundary of the Southern Rarh Plain.

forest community be found. Forests occupy a distinct position in the landscape. They occur in the well drained segments of the slope such as summit, shoulder and occasionally footslope. Thus, the undulating topography of this region appears to be crowned with forests at each convexity.

Forests were more extensive in the past, but centuries of persistent felling of trees for timber and fuel, with extension of agriculture, have diminished their area. In 1952 all forests were brought under State control by legislation. Since then afforestation has been in progress, but the Forest Department is replacing the original species composition by plantations of exotic species for rapid commercial return. Two exotic species - Eucalyptus spp. and Acacia auriculiformis have been successfully introduced to this region. Both are quick-growing and Eucalyptus spp. are raised as rotational coppice. Perennial orchards of Anacardium occidentale have also been created. The possibility of introducing a few more species such as Leucaena leucocephala and Agave sisalana is under experiment. In proportion to these species, S. robusta is given a smaller area in the afforestation programme because of its slower rate of growth. The other native species are not replanted at all. Such policy of large-scale replacement of the native forest community, although commercially attractive to the State, is disastrous to the wildlife of the region and to economic conditions and socio-religious traditions of the local people. It is obviously necessary to afforest the areas where forests have been destroyed or excessively disturbed, but the greater proportion of the area ought to be given to the native species. The Eucalyptus spp. and others should be given a smaller proportion of area.

The present forests may be classfied into four types according to the nature of their management (TABLE 2.10). These four types of forests have distinctive influence upon soils and different values as a form of land use. These are explained as follows.

Forests influence the soil mainly through canopy cover and as suppliers of organic matter. In the Southern Rarh Plain, by their typical situation on summits and shoulders, forests protect the most vulnerable parts of the slope from the direct impact of raindrops and from intense runoff. The shade of the forest canopy reduces extremes of soil temperature and excessive moisture loss from soil. These beneficial effects vary according to the density of canopy, from maximum in type D to minimum in type C forests.

The contribution of forest litter to soil organic matter is difficult to assess in this region owing to the following reasons. Firstly, the fallen leaves and twigs are collected for fuel by the local people. Secondly, the green leaves of S. robusta and other species are plucked or directly used for various purposes (TABLE 2.11). Finally, the leaves are shed in spring and, instead of being decomposed, they are dried and blown away during the hot and dry summer. These factors, in addition to the removal by overland flow, prevent greater accumulation of organic matter in the forest soils of the upper slopes. The subterranean supply through roots is more significant and sometimes organic matter is slightly higher around 25 - 50 cm depth than in the surface horizon.

The influence of exotic species on soil properties of this area

TABLE 2.10 CLASSIFICATION OF FORESTS

FOREST TYPE	NATURE OF MANAGEMENT	DEGREE OF MANAGEMENT	PLANT COMMUNITY	CANOPY	AREA AS % OF TOTAL FOREST
A	plantation: rotational coppice	strictly controlled	Eucalyptus spp. mainly, also S. robusta	open to moderate	40%
B	plantation: rotational timber	strictly controlled	S. robusta, Acacia auriculi-:formis, Anarcadium occidentale	moderate	
C	disturbed natural forest: coppice	loose control	S. robusta and associates	open	50%
D	relatively undisturbed natural forest	moderate control	S. robusta and associates	moderate to dense	10%

source: field survey (1976-1982)

TABLE 2.11 FOREST PRODUCTS

PRODUCT	PLANT SPECIES	TYPE OF FOREST
Timber: class A	Shorea robusta, Pterocarpus marsupium	B, D, A
Timber: class B	Eucalyptus spp., Acacia auriculiformis, Terminalia tomentosa, T. arjuna, Bomabax malabaricum, Bassia latifolia	A, B, D
Timber: class C	T. bellerica Lagerstroemia parviflora Melia azadirachta	D
Fuelwood	all	all
Pole	Bamboo	in open areas
Leaves (wrappers & plates)	S. robusta	C mainly
Leaves (wrapping cigars)	Diospyros melanoxylon	C, D
Leaves (rearing silkworm of Anatherea spp.)	T. tomentosa, T. arjuna, L. parviflora, Butea frondosa	C, D
Flowers (edible, alcohol)	Bassia latifolia	C, D
Fruits (edible)	Borassus flabellifer Anacardium occidentale	in open areas and B
Fruits (medicine)	T. bellerica	C, D
Nuts (edible)	Anacardium occidentale	B
Pods (fibre)	Bombax malabaricum	D, C
Sap (alcohol and gur)	Phoenix sylvestris Borassus flabellifer	in open areas
Barks (medicine)	T. arjuna, M. azadir-;achta, Holarrhena antidysenterica	C, D

Note: classes of timber according to Forest Department

source: field survey (1976-1982)

is not known. Yadav et al. (1973) reported that after fifty years of Eucalyptus spp. monoculture in a S. robusta area in Northern India, a decrease in pH and available phosphorus and slight increase of available potassium had been observed.

The commercial value of the forests varies widely from one type to another. The type D forests yield timber, fuelwood and many other produces which are listed in TABLE 2.11. The type A and B forests produce timber, fuelwood and high-value nuts, but the type C forests, occupying greater proportion of the forest areas, are of least commercial value.

The importance of strictly managed forests in supplying organic matter, regulating soil temperature and moisture conditions and preventing soil erosion cannot be over-emphasized. Forests are no less valuable as a form of land use. It is, therefore, necessary to reorganize the disturbed forest areas of this region. Considering the impact on ecological, economic and socio-religious situation, greater proportion of the afforestation should be given to the native forest species. There is, however, a demand for more land for growing food and cash crops with increasing population pressure. This competition for land between forest, pasture and food and cash crops may be resolved by allocating parcels of land to their most "suitable" use. The principles for evaluating the suitability of land for different uses are outlined in the next chapter.

CHAPTER 3

METHODS OF FIELD AND LABORATORY STUDIES

The project began with a reconnaisance survey of the natural resources of the region in 1976. During the survey, a relationship was observed bet:ween the topography, hydrology, soil and vegetation, developing character:istic patterns across the slope for each type of drainage basin. This finding led to the adoption of a land systems approach with drainage basins, classified into Strahler order, as the basic land system and slope segments as facets. A representative area for intensive studies was then selected for each system according to accessibility and availability of base maps at 1:3960 scale. The slopes were surveyed. Soil profiles were examined and additional data on "land qualities" (SECTION 3.5) were collected for each facet. Soil samples were analysed for physical and chemical properties in the laboratory. Finally, the degree of suitability of each facet for different uses was evaluated. This chapter gives an explanatory description of the methods involved at each stage.

3.1 IDENTIFICATION OF LAND FACETS AND LAND SYSTEMS

A "land facet" is defined as an area within which, for practical purposes, environmental conditions are uniform. A "land system" is an area with recurring pattern of environmentally different but genetically linked land facets (Dent and Young, 1981). The identifying environmental charact:eristics of land facets are climate, geology, landform, hydrology, soil and vegetation. Climate and geology are virtually uniform over the Southern Rarh Plain (SECTIONS 2.2 and 2.3). Therefore, the position of the facets in slope, length and angle of slope, drainage, soil and vegetation are employed as the main criteria in identifying land facets. Plinthite and calcium carbonate concretions are also diagnostic criteria because they reflect drainage conditions. The identifying characteristics of each land facet are presented in TABLE 3.1.

In the Southern Rarh Plain, land facets form a regular pattern from the summit to the base of slopes on either side of a drainage basin. The combination of facets, which make up the land systems, change with the stream order (Strahler, 1952) of the basins. There are first, second, third and fourth order stream basins and also streamless basins with or without earth mounds. These six types of drainage basins are recognized as the six land systems. Land system A represents a third order stream basin; B represents a second order stream basin and C a first order stream basin. Systems D and E are basins without permanent stream channels. System D has an effect:ive sheet flow whilst E is distinguished by earth mounds or multi-convexities. System F is the flood plain of fourth order streams. The land systems are also given descriptive names after the locality of the representative study areas. The land system and their constituent facets are listed in TABLE 3.1. Schematic block diagrams of each system are also given in FIGs. 3.1 - 3.6. There are five facets in each of the systems A - E. Since the facets occupy the same position along the slope in these systems, they are given the same name in each of them - "summit", "shoulder", "footslope", "toeslope" and "base" (SECTION 2.1). A land systems map is also prepared (FIG. 3.7). Firstly, the streams are numbered according to Strahler order on 1:50 000 maps, followed by demarcation of basin boundaries by field observation and map inter:pretation. Then, the maps are reduced and compiled on 1:1 000 000 scale. This land systems map is presented in FIG. 4.32 (p. 191a) as the catenary soil map since each system has distinct and recurrent soil pattern.

The summit, shoulder and footslope facets are similar in characteristics in all the systems A - E (TABLE 3.1). These facets are not used to disting:uish the systems. It is the toeslope and base facets which have distinctive characteristics in each system. This is due mainly to the change in hydro:logical conditions from system A to E. In system A, the third order stream has helped to develop the widest

TABLE 3.1 LAND SYSTEMS

LAND SYSTEMS		CONSTITUENT LAND FACETS				
ALPHABETICAL	DESCRIPTIVE	SUMMIT	SHOULDER	FOOTSLOPE	TOESLOPE	BASE
A	Godapiasal system	flat or gently rounded with an angle of 0.1 - 0.2 degrees; 200-500 m in slope length; well drained except when underlain by clay bed as in D; Paleustalf soils (Haplustalf in D); natural or planted forest or rough pasture.	maximum slope angle among the facets, 1-3 degrees; 100-300 m in slope length; well to excessive drainage; Paleustalf soils; natural or planted forest or rough pasture.	slope angle 0.8 - 1.2 degrees; slope length 100-500 m; imperfect drainage; lower horizons affected by fluctuating water-table where plinthite sometimes found; Plinthustalf or Haplustalf soils; cultivated terraced fields; rice and other crops; occasionally under forest.	very shallow basin; 2-3 m lower than the base; slope length 500-700 m; poorly drained; Ochraqualf soils; cultivated, single crop of rice.	alluvial levee; 2-3 m higher than the toeslope; slope angle +/- 0.5 degrees; slope length 400-600 m; poorly drained; Ochraqualf soils; cultivated, multiple crops.
B	Bankadah system				slope angle 0.8 degrees; slope length 200-300 m; poorly drained; Ochraqualf soils; cultivated, multiple crops.	flat; a little alluvial deposit; slope length 100-200 m; poorly drained; Ochraqualf soils; cultivated, multiple crops.
C	Bulanpur system				slope angle 1.0 degree; slope length 150-200 m; poorly drained; Haplaquept soils; cultivated, multiple crops.	flat; slope length 50-100 m; poorly drained; Haplaquept soils; cultivated, multiple crops.

TABLE 3.1 (continued)

LAND SYSTEMS		CONSTITUENT LAND FACETS				
ALPHABETICAL	DESCRIPTIVE	SUMMIT	SHOULDER	FOOTSLOPE	TOESLOPE	BASE
D	Sonamuki system				slope angle 1.0 degree; slope length 150-200 m; imperfectly drained; Haplustalf soils; cultivated, multiple crops.	flat; slope length 50-100 m; poorly drained; Ochraqualf soils; cultivated, multiple crops.
E	Binpur system				multi-convexities; slope angle +/- 1.1 degrees; slope length 100-500 m; imperfectly drained; Haplustalf soils; many calcium carbonate concretions at depth; cultivated, single crop of rice.	flat; slope length 50-100 m; poorly drained; Haplaquept soils, cultivated, multiple crops.
F	Floodplain system	CLIFF			FLOOD PLAIN	
		slope angle 1-30 degrees; slope length 100-1000 m; well to excessively drained; locally very severe gully erosion; natural or planted forest or rough pasture.			flat; slope length 1000-5000 m; recent river alluvium; imperfectly drained; intensive multiple cropping.	

source: field survey (1976 - 1982).

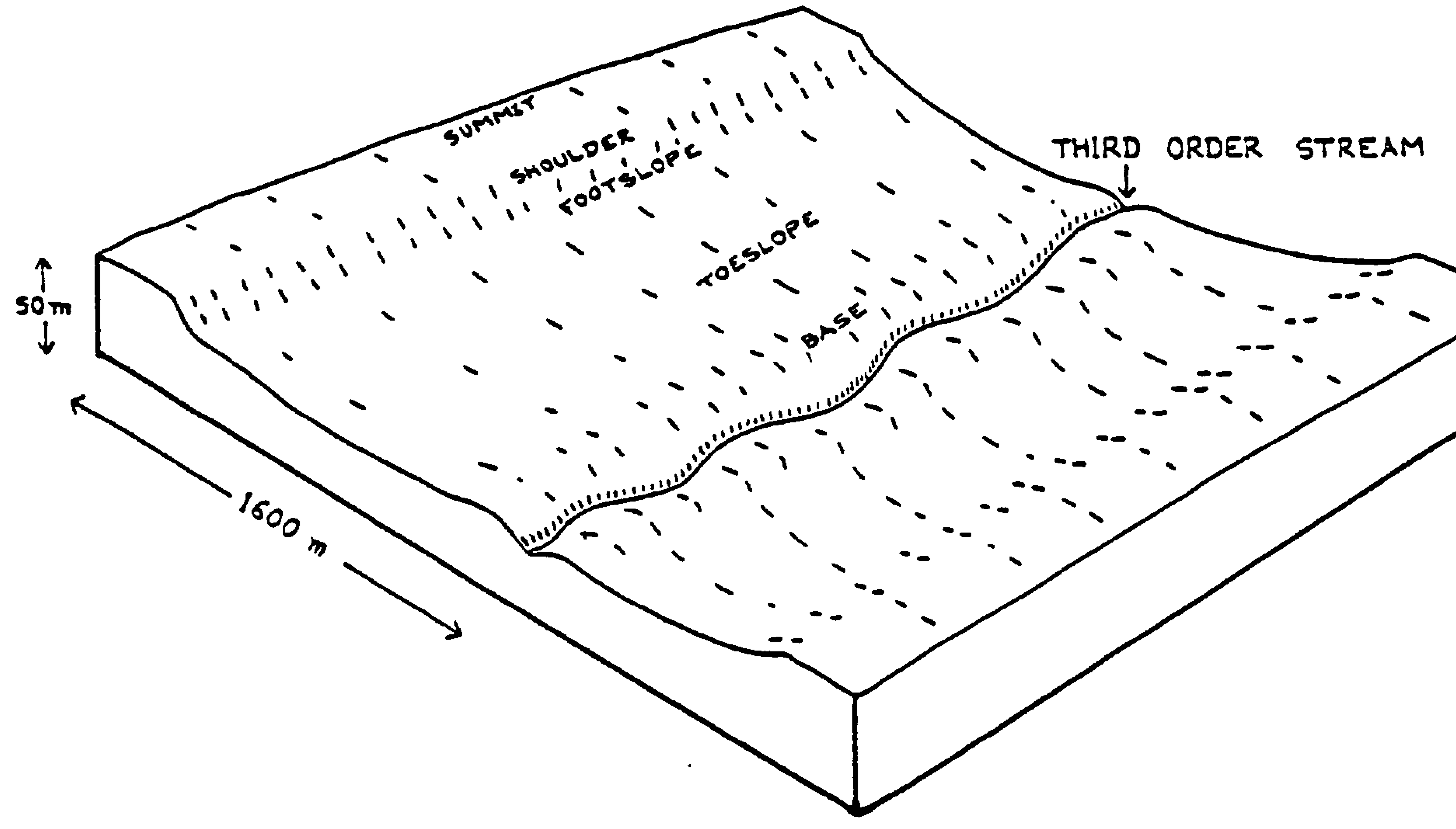


Figure 3.1 Land System A.

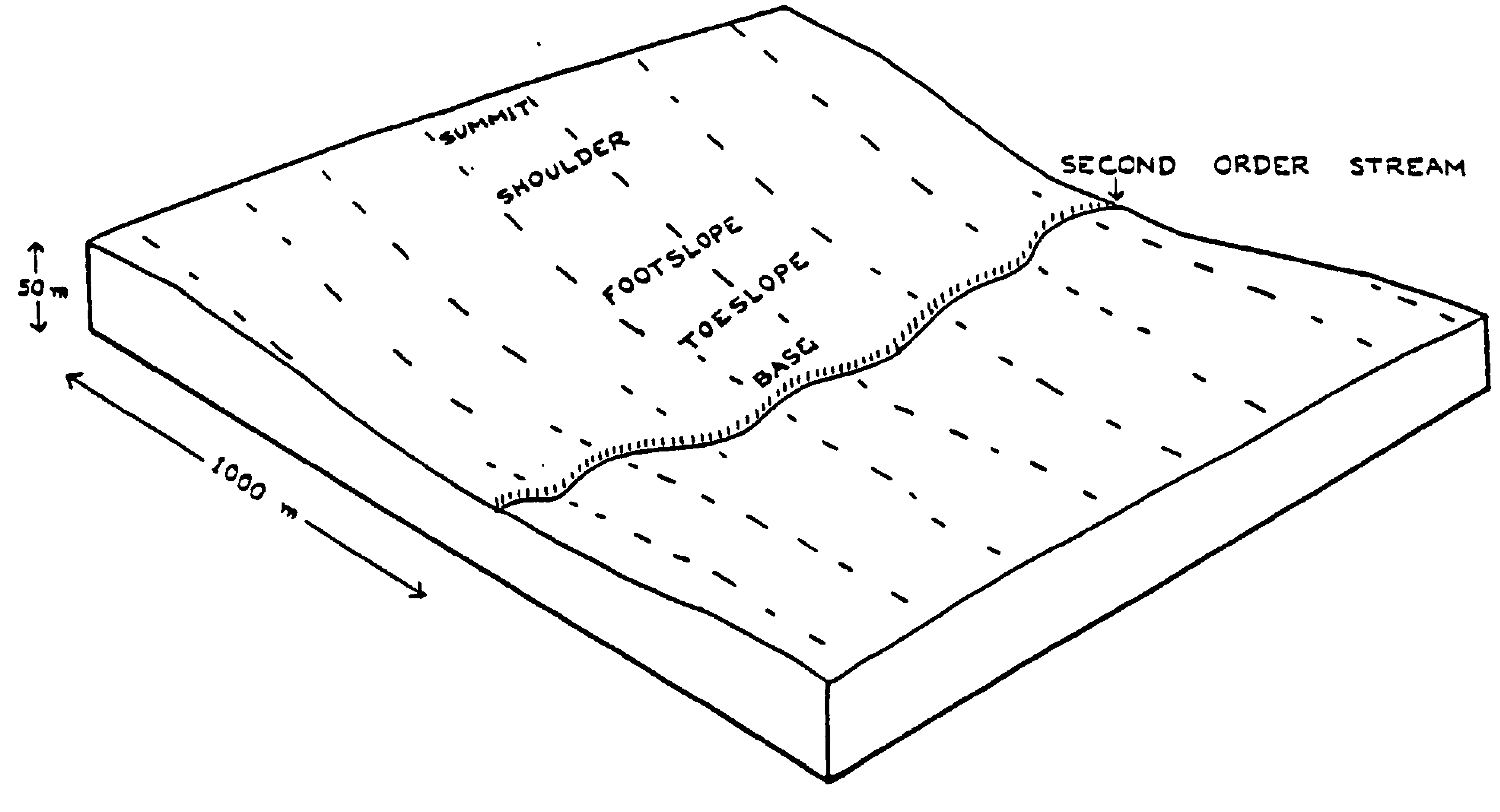


Figure 3.2 Land System B.

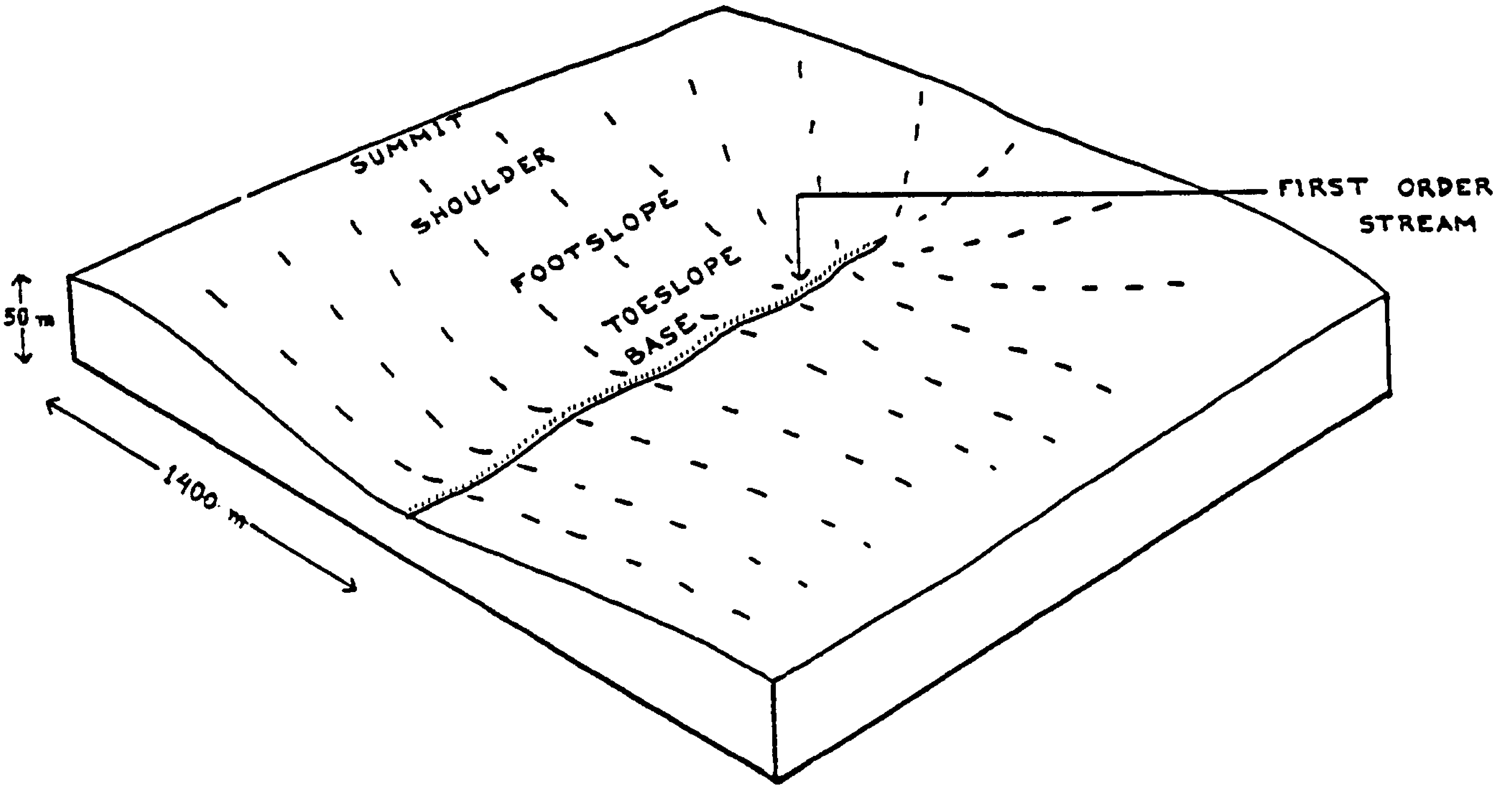


Figure 3.3 Land System C.

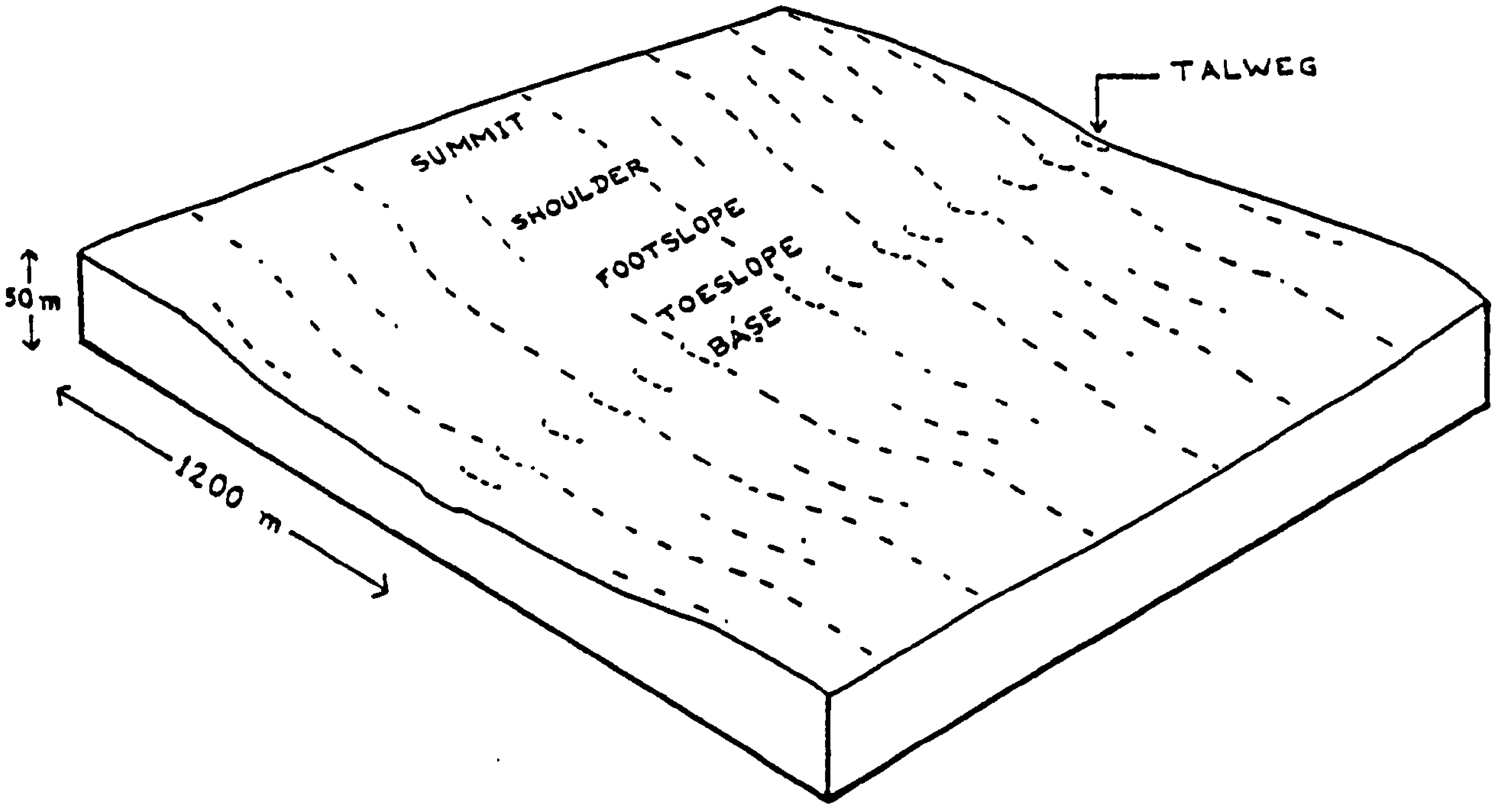


Figure 3.4 Land System D.

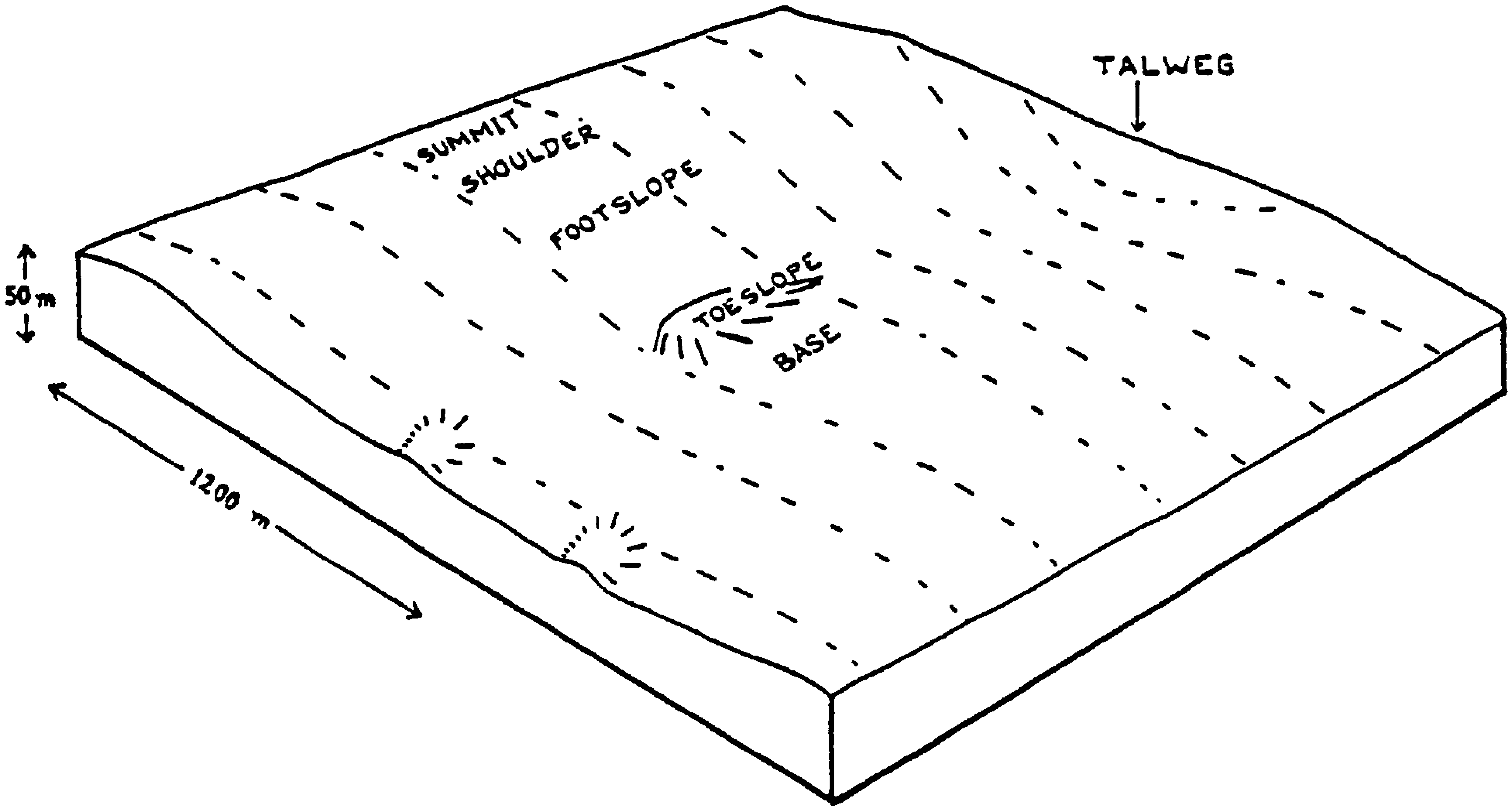


Figure 3.5 Land System E.

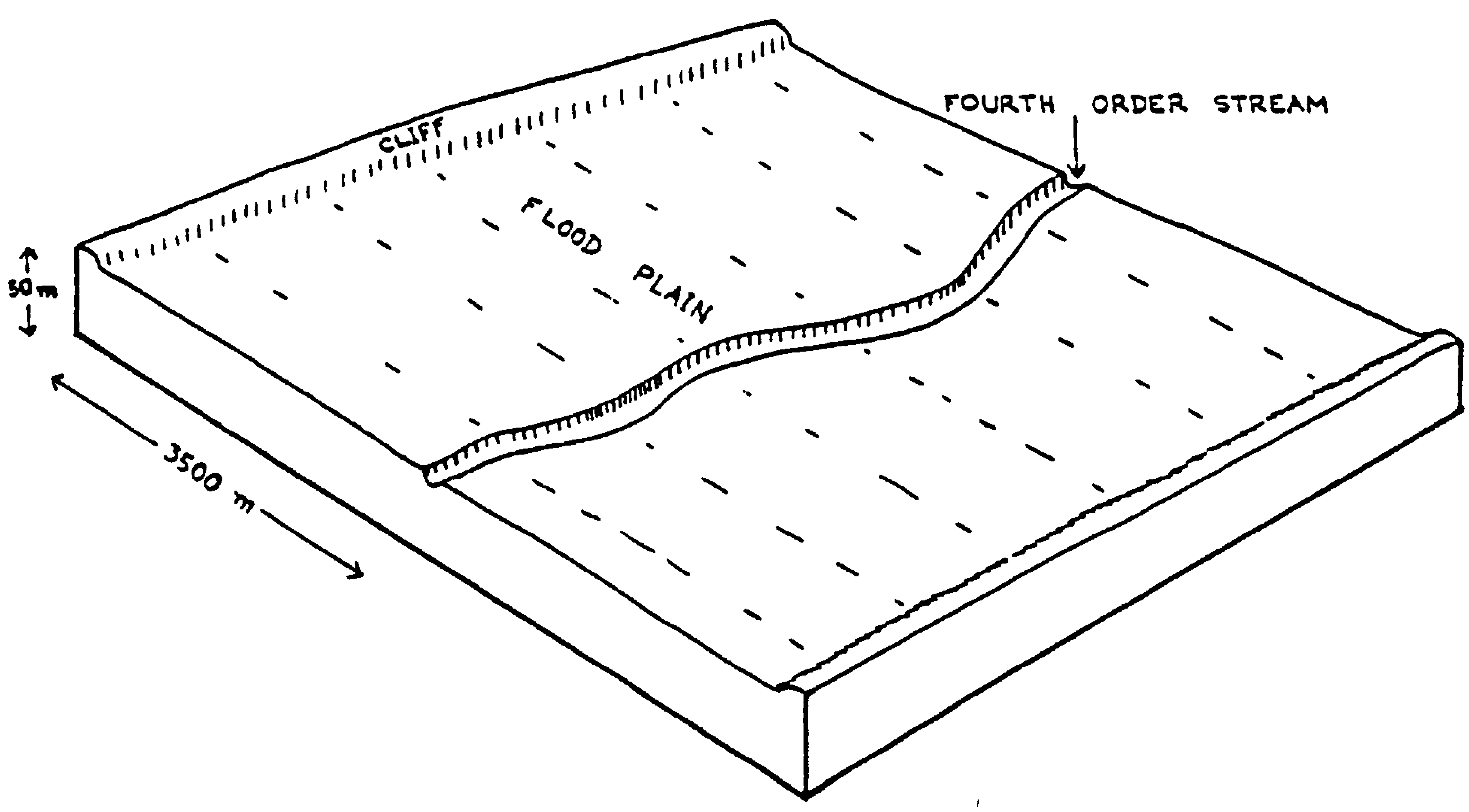


Figure 3.6 Land System F.

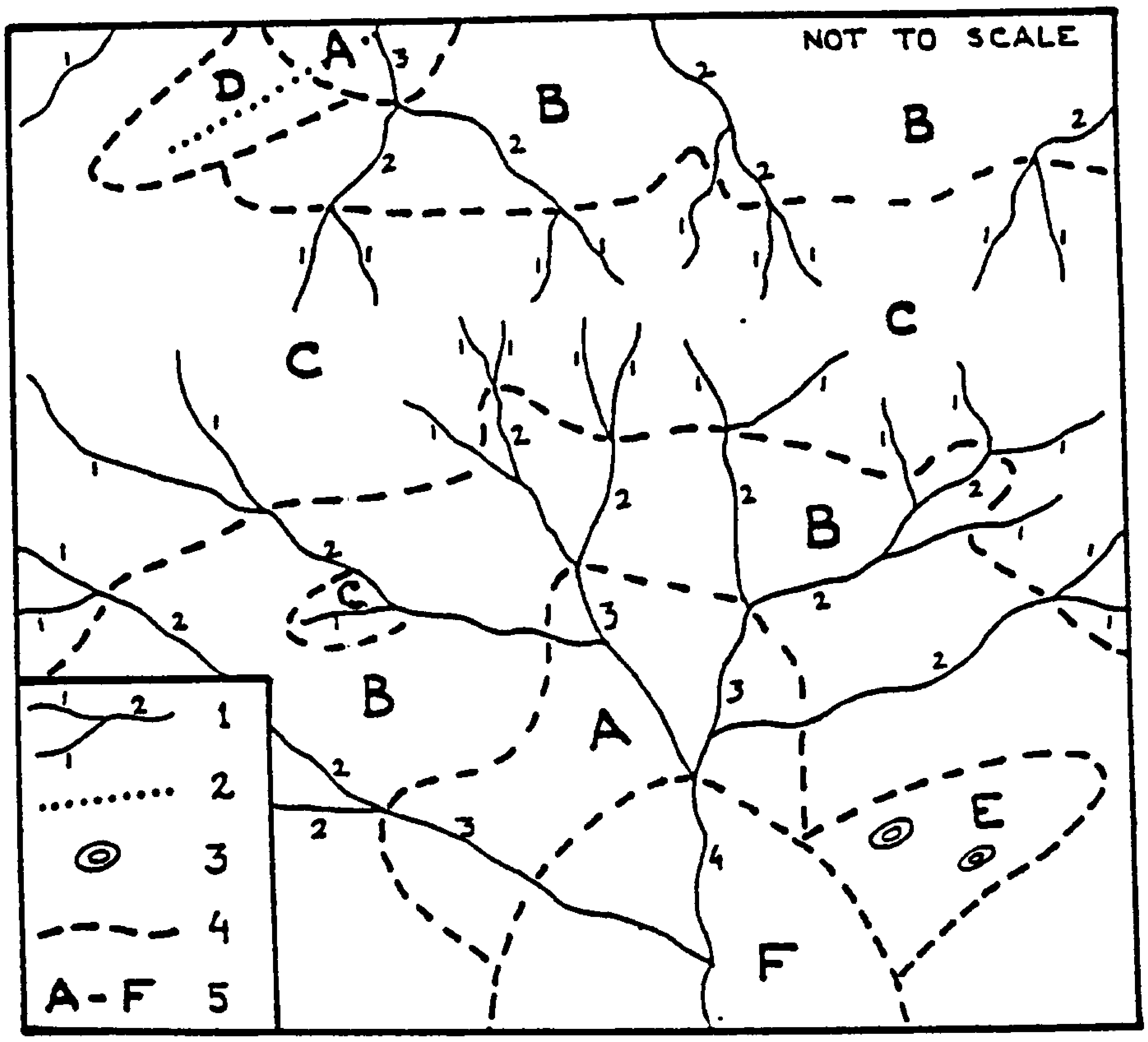


Figure 3.7 Schematic representation of classification and boundary demarcation of drainage basins to serve as land systems (stream order after Strahler, 1952).

1. Streams numbered with Strahler order; 2. Sheet flow; 3. Earth mounds; 4. Land system boundaries; 5. Alphabetical name of land systems.

The area of each order of stream basin is bounded by its junction with lower and upper order basins. For instance, a second order basin extends from the confluence of parent first order streams to the confluence with another second order stream giving rise to a third order stream or to the valley margin of a higher order stream. The area of a streamless basin extends from the valley head to the open end joining a stream basin. There are six types of drainage basins: basins of third, second and first order streams, streamless basin having effective sheet flow, streamless basin with earth mounds and flood plains of fourth order streams. Since the six types of drainage basins have distinctive patterns of topography, hydrology, soil and vegetation developed across the slope, they are called land systems, A - F respectively, and the slope segments are facets. A map showing the distribution of six drainage basins over the region may be called a land systems map. It may also be used as a catenary soil map since the soils have distinct and recurrent pattern across the slope in each system. Such a map has been prepared starting with 1:50 000 scale and then reduced to 1:1 000 000 scale. It is presented as FIGURE 4.32 (page 191a) where the land systems are called catenas.

toeslope and base facets. It has also distinguished the base facet by forming a natural levee which is higher than the toeslope. In system B, the second order stream has developed less wide toeslope and base, and in system C, they are least wide. In both of these systems, the base is flat while the toeslope is gently sloping. The toeslope and base facets are poorly drained in systems A - C. In contrast, only the base facets are poorly drained in the streamless D and E systems while the toeslope is imperfectly drained. The toeslope of E is distinguished from that of D by having mounds or multi-convexities and calcium carbonate concretions.

Thus, it is by (1) the relative width of the toeslope and base, (2) nature of stream deposition upon them, (3) their relative height and angle of slope, (4) soil drainage characteristics and (5) special features, that the facets and systems are distinguished. From detailed field survey it has become obvious that the distinction is hierarchical. Its significance in affecting the patterns of soils and land use is discussed in SECTIONS 4.8 and 5.3.

Land system F has only two facets - the "cliff" and the flood plain. It is in contrast to the toposequential nature of the other systems. It is also very extensive - 2 - 10 km in width as opposed to 1.0 - 1.5 km of the land systems A - E. The soil samples are collected here in a different way from the others (see SECTION 3.3).

The distribution of the land systems in the Southern Rarh Plain and their characteristic soils are further discussed in SECTION 4.9.

3.2 SLOPE SURVEY

The slopes in each toposequence, representing land systems A - E, were surveyed so that quantitative comparison could be made between slopes and soil properties. No survey was made in land system F because of the uniform flatness of the flood plains.

Angles were measured by Abney level and distances by a tape. This method was chosen for cheapness and lightness of instrument and rapidity of survey. More accurate methods such as theodolite survey, levelling or profile recorder were not used because of cost, the heavy weight of the instruments and the slowness of survey, given the area and personnel involved. Angles and distances between two stations were recorded following standard survey procedures (Young, 1974). In land systems A, D and E, angles were measured for every 15 metres; in systems B and C, angles were measured every 10 metres. Angles were read to nearest 10 minutes, but only single observations were made.

Rectangular co-ordinates of each observation point were calcu-:lated using standard formulas (Young, 1974). The slope profile was obtained by plotting rectangular co-ordinates as points and then joining the points by straight lines. Plotting was done by hand. The horizontal scale was plotted at 1:6000, but the vertical scale was exaggerated twelve times (1:500) to emphasize relief. Heights above mean sea-level were determined with reference to spot heights and contours on 1:50000 topographical maps of the Survey of India and, when available, from survey points in the field. The data of the slope surveys are presented in Appendix E. The slope profiles for systems A - E are shown in FIGURES 4.1, 4.6, 4.11, 4.16 and 4.21

3.3 SELECTION OF SOIL SAMPLING SITES AND STUDY OF SOIL MORPHOLOGY

Soil profiles were studied by means of transects orthogonal to the slope in land systems A - E. A profile was also studied in a very severely gully eroded river "cliff" area to enable its comparison with those of the shoulder facets of the systems A - E. Only surface soils were examined in system F because this system, being a virtually flat plain, cannot be compared with the toposequential profile development of the other systems. Moreover, the flood plain is too wide (2 - 10 km) to study soils in detail from the cliff to the edge of the river. There-:fore, ten to twelve surface soil samples were studied at random in the area of a village near the river in each of the four flood plains.

One pit was dug for each facet of the systems A - E. Three exceptions were made. The surface of the shoulder facet of system A consists of massive ironstone (U.S.D.A. rockiness, class 4). No pit could be dug here. In the system C, two additional pits were dug in the footslope facet to study some features of interest (SECTION 4.3). Lastly, the summit and shoulder facets of system E were represented by a single pit because of their similarity in soil characteristics as revealed by the reconnaissance survey.

Auger holes and shallow pits were dug in each facet to make prelim-:inary studies of soils. On the basis of these studies, a site represent-:ative of the soil characteristics of the facet was selected for the sampl-:ing pit at about the middle of the facet on the survey line avoiding disturbed grounds. The sampling pits were dug down to 125 - 150 cm unless a petroferric layer or the water-table was contacted.

The profiles in the systems A - E and in the gully eroded area as well as the surface soils in system F were examined, sampled and described according to the standard techniques set forth in the U.S.D.A.

manuals (Soil Survey Staff, 1951, 1971 and 1975). The following morphological characteristics were recorded for each horizon in the field:

1) distinctness and surface topography of horizon boundaries;
2) moist and dry soil colours with Munsell notations;
3) colour and pattern of mottles, if any;
4) texture by feel;
5) type, class and grade of structure of surface horizons;
6) consistence when wet, moist and dry;
7) number and size of roots;
8) number and type of soil meso-fauna; the U.S.D.A. manuals do not give guide-lines to describe this feature. The following were used for number: 1 = few, 2-5 = common, over 5 = many. Types were recorded as ants, termites, earthworms, spiders, centipedes and millipedes;
9) other features like calcium carbonate concretions, ironstone concretions, massive ironstone and clay skins, if any. Again, in the absence of U.S.D.A. guide-lines, the first two features were described for size: below 5 mm = small, 5-15 mm = medium, over 15 mm = big, and for abundance (by volume): below 2% = a few, 2-20% = common, over 20% = many. Massive ironstone and clay skins were mentioned whether present.

Horizons were provisionally designated by standard symbols in the field and later checked against analytical data (Soil Survey Staff, 1975). Detailed morphological descriptions are presented in Appendices A and D.

3.4 LABORATORY ANALYSES OF SOIL SAMPLES

Soil samples were collected from each horizon. These were air-dried at room temperatures, ground with mortar and pestle and then passed through a 2 mm sieve. Particles greater than 2 mm were weighed and expressed as percentage of the whole soil. These were then discarded. Particles less than 2 mm were retained for laboratory analyses. Subsamples of 2 mm soils were obtained by repeated quartering and the whole subsample was ground to pass through 0.5 mm sieve. These were kept for nitrogen, organic carbon and calcium carbonate determinations.

Soil properties for laboratory analyses were selected with regard to their significance to plant growth. Macro-nutrients and the exchange complex were given emphasis. Nitrogen, available phosphorus and available potassium were determined. Calcium, magnes-:ium, potassium and sodium were analysed as exchangeable cations. Exchange acidity was determined to get cation exchange capacity by summation and to calculate the lime requirement of soils. Organic matter, a major source and medium of exchange of these nutrients, was calculated from organic carbon.

Soils were tested for exchangeable aluminium to find its level of toxicity. The quantity of soluble salts was also checked, for it may be a possible source of agricultural problems under irrigation. The pH, which may be regarded as a reflection of many soil properties, was also determined. Calcium carbonates and free iron oxides were analysed because concretions of both of them are found in the soils of this region.

Among physical properties, importance was given to those related to supply of water to plants. Field capacity and wilting point were determined. Available water capacity, bulk density and porosity were calculated from them. Particle size distribution was analysed. Finally, moisture loss was determined to express the analytical results on oven-dry basis.

Analytical methods were selected with regard to both simplicity and accuracy. Two volumes of "Methods of Soil Analysis" edited by Black (1965) were the main sources of methods with a few additional references. The methods are listed below:

(1) moisture loss by drying soil samples overnight in an oven at 105 degree C (Black, p. 92-93);

(2) total nitrogen by the standard macro-Kjeldahl method (Black, p. 1162-1164);

(3) organic carbon by the Walkley-Black method (Black, p. 1374-1375);

(4) available phosphorus by extracting from soil with 1N ammonium acetate buffered at pH 4.5, followed by colori-:metric determination against standard phosphorus solutions at 640 mμ on EEL spectrophotometer (Van Den Hende, <u>et al</u>., 1952);

(5) available potassium by extracting soil as in (4) and flame photometric determination against standard potassium solutions (Van Den Hende, <u>et al</u>., 1952);

(6) exchangeable calcium, magnesium, potassium and sodium by leaching soil with 1N ammonium acetate buffered at pH 7.0 (Metson, 1961, p. 104 and Black, p. 894-895); flame photometric determination of potassium and sodium and atomic absorption spectrophotometric determination of calcium and magnesium in the leachate;

(7) exchange acidity by leaching soil with barium chloride-triethanolamine solution buffered at pH 8.0 and titrating the leachate with standard acid (Black, p. 910-911);

(8) exchangeable aluminium by leaching soil with 1N potassium chloride and titrating the leachate with standard alkali and acid (Black, p. 988 and 994):

(9) pH with glass electrode pH-meter in distilled water and also in 0.01M calcium chloride at soil to liquid ratio 1:2.5 (Black, p. 922-923). The salt solution is approximately equivalent to total electrolytic concentrat-:ion of soil solution and gives a pH value independent of dilution and initial amount of salt present in soil. Therefore, it reproduces pH value closer to actual field conditions regardless of the time of sampling. The pH values in salt solution are used in this thesis;

(10) electrical conductivity with EIL portable conductivity

measuring set at soil-water ratio 1:5 (Black, p. 935-939);

(11) calcium carbonate using a Collins' calcimeter (Wright, 1939);

(12) free iron oxides by reducing and releasing them into solution with sodium dithionite-citrate-bicarbonate treatment and measuring Fe by atomic absorption spectrophotometry (Black, p. 575-576);

(13) particle size by pipette sampling for silt and clay and sieving for fine and coarse sands (Black, p. 554-557);

(14) field capacity by means of porous plate assembly at a tension of 0.1 bar (Department of Agriculture, 1980);

(15) wilting point by means of pressure cell at a pressure of 15 bar (Department of Agriculture, 1980).

The physical and chemical properties of soil samples are entered in Appendices A and D.

3.5 CONCEPTS, PROCESSES AND STRUCTURES OF LAND SUITABILITY EVALUATION

Land evaluation is the process of estimating the potential of land for different kinds of use. There are several systems of evaluation in current practice. The F.A.O. framework for "Land Suitability Evaluation" (F.A.O., 1976 and Beek, 1978) is adopted in this study. Other methods such as "Land Capability Classification" (Klingebiel and Montgomery, 1961), "Land Classification for Irrigation" (U.S. Bureau of Reclamation, 1953) and "Productivity Indices" (Storie, 1954 and Riquier _et al_., 1970) are less appropriate for the present project. Land Capability Classification is simple but it refers to general types of land use only, such as arable, pasture and forest. It considers the capability of land but the requirements of specific land use types are not analysed in any detail. For example, the lower facets of the land systems, which are the best lands for rice, fall into the non-arable class (V) in this system because of wetness.

"Land Classification for Irrigation" assesses the "payment capacity" of land under irrigation. However, in this region the State policy is to provide irrigation to all agricultural land regardless of the degree of economic return. "Productivity Indices" are not used because these refer to plant nutrients, soil toxicity, soil drainage and other soil related factors, but the influences of temperature, photoperiod and other climatic factors upon plant growth are not considered. The new system of "Fertility Capability Classification" (Sanchez _et al._, 1982) is not attempted for the same reason.

Land suitability is the fitness of a unit of land for a defined use. Separate classifications are made with respect to each type of land use relevant to the area. The land may be considered in its present condition or after improvements. The F.A.O. framework does not by itself constitute a system. It is a set of principles and concepts on the basis of which evaluation systems can be constructed. These concepts are defined below (F.A.O., 1976 and Beek, 1978).

1. LAND is an area of earth's surface, the characteristics of which include topography, geology, soil, hydrology, climate, plants, animals and the results of past and present human activity, to the extent that these influence potential for land use.

2. LAND MAPPING UNIT (LU) is an area of land demarcated on map, and possessing specified land characteristics. Land facets are employed as land mapping units in this thesis.

3. LAND CHARACTERISTIC is an attribute of land that can be measured or estimated. Examples are slope, angle, soil texture, rainfall, etc.

Land characteristics are difficult to use directly in evaluation because of interaction between them. For example, resis-:tance to erosion is determined by interactions between angle and length of slope, soil structure, permeability, time and intensity of rainfall and vegetation cover. Therefore, land qualities are used in the evaluation process.

4. LAND QUALITY (LQ) is a complex attribute of land which acts distinctly from other qualities in its influence on the suitability land for a specified kind of use. The expression of each land quality is determined by single or compound land characteristic. The land quality is more useful than land characteristics, but more subject-:ive at present. Examples of land qualities are water availability, resistance to erosion, etc.

5. MAJOR KIND OF LAND USE is a major subdivision of rural land use, such as rainfed agriculture, irrigated agriculture, grassland, forest and recreation.

6. LAND UTILIZATION TYPE (LUT) is a kind of land use described in greater detail than a major kind of use. The attributes for description are produce, market orientation, capital intensity, labour intensity, technology, power sources, size and configuration of holding and land tenure. An example is "rainfed rice for subsistence consump-:tion by owner/tenant small-holders with low capital, high labour intensity using cattle-drawn and hand implements on small scattered plots, 0.1-3.0 ha in total size". In this project, land utilization types are used in evaluation.

7. LAND USE REQUIREMENT (LR) refers to the set of land qualit-:ies required for proper functioning of a land utilization type.

Examples are water requirement, nutrient requirement, oxygen require-:ment for roots, etc.

Land mapping units i.e. the land facets are described in SECTION 3.1. A list of land characteristics appropriate to the Southern Rarh Plain is given in TABLE 3.2. Since the land qualities and land use requirements are associated, they are presented together in TABLE 3.3. Current and potential land use types are described in TABLE 3.4.

Each land (mapping) unit is evaluated by comparing its qualities with the requirements of each land use type. The comparison leads to land suitability classification. A very good match is classed as "highly suitable" i.e. all the requirements are satisfied by the qualities and a sustained high yield of the LUT can be obtained. Then there is the "moderately suitable" class where the qualities fail to meet one or more requirements at their optimum level so that the yield of the LUT is reduced. When the qualities are at the limit of the tolerance range of one or more requirements, the land unit is classed as "marginally suitable" and signifies a low yield of the LUT. If the qualities are beyond the tolerance range of one or more requirements, the yield becomes too low and the land unit is classed as "not suitable" for that LUT. There are two "not suitable" classes - currently and permanently not suitable. Only the "perman-:ently not suitable" class is employed in this project for the sake of simplicity. There is another class "conditionally suitable", but its excessive use is discouraged by the F.A.O. (1976) for it may lead to complication. This class is entirely avoided in this project.

The suitability class names are represented by upper case letters

TABLE 3.2 LAND CHARACTERISTICS

SL. NO.	LAND CHARACTERISTICS	UNIT OF MEASUREMENT	METHOD OF MEASUREMENT	REFERENCE
1	position on slope	facet	slope survey	Young, 1974
2	slope angle	degree	slope survey	"
3	slope length	metre	slope survey	"
4	soil erosion	class	field work	Soil Survey
5	damaging floods	class	reports	Staff, 1951
6	soil drainage	class	field work	"
7	depth to water-table	class	field work	"
8	effective soil depth	class	field work	"
9	soil structure	class	field work	"
10	soil consistence	class	field work	"
11	soil texture	class	lab. expt.	"
12	soil reaction	pH	lab. expt.	Black, 1965
13	organic matter	%	lab. expt.	"
14	nitrogen	%	lab. expt.	"
15	available phosphorus	µg/g	lab. expt.	"
16	available potassium	µg/g	lab. expt.	"
17	cation exchange capacity	me/100g	lab. expt.	"
18	exchangeable bases	me/100g	lab. expt.	"
19	base saturation	%	lab. expt.	"
20	aluminium saturation	%	lab. expt.	"
21	sodium saturation	%	lab. expt.	"
22	electrical conductivity	mmhos/cm	lab. expt.	"
23	mean daily sunshine	h	reports	India Met.
24	length of day	h	reports	Dept., 1967
25	temperature regime	degree C	reports	"
26	rainfall regime	mm	reports	"
27	damaging drought	frequency	reports	"
28	relative humidity	%	reports	"
29	damaging storms	frequency	reports	"
30	damaging hail	frequency	reports	"
31	pests, related to land, affecting plants	type	field work	Purseglove, 1968 & 1972
32	diseases, caused by soil or climate, affecting plants	type	field work and reports	"

TABLE 3.3 LAND QUALITIES AND LAND USE REQUIREMENTS

Serial No.	LAND QUALITIES/LAND USE REQUIREMENTS	CONSTITUENT LAND CHARACTERISTICS
1	Temperature	mean monthly max. and min. temp. in degree C.
2	Photoperiod	short day (below 12 h), long day (above 12 h) and day neutral.
3	Water for plant uptake	monthly water in mm (for estimation of water, see SECTION 3.6).
4	Other climatic conditions	relative humidity (%), frequency of hail, frequency of storm, frequency of heavy rains, frequency of drought, dry period for ripening, sunshine (h).
5	Soil conditions	texture (U.S.D.A. class), structure (U.S.D.A. class), consistence (U.S.D.A. class), depth: shallow = 0-50 cm, moderately deep = 50-100 cm, deep = more than 100 cm.
6	Soil drainage	drainage class (U.S.D.A.).
7	Nutrients	(see below)
8	Salinity	electrical conductivity mmhos/cm - 0-2 = non-saline, 2-4 = moderately sline, above 4 = saline.

7 Nutrients:

	LOW	MEDIUM	HIGH
organic matter (%)	0-1	1-2	above 2
nitrogen (%)	0-0.05	0.05-0.1	above 0.1
available P (kg/ha)	0-10	10-50	above 50
available K (kg/ha)	0-150	150-400	above 40C
C.E.C. (me/100g)	0-10	10-20	above 20
exchangeable Ca (me/100g)	0-6	6-12	above 12
exchangeable Mg (me/100g)	0-1.5	1.5-3.0	above 3.C
base saturation (%)	0-50	50-75	above 75

(after I.C.A.R., 1980)

TABLE 3.3 (continued)

Serial No.	LAND QUALITIES/LAND USE REQUIREMENTS	CONSTITUENT LAND CHARACTERISTICS
9	Soil toxicity	exchangeable sodium percentage below 15 and pH below 8.5 = non-toxic; aluminium saturation percentage below 60 = non-toxic.
10	Pests and diseases	termites, locusts, high humidity and poor drainage encouraging disease.
11	Soil erosion	erosion class (U.S.D.A.).
12	Flood hazard	flooding class (U.S.D.A.).

source: see TABLE 3.2 and SECTION 3.6

TABLE 3.4 LAND UTILIZATION TYPES

(a) CURRENT LUT (source: see SECTION 3.6)

LUT	PRODUCE	MARKET	CAPITAL	LABOUR	TECHNOLOGY	POWER	HOLDING	LAND TENURE
Rainfed annual food crops	18 crops; rice, pulses, beans, etc.	subsist-:ence & trade	low	high	traditional	animal & human	small & scattered	owner & tenant
Rainfed annual cash crops	2 crops; safflower & castor	trade & subsist-:ence	low	high	traditional	animal & human	small & scattered	owner & tenant
Rainfed perennial food crops	2 crops; papaya & banana	subsist-:ence & trade	low	medium	traditional	human	small & scattered	owner
Rainfed perennial orchard	11 crops; mango, guava,etc.	subsist-:ence & trade	low	medium	traditional	human	small & scattered	owner & tenant
Irrigated annual food crops	16 crops; wheat, potato, etc.	subsist-:ence & trade.	medium	high	intermediate	animal, human, diesel	small & scattered	owner & tenant
Irrigated annual cash crops	4 crops; mustard, sesame, etc.	trade & subsist-:ence	medium	high	intermediate	animal, human, diesel	small & scattered	owner & tenant
Irrigated perennial cash crops	2 crops; sugarcane & betel	trade & subsist-:ence	medium	high	intermediate	animal, human, diesel	small & scattered	owner & tenant

TABLE 3.4 (continued)

(a) CURRENT LUT (continued)

LUT	PRODUCE	MARKET	CAPITAL	LABOUR	TECHNOLOGY	POWER	HOLDING	LAND TENURE
Natural pasture	15 grasses & legumes	-	-	-	-	-	various	"common"
Planted grass & bamboo	1 grass & 2 bamboos	subsist-:ence & trade	low	low	traditional	human	various	owner
Natural forest	11 trees; <u>S. robusta</u>, etc.	gather-:ing & trade	-	-	-	-	various	state & "common"
Forest plant-:ation	3 trees; <u>Eucalyptus</u>, etc.	trade	low	low	intermediate	human	various	state

TABLE 3.4 (continued)

(b) POTENTIAL LUT (source: see SECTION 3.6)

LUT	PRODUCE	MARKET	CAPITAL	LABOUR	TECHNOLOGY	POWER	HOLDING	LAND TENURE
Rainfed annual food crops	15 crops; soya bean, millets, etc.	subsist-:ence & trade	low	high	traditional	animal & human	small & scattered	owner & tenant
Rainfed annual cash crops	7 crops; groundnut, cotton et.	trade & subsist-:ence	low	high	traditional	animal & human	small & scattered	owner & tenant
Rainfed perennial food crop	1 crop; cassava	subsist-:ence & trade	low	medium	traditional	animal & human	small & scattered	owner & tenant
Rainfed perennial cash crops	3 crops; sisal, cantala,etc.	trade & subsist-ence	low	medium	traditional	human	small & scattered	owner & tenant
Rainfed perennial orchard	13 crops; pineapple, citrus, etc.	trade & subsist-:ence	low	medium	traditional	human	small & scattered	owner & tenant
Irrigated annual food crop	1 crop; barley	subsist-:ence & trade	medium	high	intermediate	animal, human, diesel	small & scattered	owner & tenant
Irrigated annual cash crops	2 crops; sunflower & jute	trade & subsist-:ence	medium	high	intermediate	animal human, diesel	small & scattered	owner & tenant

TABLE 3.4 (continued)

(b) POTENTIAL LUT (continued)

LUT	PRODUCE	MARKET	CAPITAL	LABOUR	TECHNOLOGY	POWER	HOLDING	LAND TENURE
Irrigated perennial cash crops	2 crops; ramie & black pepper	trade & subsist-:ence	medium	high	intermediate	animal, human, diesel	small & scattered	owner & tenant
Irrigated perennial orchard	2 crops; papaya & banana	trade & subsist-:ence	medium	medium	intermediate	animal, human, diesel	small & scattered	owner & tenant
Improved pasture	15 grasses & legumes	subsist-:ence	medium	medium	intermediate	animal & human	various	"common" & owner
Forest plant-:ation	6 trees	subsist-:ence	low	low	traditional	human	various	"common" & owner

and arabic numerals. The unsatisfied requirements or the limiting land qualities are added to them as lower case letter symbols to distinguish at subclass level. Obviously no subclass symbols are used in case of "highly suitable" class where there is no unsatisfied requirement. The subclasses may be further divided, according to minor differences in management, into "units" at the subsequent level. The classification into units is required for detailed farm planning. Since this is beyond the scope of this project, the suitability classification is not made beyond the subclass level. The structure of the suitability classification as adapted for this thesis, together with the symbols used, is summarized in TABLE 3.5. The sequence of activities in conducting a suitability evaluation is presented in FIG. 3.8. The process of comparing land qualities with requirements is explained as follows.

The determination of the suitability classes is made by the "limiting conditions" method (Dent and Young, 1981). This involved comparison of each quality with the corresponding requirement and their individual suitability classification. Then the lowest individual class is taken as the suitability class of the land unit for that land use type.

This process may be illustrated by evaluating the toeslope facet of land system B for a potential rainfed annual food crop - soya bean. This crop can be grown between July and November when the mean maximum and minimum temperatures should be 30 and 20 degrees C respectively. The mean maximum temperature of the toeslope of system B (31.2 degrees C) just falls beyond the optimum, but within the tolerance range. The land unit is, therefore, rated <u>S2</u> on temper-

TABLE 3.5 STRUCTURE OF LAND SUITABILITY CLASSIFICATION

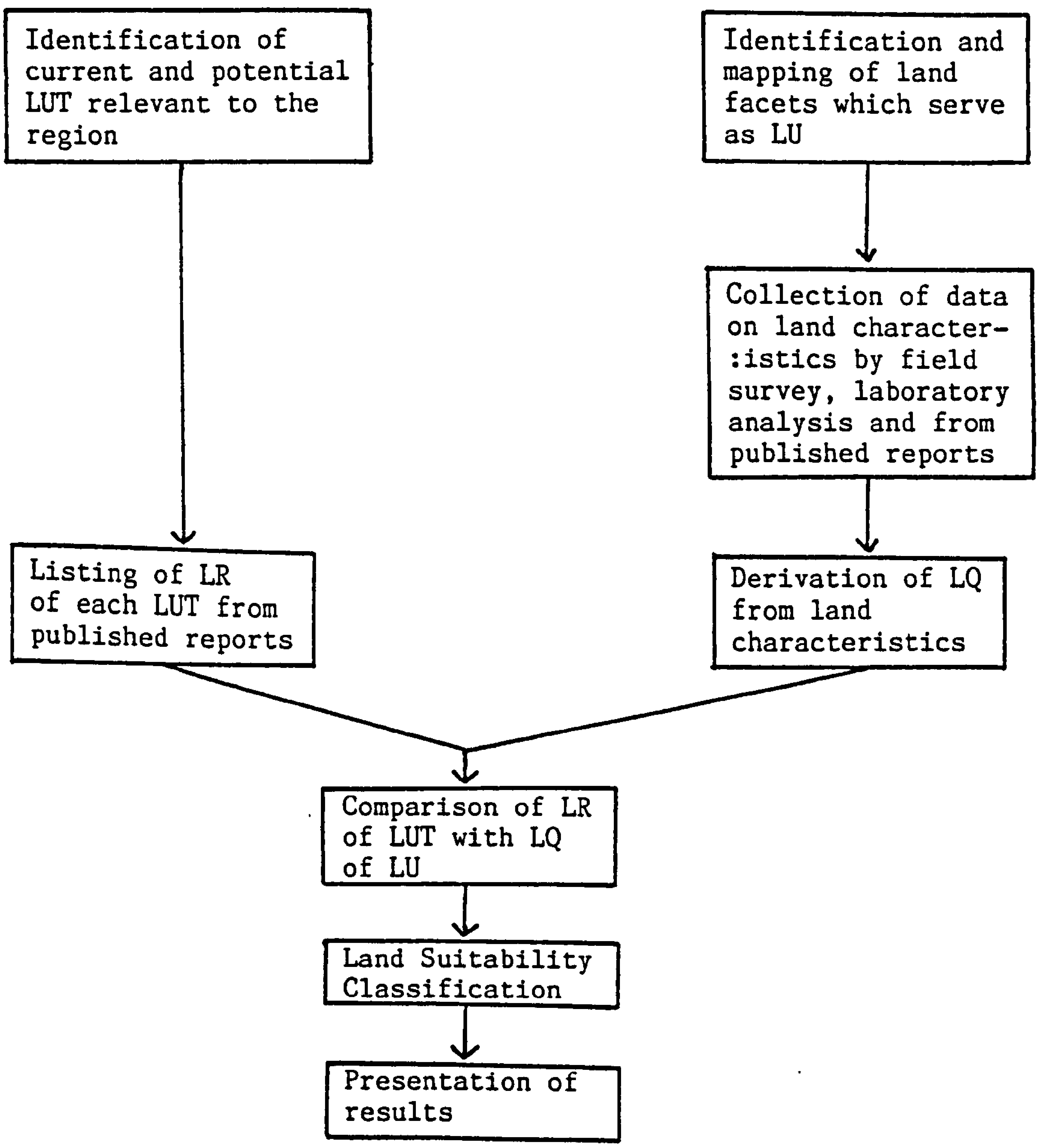
ORDER (Kind of Suitability)	CLASS (Degree of Suitability)	SUBCLASS (Kind of Limitation)
S (suitable)	S1 (highly suitable)	no subclass
	S2 (moderately suitable)	S2m, S2o, S2n, etc. (see note)
	S3 (marginally suitable)	S3m, S3o, S3t, etc.
N (not suitable)	N2 (permanently not suitable)	N2o, N2s, N2m, etc.

source: adapted from F.A.O., 1976

NOTE: SUBCLASS SYMBOLS DENOTING KINDS OF LIMITATION

c = climate
d = pests and diseases
e = erosion
f = flood
m = moisture
n = nutrients
o = oxygen deficiency (soil drainage)
p = photoperiod
r = soil reaction
s = soil depth, texture, structure and consistence
t = temperature

FIG. 3.8 SCHEMATIC REPRESENTATION OF ACTIVITIES IN LAND SUITABILITY CLASSIFICATION (after F.A.O., 1976)



:ature. Similarly, the land unit is rated S1 on soil conditions because it has the deep loamy soil required by the crop. The soya bean has "day neutral" varieties; so the land unit may be rated S1 on photoperiod also. The nutrient requirement of the crop is "high", but the nutrient status of the land unit is "low-medium". However, nutrient is not regarded as a significant limitation, for it can be improved. The land unit is rated S2 on nutrients. The water availability of the land unit during July-November (1094 mm) is more than the optimum level for the crop (600-900 mm). So the unit is also S2 on water. Lastly, the crop requires "moderately well" drainage for optimum yield, but the land unit is poorly drained and, therefore, falls just at the tolerance limit of the crop. Since drainage is a significant requirement and can reduce the yield sub:stantially, the land is rated S3 on drainage. Therefore, accord:ing to the principles of "limiting conditions", the toeslope of system B is classified as S3o for soya bean, the symbol "o" representing drainage limitation or oxygen deficiency for roots (TABLE 3.5). Only the limitation(s), determining the class, is indicated with the subclass symbol in the final classification.

3.6 COLLECTION OF DATA FOR EVALUATION PROCESSES

Two sets of data are required for land suitability evaluation: (1) the land qualities of each land unit and (2) the land requirements of each land use type. The land units are identified by surveys as described in SECTION 3.1. Then the data on their land character:istics are compiled (TABLE 3.2). The characteristics related to landform are obtained by slope survey, field measurements and observ:ations. The morphological, physical and chemical characteristics of soils are gathered from field and laboratory studies. The characteristics of climate, excepting rainfall, are virtually uniform over the region (SECTION 2.3). The regional average values of temperature, photoperiod and other climatic elements have been calculated from the climatic data of the five meteorological stations (TABLES 2.4 - 2.8). These average values are used for all the study areas. The monthly rainfall for each study area has been obtained by interpolation method from the rainfall data of the five stations. The rainfall figures are then used with other land characteristics to determine the availability of water (see below).

(1) LAND QUALITIES: The land qualities are single or com-:pound land characteristics (see SECTION 3.5). There are twelve land qualities relevant to this region (TABLE 3.3). The "temperature", "photoperiod", "salinity" and "flood" consist of single characteristics. The values of temperature are used directly. But the others are classified or categorized for convenience in handling the data. The photoperiod is categorized according to standard practice in botany (Purseglove, 1968 and 1972). The salinity and flood are classified following Soil Survey Staff (1951)

The remaining land qualities consist of more than one land characteristic. But the interaction between the constituent characteristics in forming a quality is apparent only in case of "water for plant uptake", "soil drainage", "soil erosion" and "nutrients". A compound classification, taking account of the constituent character-:istics, has been made for each of them: drainage and erosion, following Soil Survey Staff (1951) and nutrients, after Indian Council of Agricultural Research (1980). But in case of "water for plant uptake", sufficient data have not been available for all the character:istics. This quality has been estimated from the limited amount of data available at present but it needs to be improved by collecting the relevant data from field experiments. The processes of estimat:ion of this quality are described in detail later in this section.

In case of "soil conditions", "other climatic conditions", "soil toxicity" and "pests and diseases", the interaction between the constituent land characteristics is not apparent. The characteristics are, therefore, used singly in the evaluation. The values for climatic elements and the types of pests and diseases are used directly. Soil toxicity may be due to either sodium plus pH or aluminium; the former is classified after Soil Survey Staff (1975) and the latter according to Sanchez et al. (1982). Each of the four characteristics of "soil conditions" is classified according to Soil Survey Staff (1951). It seems that, although the F.A.O. (1976) suggests the use of land qualities or compound characteristics, the individual characteristics may be more effectively employed in land evaluation in case of the above four qualities.

A special note is necessary on the "availability of water for plant uptake". It has been indicated above that this quality depends on the interaction of many characteristics. The relationship may be expressed by the following equation:

$$W = (R + S + G) - (SS + P + E)$$

where, W = availability of water for plant uptake (actual use and transpiration),
R = rainfall,
S = incoming surface and subsurface flow,
G = income from shallow groundwater,
SS = outgoing surface and subsurface flow,
P = deep percolation,
E = evaporation.

But, since no data, except rainfall, is available, the equation cannot be solved at present. Moreover, the corresponding "water require-:ments" of crops are quoted from the books and papers where these are given simply in terms of rainfall, assuming the rain is falling on a flat land. Therefore, to keep the two sets of data comparable, the rainfall figures are only used directly as the land quality "avail-:ability of water" in case of the flat flood plains (land system F). The calculation of available water over the toposequences (land systems A - E) is more complex. It is necessary to take account of the incoming and outgoing surface and subsurface flow of water determined by the sloping landform. As no field data was available, an approximate estimate has been made from the intensity of rainfall, slope angle and form of the slope. Firstly, the rainfall figures for December, January, February and March are used directly as the land quality "water" for all facets, because the intensity of the rain is too low in these months to cause substantial surface or subsurface flow. Secondly, it has been assumed that there is a 10% loss of the rain for every degree of slope angle from the summit and shoulder to the lower facets during the rest of the year. The footslope, by its situation, receives water from the summit and shoulder as well as losing water to the toeslope and base facets. Since it is difficult to estimate the balance, the actual rainfall figures have been used for the rest of the year in this facet. The toeslope and base facets gain the water coming down from the summit and shoulder areas according to their angle and form of slope. In the land systems B, C and D, the toeslopes are gently sloping and the bases are flat. So, 40% of the incoming water has been added to the rainfall figures at the toeslope and 60% is added to the rainfall value at the base.

But in system A, the base facet, being a natural levee, is slightly higher than the toeslope (FIG. 4.1). So, 60% of the incoming water has been added to the rainfall at the toeslope and 40% added to the rainfall at the base. In case of land system E, where the toeslope consists of multi-convexities, only 30% of the incoming water is added to the rainfall of that facet and 70% is added to the rainfall at the base facet. This method is, therefore, a series of "best approxi:mations" which are nevertheless essential to the calculation of available water for crop growth.

The water availability and other qualities for each facet in turn are presented in Appendix F. Some of the qualities, such as temperature, photoperiod and other climatic conditions are virtually uniform for all facets. They are listed separately. All the land facets of this region are free from salinity and soil toxicity (sodium or aluminium). They are not, therefore, entered in the Appendix.

(2) REQUIREMENTS OF LAND USE TYPES: The current land use types are identified by field survey and from Indian Council of Agricultural Research (1980). The potential land use types are selected from Purseglove (1968 and 1972) and Indian Council of Agricultural Research (1980) primarily on the basis of their adapt:ability to the climate of this region. For example, crops like rye, tea, apple or spruce have not been considered. Secondly, the social and economic necessities of the region are taken into account. Nutritious food and fruit crops like soya bean and citrus, valuable cash crops like black pepper and jute, high yielding and nutritious pasture crops and trees having multiple use are given priority in

selection.

The requirements of both the current and potential land use types are compiled from a variety of books and papers. The major sources for the requirements of food crops, cash crops, fruit and pasture crops are Purseglove (1968 and 1972) and Indian Council of Agricultural Research (1980). Other books and papers which have supplied data on specific crops are Grist (1975) for rice, Peterson (1965) for wheat, Doggett (1970) for sorghum, Wallace and Bressman (1949) for maize and Schaaffhausen (1952) for Job's tears. Some information on manioc is gathered from Jones (1959), sweet potato from Macdonald (1963), potato from Burton (1966), yam from Coursey (1967), soya bean from Markley (1950), pigeon pea from Gooding (1962) and green gram from Bose (1932). Nieuwhof (1969) has supplied valuable data for cole crops, Jones and Mann (1963) for onions, Whitaker and Davis (1962) for cucurbits and Singer (1961) for mush-:rooms. Other sources are Barnes (1964) on sugarcane, Simmonds (1966) on banana, Hume (1957) on citrus fruits, Kirby (1963) on fibre plants, Lock (1969) on sisal and Cardozier (1957) on cotton. Additional data on pasture crops are collected from Dabadghao and Shankarnarayan (1973). The requirements of forest trees are obtained from Champion (1936), Puri (1960) and Penfold and Willis (1961).

The land use types are described in TABLE 3.4. The land requirements are categorized together with their corresponding land qualities in TABLE 3.3. The requirements of each crop dealt with in this study are presented in Appendix G.

CHAPTER 4

SOILS OF THE SIX LAND SYSTEMS

The morphological, physical and chemical properties of soils in the six land systems are discussed in this chapter with the aim of understanding the general pattern of soils as well as revealing the distinction between soil characteristics of the land systems. Firstly, each system is described and examined separately. The surface soil properties are then outlined and their relationship to each other and to the topography is analysed. A correlation matrix between the surface soil properties and topography is developed, with the topo:graphic factor being assessed by means of three variables - distance from the summit to the base, height above mean sea level and angle of slope. The soil profiles are then discussed, followed by their classification according to the U.S.D.A. soil taxonomy (Soil Survey Staff, 1975). The profiles are compared with each other and with topography using weighted means of 120 cm profiles. In case of land system F, only the surface soil properties are discussed, because no profiles were examined here (SECTION 3.3). Next, a comparative study of the six land systems is presented. Finally, a catenary soil map of the Southern Rarh Plain, based on land systems survey, is compiled. A note on the localized cases of very severe gully erosion is also included in this chapter.

The morphological descriptions and physical and chemical propert:ies of soils of land systems A - E are presented in Appendix A. The correlation between surface soil properties and topographic factors is tabulated in Appendix B. The weighted means of properties of 120 cm soil profiles are entered in Appendix C. The morphological,physical and chemical properties of surface soils of the four flood plains are presented in Appendix D.

4.1 LAND SYSTEM A (GODAPIASAL SYSTEM)

This system represents the valley of a third order stream. The name of the system is taken from the locality where it was studied. The area of study is a village, situated in the valley of the R. Parang (latitude 22 degrees, 31 minutes north and longitude 87 degrees, 19 minutes east). Its location is shown in FIG. 4.32 (in SECTION 4.9).

The topographical character of this system is distinctive (FIGS. 4.1 and 4.2). The slope does not fall regularly from summit to the base. Instead, there is a flat summit, relatively steep shoulder and a wide, shallow concavity forming footslope, toeslope and base. The concavity occupies 80% of the slope profile. The toeslope lies at the middle of the concavity. The base is about 2 m higher than the toeslope because it is, in fact, a natural levee formed by the stream.

Drainage is closely related to topography. The summit is well drained because of its relative height. The steep shoulder is excessively drained. Soil cover has been removed by erosion, exposing massive ironstone. The footslope zone suffers from imperfect drainage by the influence of fluctuating water-table (FIG. 4.2). The toeslope is poorly drained throughout the profile. Drainage of the

Figure 4.1 Land System A: slope and soils (source: field work; see Appendices A and E).

1. Massive ironstone; 2. Ironstone concretions; 3. Mottles; 4. Plinthite; 5. Strong gleying; 6. Argillic horizon.

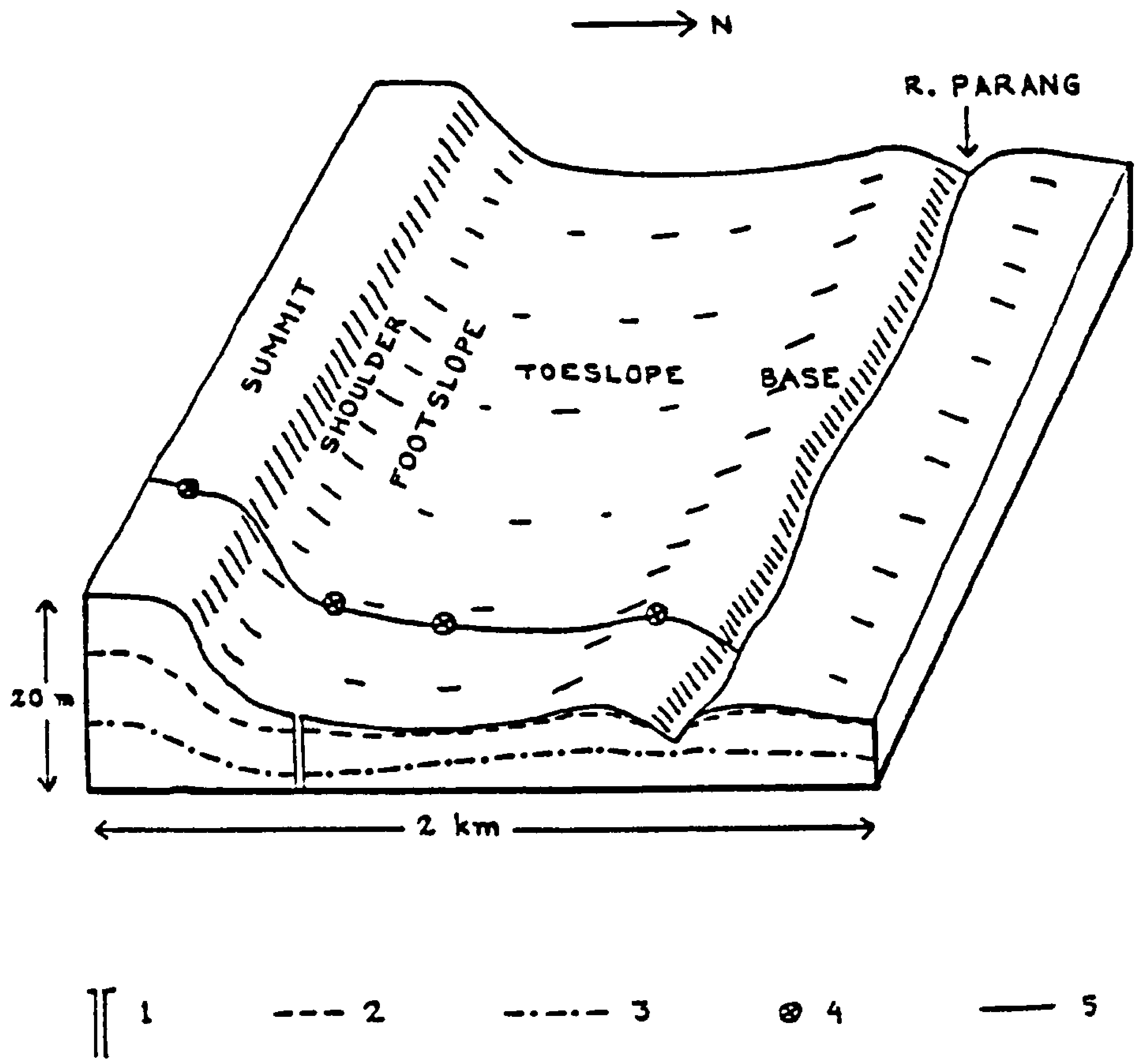


Figure 4.2 A schematic block diagram of System A.

1. Well where depth to water-table was measured; 2. Wet season water-table; 3. Summer water-table; 4. Soil sampling site; 5. Survey line.

surface horizon is slightly better at the base area than in the toeslope because of height and nearness of the stream.

Land use pattern of the village, including distribution of facets and soil sampling sites, is presented in FIG. 4.3. The summit and shoulder facets have 'type C' open coppice wood of Shorea robusta and associates (TABLE 2.10). Part of the footslope is occupied by settlements. There are also small areas of perennial crops and bamboo groves. Rice is cultivated over the remaining area during wet season. The entire toeslope and base are given over to rice in wet season. Parts of the base are also cultivated in winter and summer for irrigated crops like wheat, potato, oilseeds and vegetables. The areas of footslope, toeslope and base which are left fallow during winter and summer carry grasses and herbs.

The influences of topography, drainage and land use are discussed in the following subsections.

4.1.1 SURFACE SOIL PROPERTIES

The morphological, physical and chemical properties of the surface horizons of four soil profiles are discussed in this subsection. They represent summit, footslope, toeslope and base facets. No sample could be taken from the shoulder area because of rockiness which results from outcrops of massive ironstone. The distributions of the surface soil properties over the land facets are shown in FIG. 4.4.

The soil colour changes from red at the summit to grey downslope

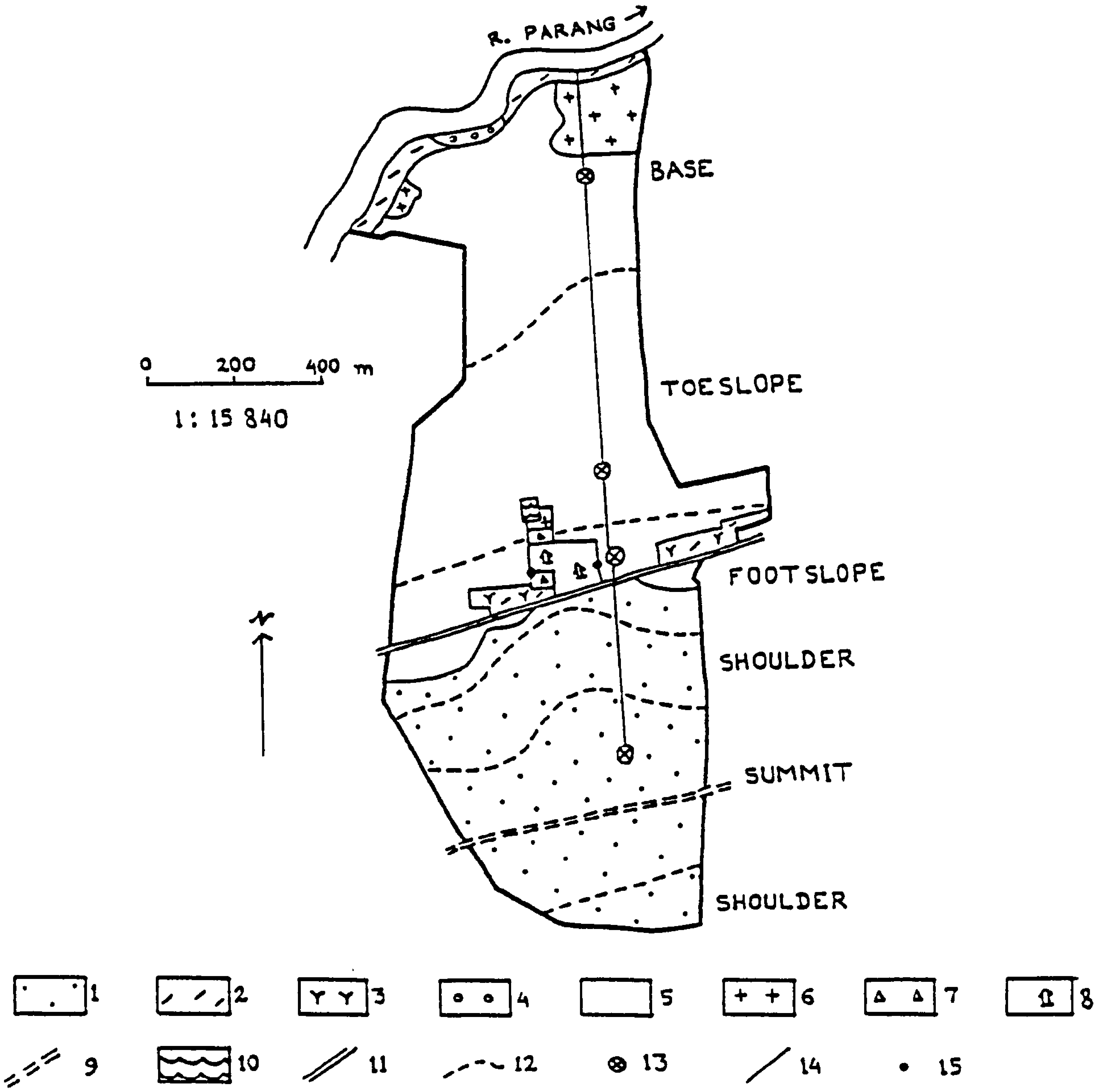


Figure 4.3 Land use pattern of System A (source: field mapping in Bhabrigere village, 1982-82).

1. Forest; 2. Pasture; 3. Bamboo; 4. Orchard; 5. Rice (single crop); 6. Multiple crops; 7. Perennial crops; 8. Settlements; 9. Canal; 10. Pond; 11. Road; 12. Land facet boundary; 13. Soil sampling site; 14. Survey line; 15. Well.

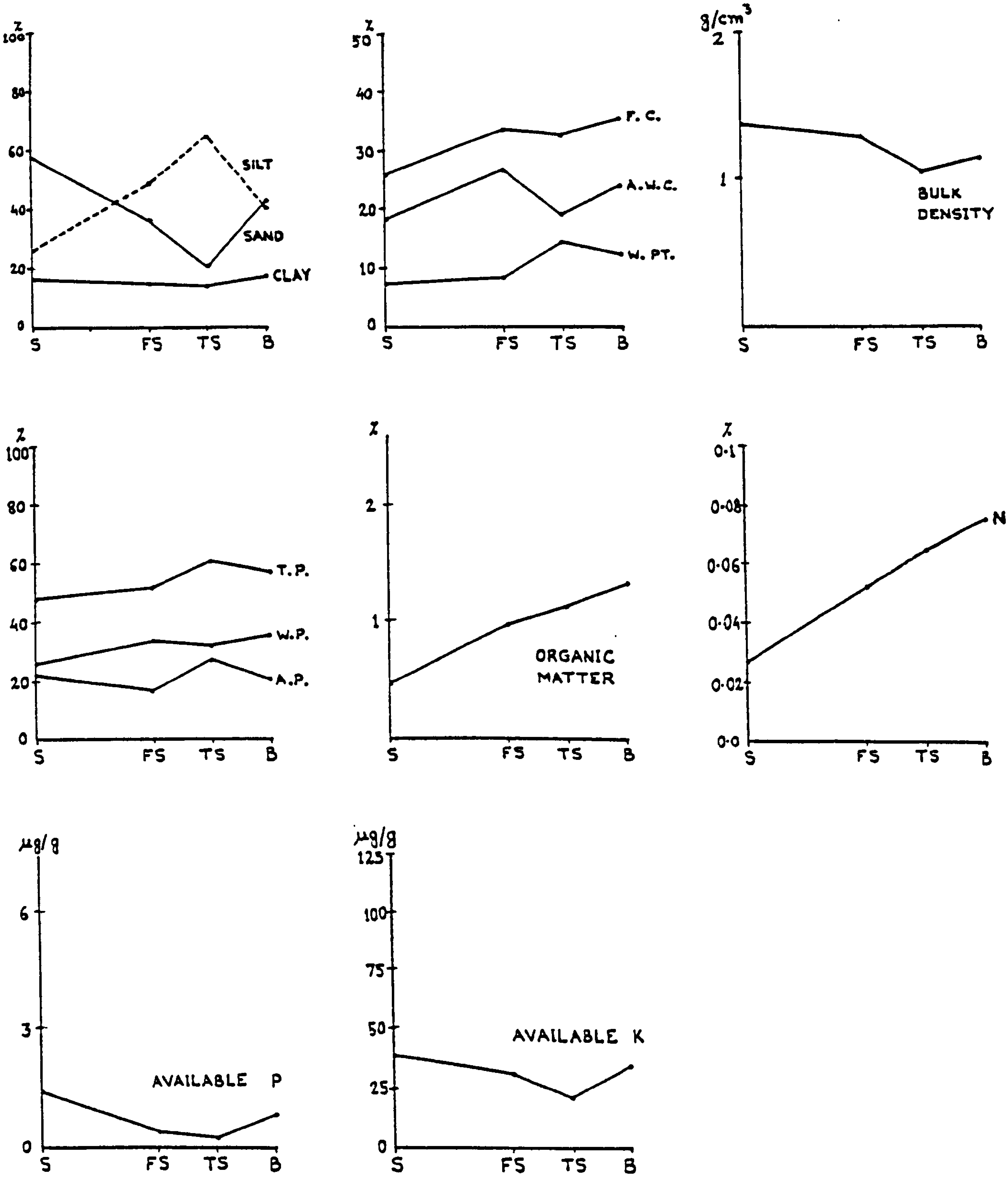


Figure 4.4 Surface soil properties of System A (source: laboratory work; see Appendix A).

S = Summit; FS = Footslope; TS = Toeslope; B = Base.
F.C. = Field capacity; W.PT. = Wilting point; A.W.C. = Available water capacity; T.P. = Total porosity; W.P. = Water-filled porosity; A.P. = Air-filled porosity.

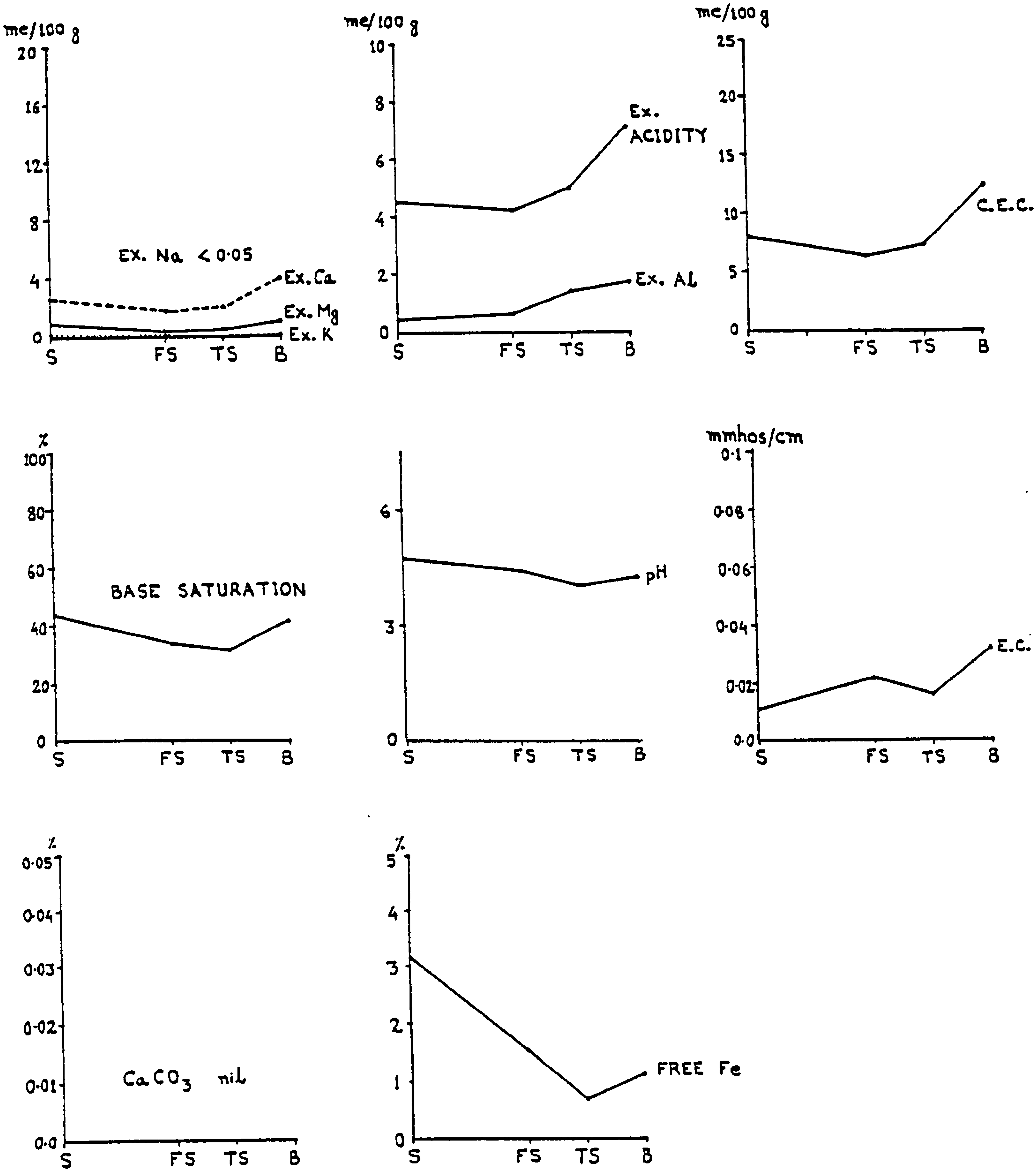


Figure 4.4 (continued)

EX. = Exchangeable; C.E.C. = Cation exchange capacity;
E.C. = Electrical conductivity.

as drainage becomes poorer. Mottles are found in the poorly drained facets, mainly along rice roots. The ironstone concretions, on the other hand, are less frequent in the lower facets. The type of soil animal also changes from termites to earthworms with increasing soil moisture.

In general, the texture is loamy: it becomes finer away from the summit because of selective removal and deposition of fine particles by surface water flow. Sand decreases away from the summit while silt increases. Clay is low throughout (FIG. 4.4), averaging 16% only. It is likely that clay particles are drained into the stream instead of being deposited at the lower facets. There is an increase of sand at the base facet due to stream deposit:ion upon the natural levee. This character of the base facet prevents a significant statistical relationship between sand or silt and distance downslope (see Appendix B for details of correlation between variables).

Unlike the textural components, organic matter correlates with distance at significant level. It increases regularly from low at the summit to reach medium level at the base (FIG. 4.4). This downslope increase is due to increasing density and luxuriance of the grass vegetation, poor drainage, deposition from overland flow and probably also input of manures.

In response to the increasingly finer texture and greater organic matter towards the lower facets, together with an abundance of earthworms, the structure improves from massive at the summit to a crumb morphology at the lower facets. Accordingly, field capacity increases in the same direction (FIG. 4.4), developing a positive relationship with distance. Wilting point also increases towards the lower facets, but the pattern is less regular, probably under the influence of silt particles (FIG. 4.4). As a result, available water capacity increases irregularly from 18% over the summit to 24% at the base. These latter two properties do not form a significant statistical relationship with distance.

The bulk density and porosities of these loamy soils are medium on average over the land system. With finer texture and improved structure, there is an increase of total and water porosities and corresponding decrease of bulk density towards the lower facets (FIG. 4.4). But the pattern becomes irregular over the lower facets through the influence of texture. This is why, these properties, like sand and silt, fail to show significant statistical relationship with distance.

Among the chemical properties nitrogen, like organic matter, is low at the summit, but regularly increases down the slope to reach medium level at the lower facets (FIG. 4.4). The C/N ratio is 10 throughout the facets, indicating a well humified organic matter. But available phosphorus and potassium remain very low through the system (FIG. 4.4). Their unavailability is probably due to extremely acidic condition (average pH 4.3). The distribution curves of available phosphorus, potassium and pH are comparable.

The exchangeable calcium, magnesium, sodium and potassium are also very low in this land system. Total exchangeable bases average only 3.3 me/100g for the four facets. The exchangeable bases are higher at the base facet than over the summit, but the trend pattern is not regular (FIG. 4.4). It would appear that the exchangeable bases are influenced by complex chemical factors in addition to downslope transport by surface water flow.

The exchange acidity is higher than the total exchangeable bases in all the facets. As a result base saturation remains low, averaging only 38% for the four facets. Accordingly, soil reaction is extreme to very strongly acidic. Exchange acidity increases downslope, developing a positive correlation with distance. In response to it, the base saturation and pH decrease, but their trend patterns are made irregular by the influence of the exchangeable bases (FIG. 4.4). The cation exchange capacity increases from low level over the summit to medium level at the base and forms a signi-:ficant statistical relationship with distance by the influence of its predominant component, exchange acidity.

Although exchange acidity is relatively higher, exchangeable aluminium forms a small part of it. Exchangeable aluminium increases downslope, but the saturation percentage is no more than 20 in any of the facets. Sodium saturation is also very low. There is, there-:fore, no toxic threat to plant growth.

The electrical conductivity increases towards the base facet (FIG. 4.4), apparently as soluble salts are transported by lateral flows of water. But its quantity is very low. The salts are probably drained out of the valley by stream flow. There is, therefore, little danger of salination under heavier irrigation. Calcium carbonate is totally absent from the surface soils (FIG. 4.4). Free iron is present only in low amounts although ironstones are abundant over the upper facets. Free iron decreases towards the lower facets, probably because of poor drainage.

In summary, the properties of the surface soils, excepting available phosphorus and potassium and pH, improve towards the lower facets mainly due to transport and deposition of silt, organic matter and exchangeable bases by surface water flow. But the trend patterns of some properties are irregular. In case of physical properties like wilting point, bulk density and total porosity, the irregularity is caused by the distribution of textural components. The downslope increase of silt and corresponding decrease of sand are reversed at the base facet of this land system by alluvial deposition of the third order stream. The irregular pattern of exchangeable bases, pH or available phosphorus are probably due to complex factors of chemical environment.

The surface soils of the summit area are less suited to culti:vated crops on account of massive structure and very low content of nutrients. But this facet is more suitable for perennial trees than the lower facets because of its free drainage. The shoulder area which consists of outcrops of massive ironstone can only support trees like _Shorea robusta_. The footslope, toeslope and base areas are suitable for cultivation of annual crops, but their nutrient status, particularly available phosphorus and potassium, requires to be improved. Since the cation exchange capacity is low, organic manures may be more successful and economic than the chemical fertilizers.

4.1.2 SOIL PROFILES

Four soil profiles, representing summit, footslope, toeslope and base, are discussed in this subsection. No profile could be examined in the facet defined as shoulder because of its rockiness. The morphological characteristics are discussed first, followed by physical and chemical properties. The data are listed in Appendix A. FIG. 4.1 shows some morphological properties in profile. Profile diagrams of physical and chemical properties are presented in FIG. 4.5.

The footslope, toeslope and base areas have deep soils. But the soils over the summit area are limited to medium depth by occurr-:ence of cemented nodular and massive ironstones. The soils become very gravelly at 60 cm depth and reach petroferic contact at 100 cm. The shoulder area has little soil; it is occupied by outcrops of massive ironstone.

Soil colour of the well drained summit area turns from dark red to dark reddish brown with depth. The hue is 2.5YR with medium value and high chroma. There are no mottles. At the imperfectly drained footslope area the matrix colour is pale yellow (2.5Y with high value and medium chroma) above 97 cm depth. Then the hue becomes 7.5Y and chroma 1, giving a light grey colour characteristic of strong gleying. Mottles of red colour are present throughout the profile. They increase in abundance, size and distinctiveness with depth under the influence of fluctuating water-table. Below 75 cm they occupy more than 50% of the horizons where they are classed as plinthite (as defined by Soil Survey Staff, 1975). Both the toeslope and base areas are strongly gleyed by the influence of a shallow water-table persisting throughout the wet season. The soil colour is neutral in hue throughout the profile at the toeslope area. Mottles are present only in the upper part of the profile. The lower parts are entirely under reducing conditions. The base area, because of its relatively higher situation as a natural levee, shows

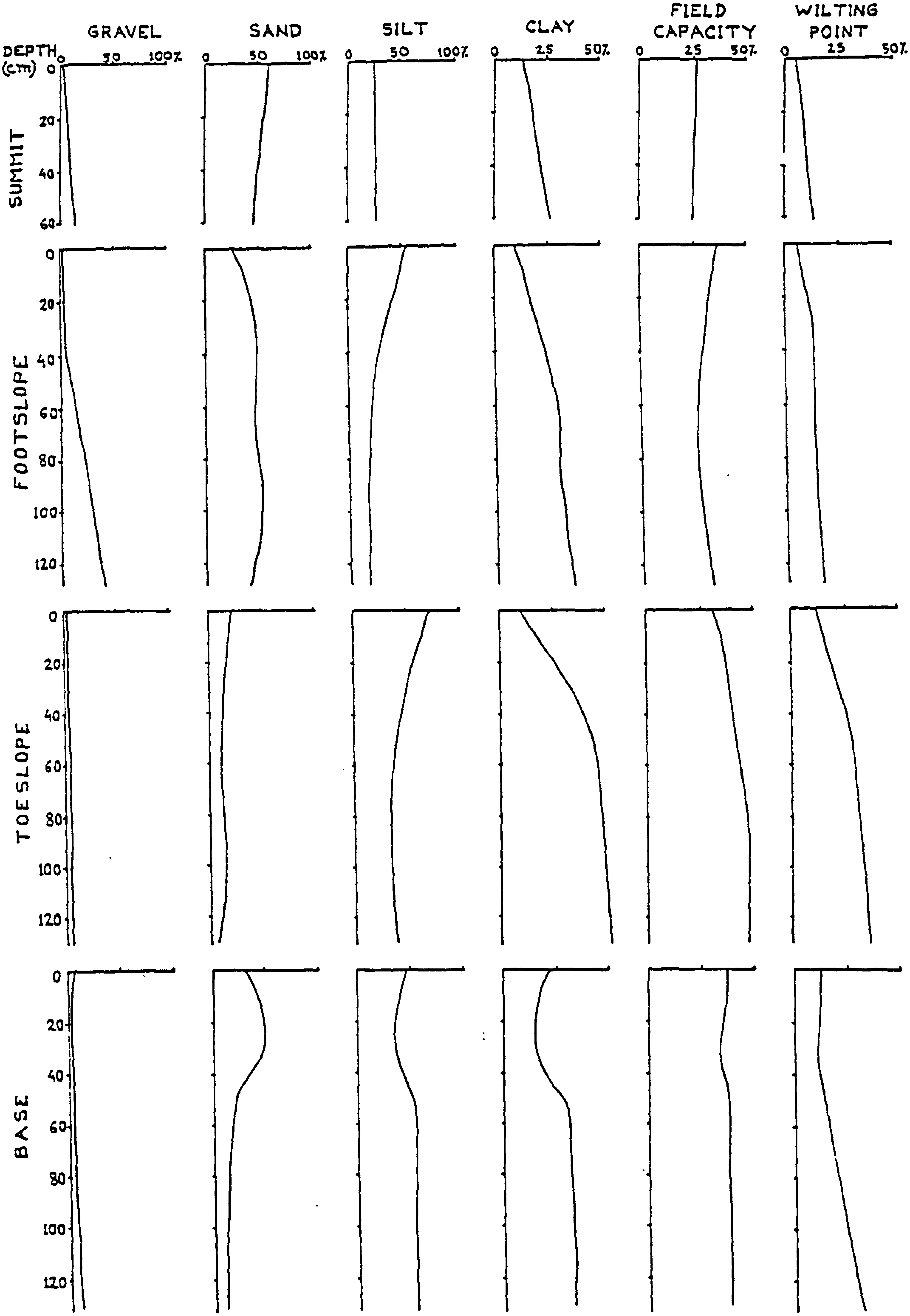


Figure 4.5 Soil profile properties of System A (source: laboratory work; see Appendix A).

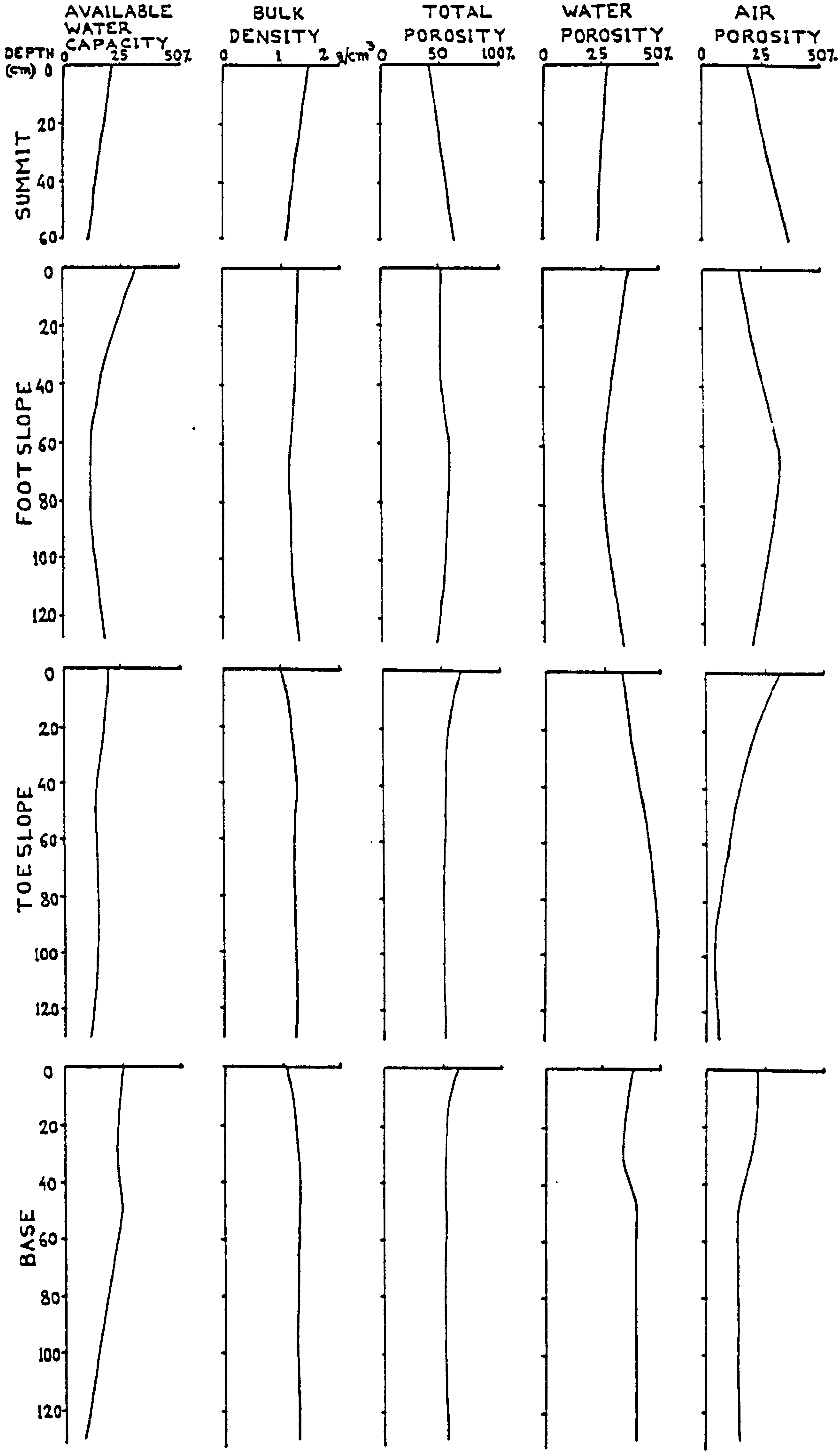
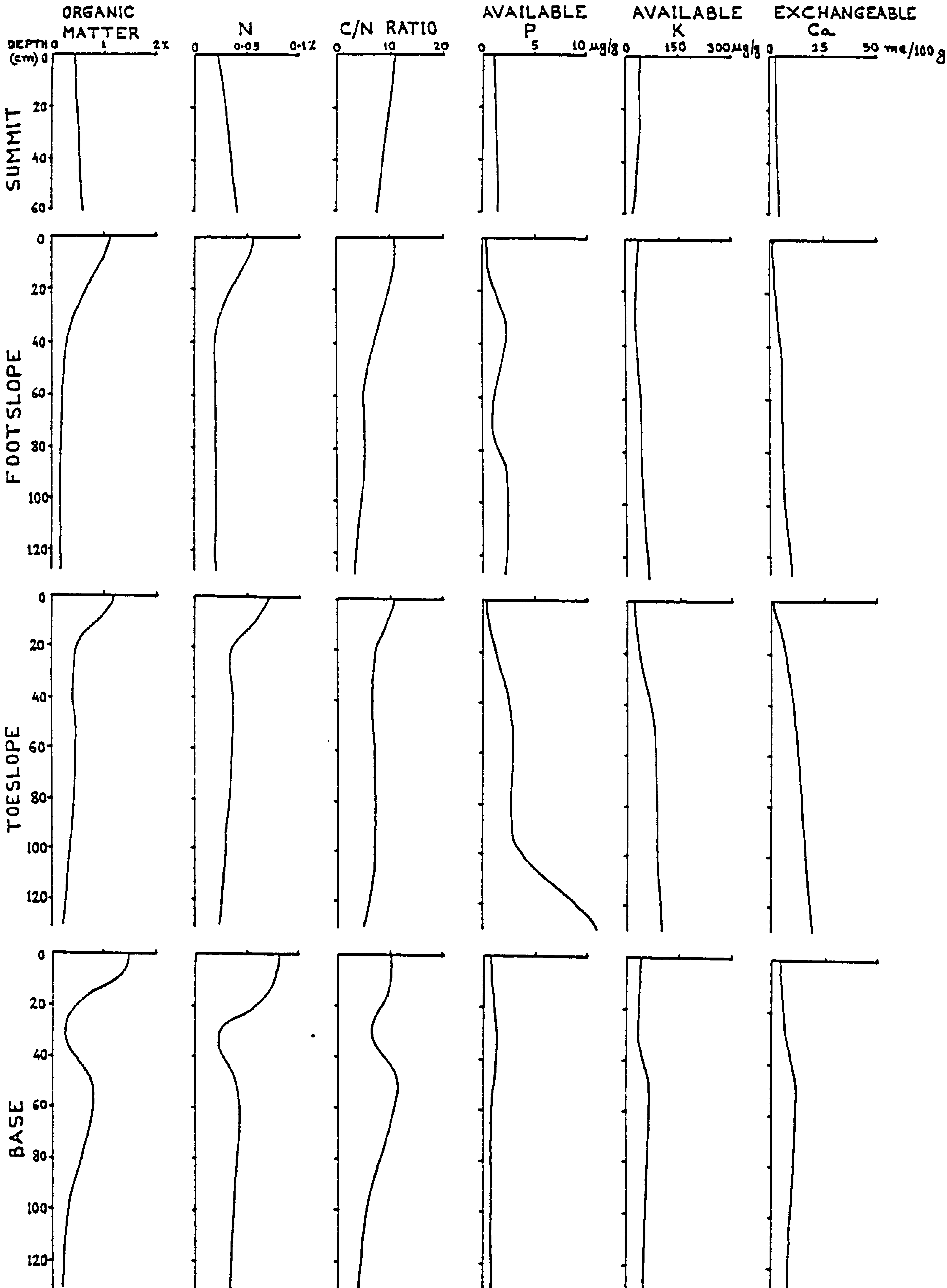


Figure 4.5 (continued)



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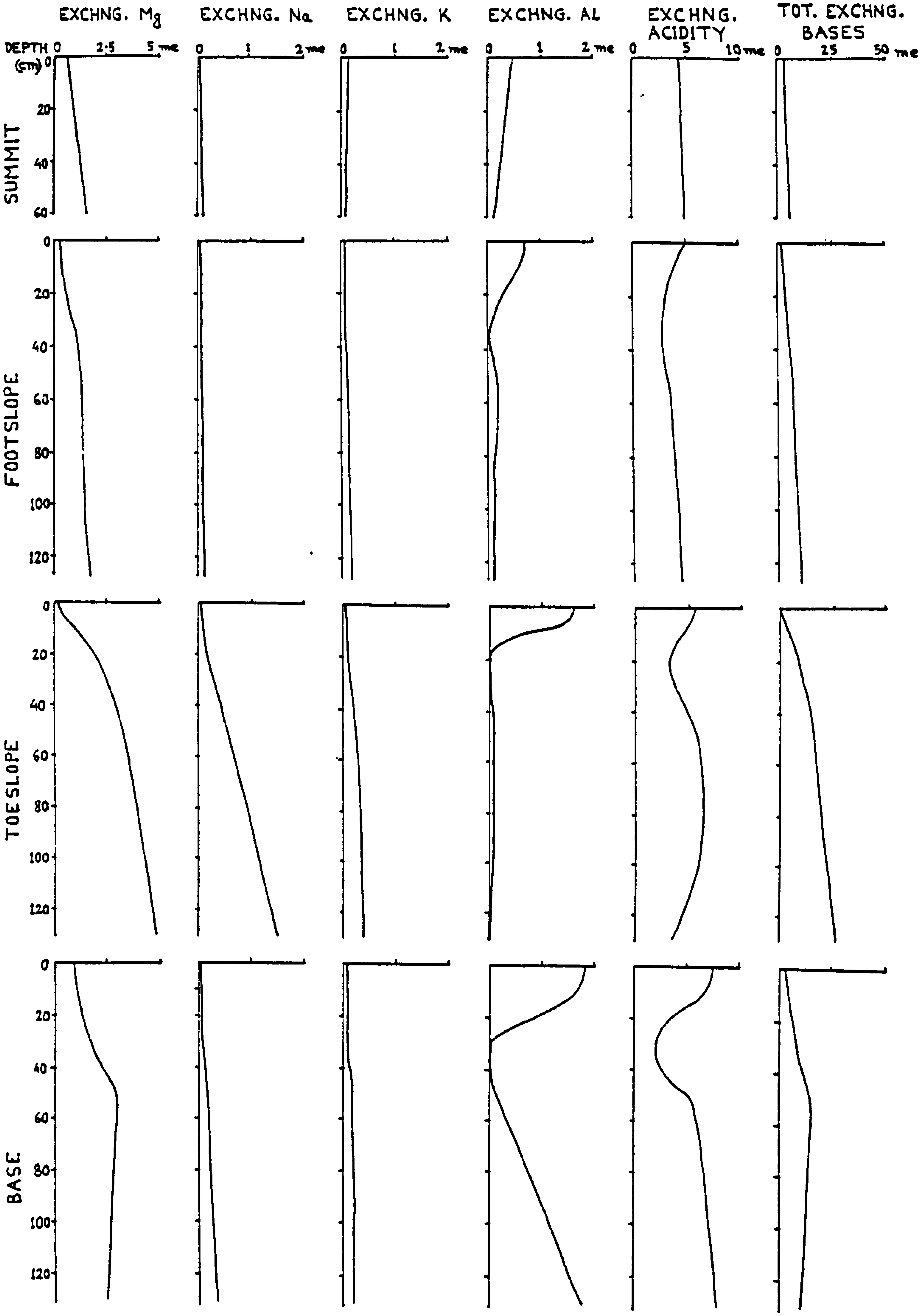

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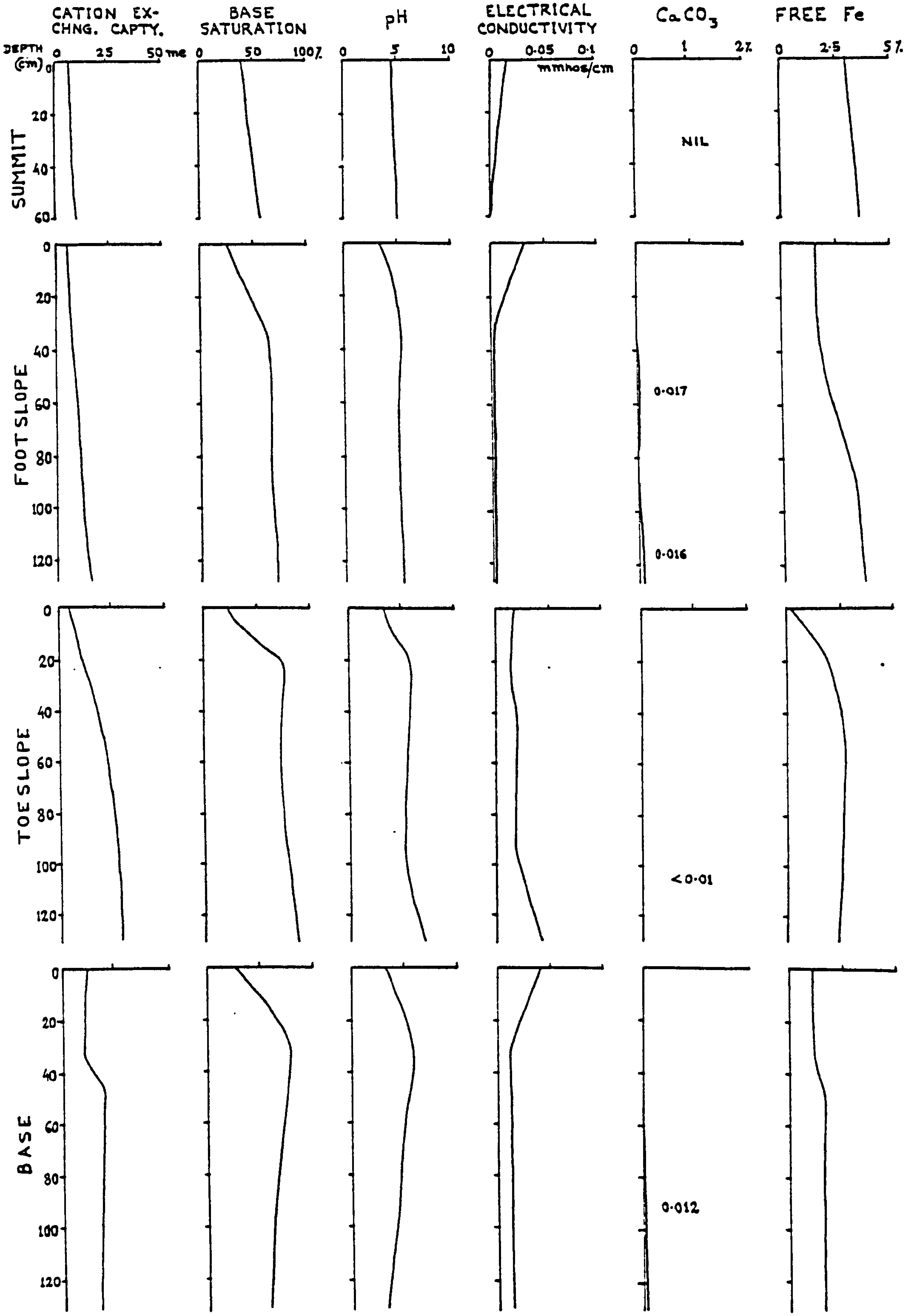


Figure 4.5 (continued)

neutral hue from below the surface horizon. It contains mottles throughout the profile, although their abundance decreases with depth.

In all four profiles texture becomes gradually finer with depth because of downward movement of fine particles forming argillic horizons. The summit and footslope profiles become sandy clay loam at depth. The toeslope area has greater argillation so that its lower horizons are clay in texture. But the base area, being composed of relatively coarser particles, is silty clay loam at depth.

In response to argillation, soil consistence becomes more sticky, plastic, firm and hard with depth. But consistence is also influenced by the type of clay. The change of consistence with depth is little at the summit area where the clays are probably hydrous oxides in nature. But the change becomes increasingly greater towards the lower facets probably with greater abundance of silicate clays.

The frequency of the plant roots indicates drainage conditions of the profiles very clearly. They are 'common' throughout the summit profile. In the footslope and base areas, roots are absent from the strongly gleyed horizons. The toeslope profile, although strongly gleyed throughout, contains a few roots, but these are probably roots of grasses adapted to waterlogged soils.

Soil animals, like plant roots, are absent from the strongly gleyed horizons. In well drained areas ants and termites are common. Earthworms appear, with greater moisture content, at the toeslope and base.

Ironstone concretions increase with depth in the summit area and finally consolidate into petroferric horizon. In the footslope zone, ironstone concretions are common just above and in the upper part of the plinthite horizon where they are probably forming at present (FIG. 4.1). In the toeslope and base profiles only a few ironstone and manganese concretions are found.

In the summit profile, boundaries between horizons are diffuse in spite of change in texture and in frequency of concretions (FIG. 4.1). It is possible that other visible features are masked by red colour of the soil. In the remaining three profiles, boundaries of the argillic horizons are clear to abrupt and boundaries within argillic horizons are gradual.

The nature of argillation in these soils has already been described. It becomes clearer when the profile diagrams and weighted means of sand, silt and clay are compared between the four facets (FIG. 4.5 and Appendix C). There is a sharp increase of clay content and corresponding decrease of sand and silt within 60 cm in all profiles. Below this depth the amount of clay increases gradually. The degree of argillation increases, with greater availability of water and fine particles, from the summit to the toeslope facet where it reaches maxi:mum. The base area has a smaller degree of argillation than the toeslope because of coarser composition and lesser amount of water available. The seasonal rainfall and moderately high porosity of these soils favour argillation at all facets.

The profile distributions of other physical properties at each facet and over the land system are strongly influenced by the textural pattern. The effect of organic matter becomes more limited with depth as its quantity decreases. Following argillation water porosity increases with depth whilst air porosity and total porosity decrease (FIG. 4.5). As a corollary, bulk density increases with depth. The summit profile, however, has an increase of total and air porosities at depth because of activities of forest tree roots and termites (Appendix A). The field capacity, which depends on the frequency of water pores, increases like the latter with depth, except at the summit area. The wilting point, on the other hand, is controlled by clay content and increases with depth in all profiles (FIG. 4.5). Between field capacity and wilting point, the latter increases more sharply with depth so that available water capacity gradually decreases down the profiles.

In distribution over the land system, weighted profile means of water porosity, field capacity and wilting point, like that of clay, increase from the summit to the toeslope and then decline at the base facet (Appendix C). The weighted mean of air porosity correspond-:ingly decreases to the toeslope and increases at the base facet.

In contrast to the textural control of profile behaviour of the physical properties, the profiles of chemical properties are influenced by various factors. The distribution of organic matter and nitrogen strongly reflects the influence of drainage conditions. In the poorly drained toeslope and base facets, organic matter and nitrogen reach a very low level within 20 cm from the surface (FIG. 4.5). The imper-:fectly drained footslope has the same characteristic except that the low point is reached at about 40 cm. In contrast, organic matter and nitrogen slightly increase with depth in the well drained summit profile. The activities of termites and higher concentration of tree roots in the lower horizons may contribute to this increase. As a result of such profile patterns, weighted means of organic matter and nitrogen are greatest at the summit area (Appendix C). The lowest profile mean is over the footslope area from where it increases towards the base facet. The base profile is characterized by a secondary influx of organic matter around 50 cm depth which is probably due to migration of humus as complexes with clay (FIG. 4.5). The C/N ratio decreases with depth to about 5:1 in all profiles, indicating advanced humifi-:cation of organic matter.

The available phosphorus is controlled by pH in its profile distribution (FIG. 4.5). It increases with depth at the summit, footslope and toeslope facets and decreases at the base area like the latter. The weighted profile mean likewise increases from the summit to the toeslope and then decreases at the base facet (Appendix C). The available potassium, on the other hand, decreases with depth in the summit area but increases in the lower horizons of the other facets. The reason for such behaviour is not fully understood at present.

The exchangeable bases, cation exchange capacity, base saturation and pH value increase with depth at the summit, footslope and toeslope areas. But at the base facet, they increase down to 50 cm only and then decreases gradually (FIG. 4.5). The weighted profile means of these properties increase from the summit to the toeslope and then decrease at the base facet (Appendix C). Apparently the exchangeable bases move down the profile as well as down the slope in solution and as complexes with clay and humus. Their decline at the base facet is probably because of partial removal by draining into the stream.

The exchange acidity also increases with depth like the exchangeable bases, but less sharply (FIG. 4.5). Its increase is due mainly to exchangeable hydrogen, for exchangeable aluminium decreases with depth. But the reason for accumulation of exchange acidity together with exchangeable bases is not understood. There is an increase of aluminium in the lower horizon of the base profile which is probably related to the removal of exchangeable bases.

Although exchangeable bases accumulate in the lower horizons, the soluble salts are washed out of the profiles, particularly in the better drained summit and footslope areas. There is an increase of salts in the lower horizons of the toeslope facet where they may accumulate because of the situation of this facet in the middle of the concavity (FIG. 4.1). The increase is, however, very small, in the order of 0.04 mmhos/cm.

The calcium carbonate is totally absent from the summit area and in the other three facets it occurs only at depth in very small quantities - around 0.01% (FIG. 4.5). Free iron is present in all facets and increases with depth. The weighted profile mean of calcium carbonate increases whilst that of free iron decreases towards the base facet, probably in response to soil drainage.

To sum up it may be said that argillation and drainage conditions are the main factors controlling the profile behaviour of other soil properties. With maximum argillation and strongest gleying at the toe-:slope area, soil physical conditions deteriorate but properties of the exchange complex and available phosphorus and potassium improve with depth. The greater nutrient status of the lower horizons can only be utilized by deep rooted plants adapted to gleyed soils. In the foot-:slope and base facets the nutrient status of the deeper horizons is relatively lower but the comparatively better drainage conditions make these areas more successful for plant growth. The summit area is unsuitable for many cultivated crops because of its limited depth and gravelly soils. But the increasing organic matter and aeration with depth are favourable for perennial trees.

4.1.3 CLASSIFICATION OF SOILS

The soil profiles are classified to subgroup level. A step by step process from order to subgroup is used, applying the criteria laid down by Soil Survey Staff (1975).

All four profiles have ochric epipedons and argillic horizons. Since the base saturation of the argillic horizon is greater than 35%, they belong to the Alfisol order. The toeslope and base profiles have mottles and low chroma throughout which indicate an aquic moisture regime. Hence they are classified as Aqualf. They have no plin-:thite nor an iso-temperature regime, but both have ochric epipedons. Since their characteristics correspond to the central concept of Ochraqualfs, they are finally classified as <u>Typic Ochraqualfs</u>.

The summit and footslope profiles have ustic moisture regimes. The footslope has plinthite within 125 cm of surface. It is, therefore, a <u>Plinthustalf</u>. The summit profile does not have plinthite but meets the requirements of Paleustalf. Since the colour of the argillic horizon is redder than 5YR, it is placed as <u>Rhodic Paleustalf</u>.

The classification shows that these are moderately weathered, medium to high base status soils. The change of moisture regime from ustic to aquic at the footslope-toeslope junction is also evident. The lower horizons of the footslope are influenced by fluctuating water-table where plinthite has formed. But there is no plinthite in the strongly gleyed toeslope and base nor in the well drained summit.

The summit and shoulder areas, however, contain cemented nodular and massive ironstones which might have hardened from plinthites at an earlier date.

4.2 LAND SYSTEM B (BANKADAH SYSTEM)

This system is the valley of a second order stream. The representative toposequence is within the area of a village near Bankadah (latitude 22 degrees, 59 minutes north and longitude 87 degrees, 22 minutes east). It occupies the right-hand slope of R. Chanpa. Its location is shown in FIG. 4.32 (in SECTION 4.9).

The slope profile of the toposequence is flat-rectilinear-flat (FIGS. 4.6 and 4.7). The valley flattening is less advanced in this system than in system A. The footslope, toeslope and base facets, unlike those of system A, occupy only a small portion (36%) of the slope profile. The base is flat while the footslope and toeslope are very gently sloping. The summit and shoulder facets are extensive, with level ground at the summit. The shoulder has an average slope of 1.6 degrees, with local maximum of 5.0 degrees.

Despite its flat nature the summit is well drained on account of its relative height. The shoulder is slightly better drained than the summit because of its greater degree of slope. Soil erosion is limited to moderate level. The footslope is imperfectly drained by the influ:ence of rising water-table during wet season. The toeslope and base areas are poorly drained on account of shallow water-table persisting for a greater proportion of the year. In this toposequence the water-table is further raised by ponded stream water behind a low dam (FIGS. 4.7 and 4.8).

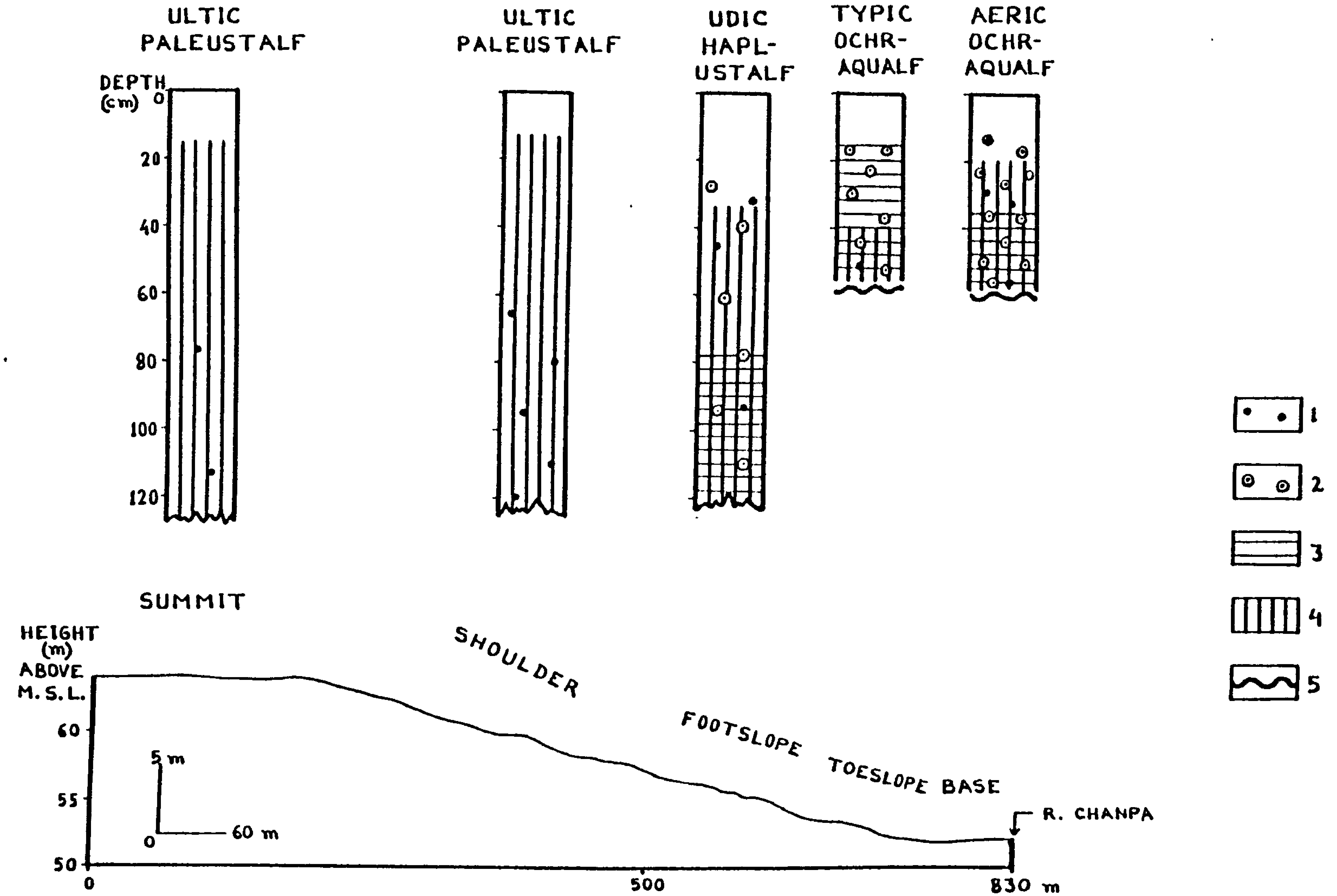


Figure 4.6 Land System B: slope and soils (source: field work; see Appendices A and E).

1. Ironstone concretions; 2. Mottles; 3. Strong gleying; 4. Argillic horizon; 5. Water-table during field work.

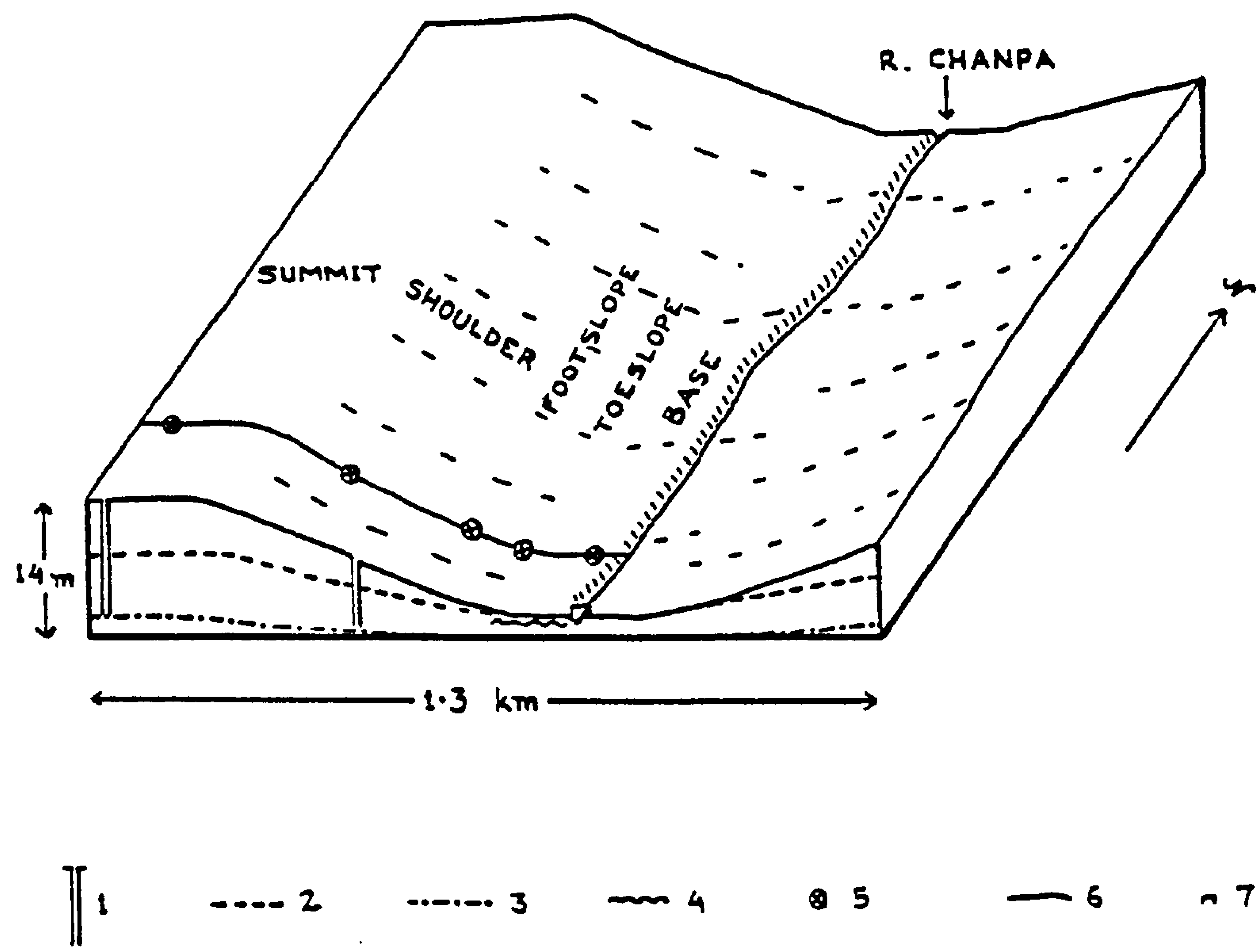


Figure 4.7 A schematic block diagram of System B.

1. Well where depth to water-table was measured; 2. Wet season water-table; 3. Summer water-table; 4. Water-table encountered in a pit during field work; 5. Soil sampling site; 6. Survey line; 7. Dam.

The land use pattern of the village, facet boundaries and soil sampling sites are shown in FIG. 4.8. A small part of the summit has 'type B' plantation (TABLE 2.10) of Acacia auriculiformis with cashew nuts. The rest of the summit consists of widely scattered individuals of 'type C' vegetation, palmyra palm and bamboo. On the whole they form a very open canopy. Settlements occupy parts of the shoulder facet with fruit-trees, bamboos and palms around them. Over the remaining part, cucurbits are grown with hand watering during summer. Grasses are present over these two facets but their condition is very poor on account of overgrazing. The footslope, toeslope and base facets are given over to rice in the wet season. Parts of these three facets are also cultivated with irrigation during winter and summer. Rice is continued as the main winter crop at the base facet which remains water-saturated. Potato, wheat, oilseeds and vegetables are grown at the footslope and toeslope. These facets also carry grasses and herbs when left fallow.

In the following subsections the distribution patterns of soil properties along the toposequence are described and the influences of topography, drainage, vegetation and others upon them are analysed.

4.2.1 SURFACE SOIL PROPERTIES

Five surface soil samples representing the five facets of this land system are discussed in this subsection. The distribution of physical and chemical properties over the facets is presented in FIG. 4.9.

The well drained summit has a strong brown colour at the surface. The shoulder, which is slightly better drained, has a reddish brown

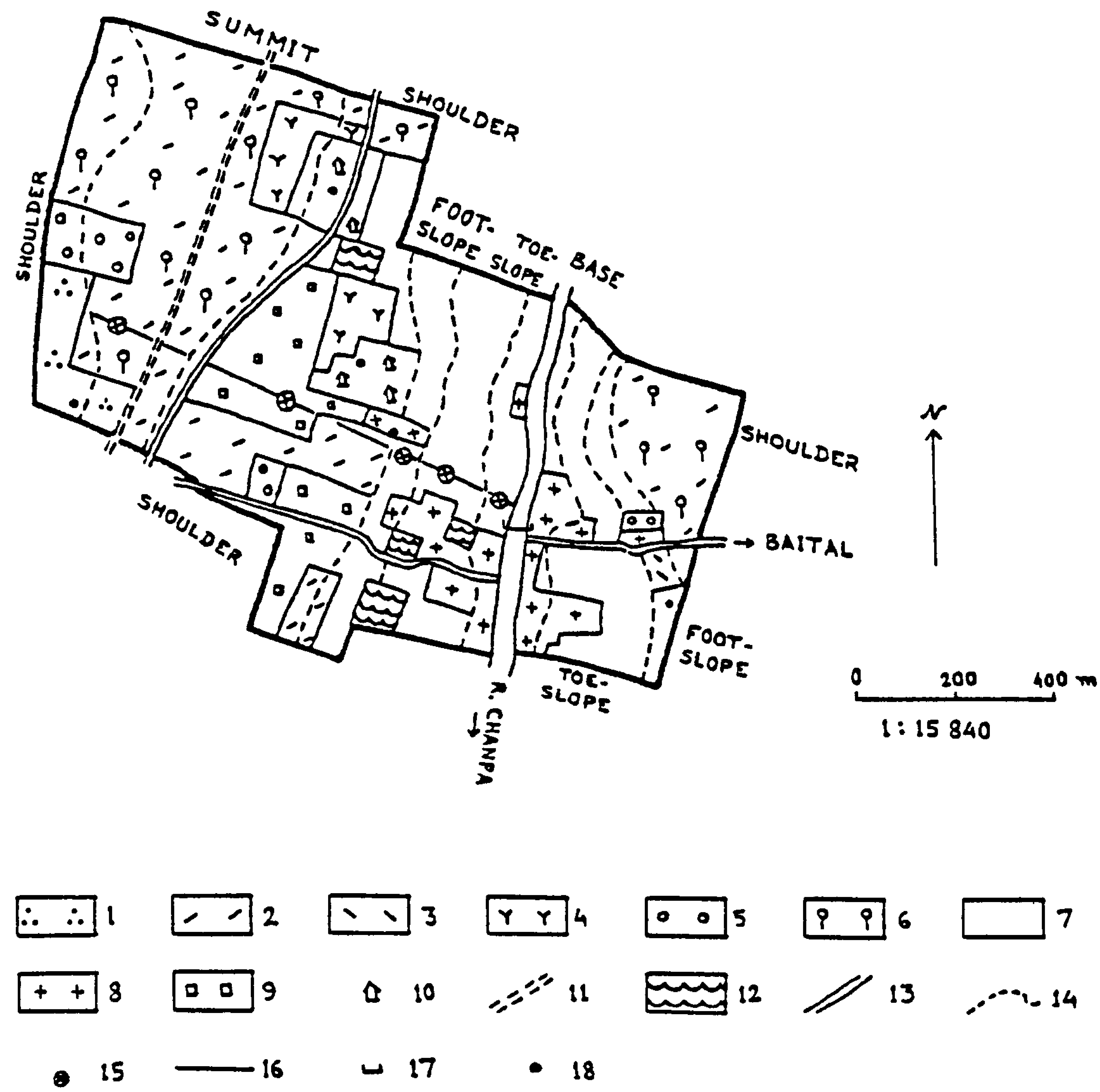


Figure 4.8 Land use pattern of System B (source: field mapping in Upar Amdahara village, 1981-82).

1. Forest plantation; 2. Pasture; 3. Planted grass; 4. Bamboo; 5. Orchard; 6. Trees; 7. Rice (single crop); 8. Multiple crops; 9. Vegetables; 10. Settlements; 11. Canal; 12. Pond; 13. Road; 14. Land facet boundary; 15. Soil sampling site; 16. Survey line; 17. Dam; 18 Well.

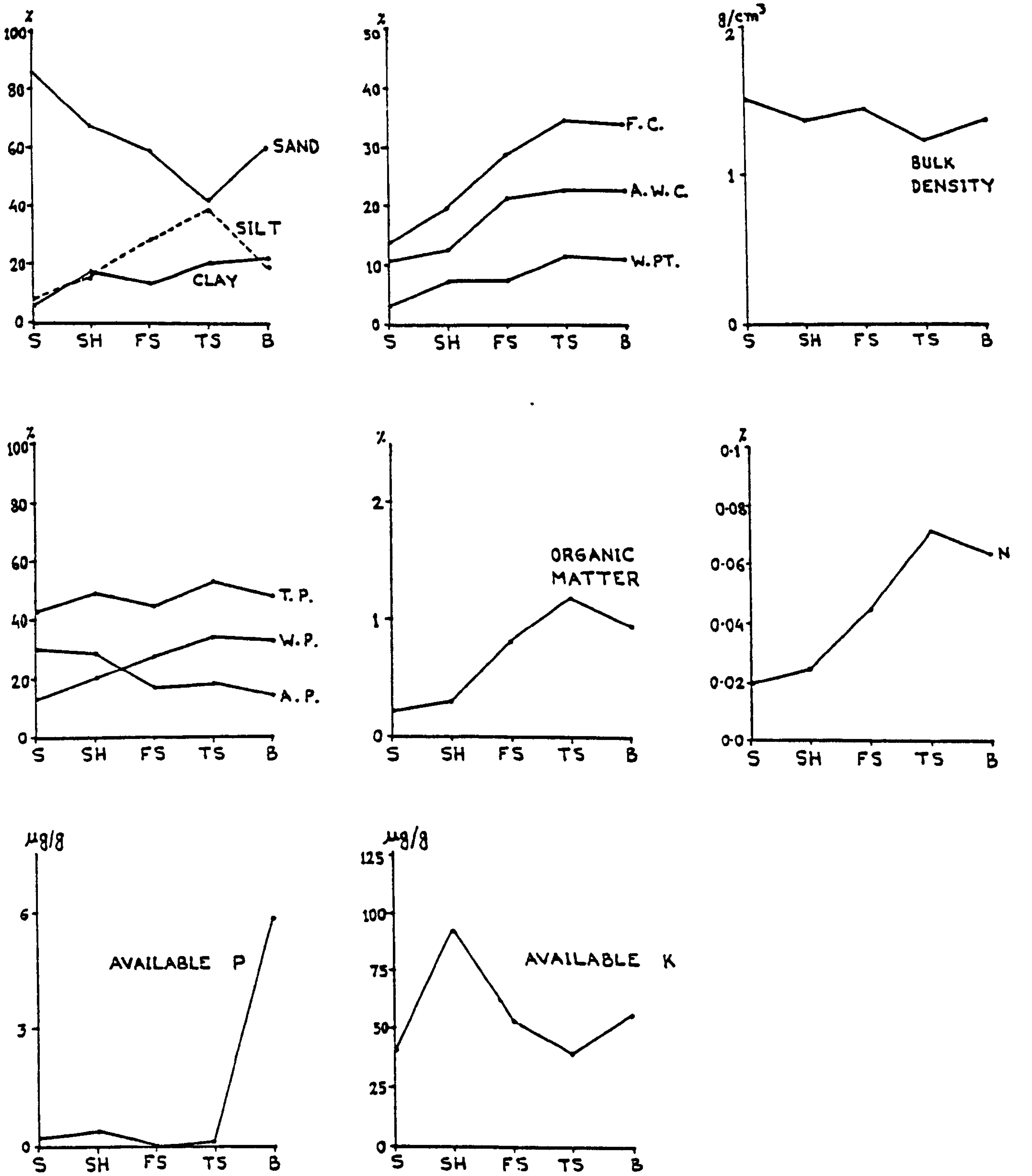


Figure 4.9 Surface soil properties of System B (source: laboratory work; see Appendix A).

S = Summit; SH = Shoulder; FS = Footslope; TS = Toeslope; B = Base. F.C. = Field capacity; W.PT. = Wilting point; A.W.C. = Available water capacity; T.P. = Total porosity; W.P. = Water-filled porosity; A.P. = Air-filled porosity.

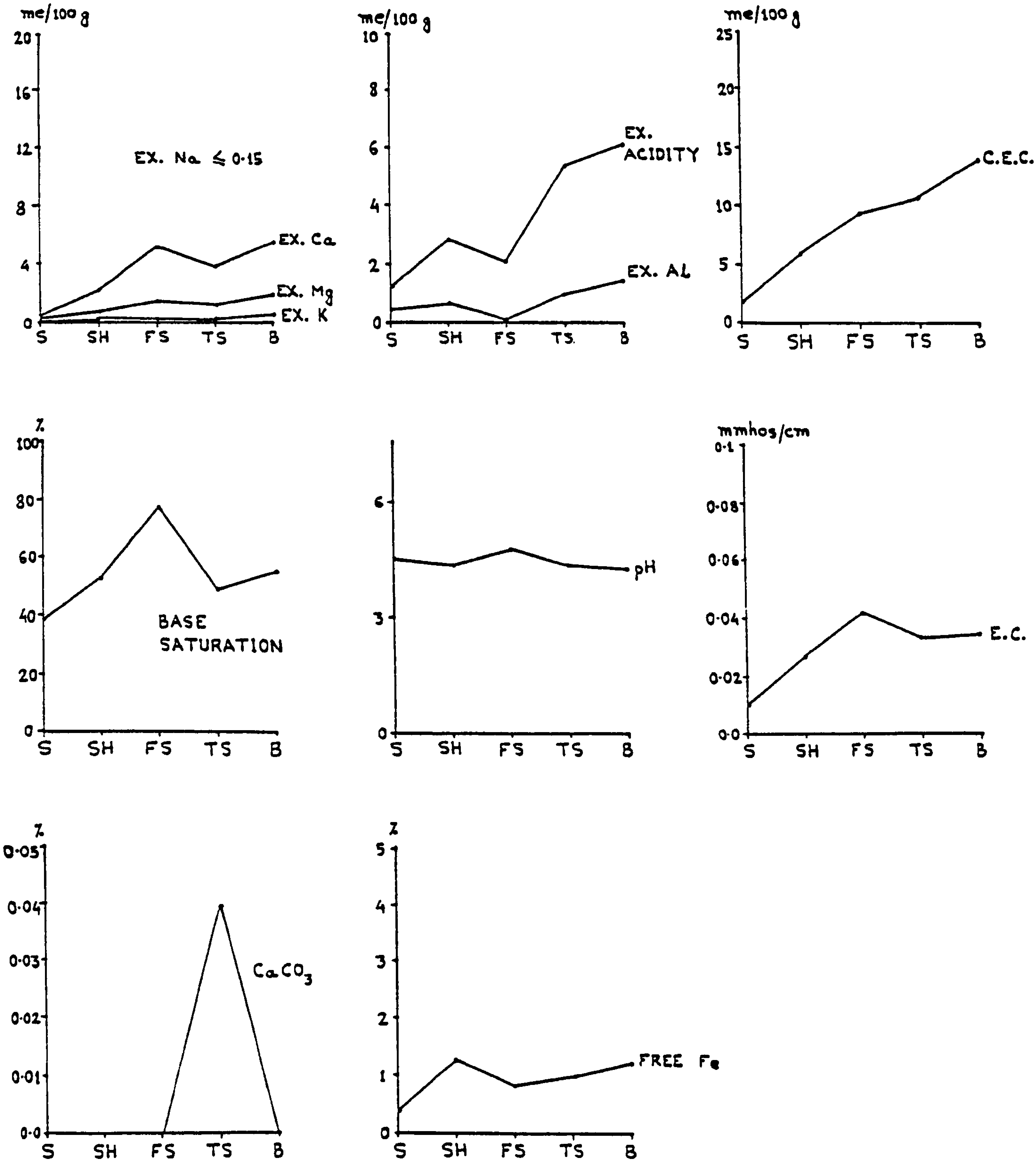


Figure 4.9 (continued)

EX. = Exchangeable; C.E.C. = Cation exchange capacity;
E.C. = Electrical conductivity.

colour. Then the colour changes, with increasingly poor drainage, to yellowish brown at the footslope and finally, to light grey at the toe-:slope and base. In Munsell notation the hue becomes more yellow, value higher and chroma lower with poor drainage condition. Mottles are absent from the surface horizons, except those along rice root channels at the toeslope and base facets. Ironstone concretions are limited in occurrence over this toposequence.

Roots are abundant in all facets. Ant activity is readily observed in all facets. Earthworms appear in the toeslope and base where moisture is plentiful.

The other physical properties are strongly controlled by the textural pattern as well as the amount of organic matter. These two properties are, therefore, described first. The textural pattern over this land system is determined by two factors: (1) selective transport and deposition of fine particles by surface water flow across the slope and (2) alluvial deposition by the stream over the base facet. The texture becomes increasingly finer from loamy coarse sand over the summit to loam at the toeslope. Sand decreases regularly whilst silt and also a little clay increase between these two facets (FIG. 4.9). But the base facet, instead of being still finer, is relatively coarser in texture (sandy clay loam) due to alluvial deposition by the stream. The deposition, however, is not great enough to form a levee. Since the irregularity at the base facet is small, all the textural components have developed statistical relationship with distance at significant level. Sand is negatively related whilst silt and clay have positive relationship.

Organic matter increases down the slope from low level at the summit to reach medium level at the toeslope facet. Then it slightly declines at the base area. The increase down to the toeslope facet is obviously due to transport and deposition of organic matter by surface flow, poorer drainage and manuring. The decline at the base area is probably due to low retaining capacity of the relatively coarser soil. Nevertheless organic matter shows, like the textural components, significant statistical relationship with distance. The organic matter is apparently well humified, for average C/N ratio is only 8.6.

The influence of this distribution pattern of texture and organic matter upon other physical properties is clearly seen in FIG. 4.9. Field capacity, wilting point, available water capacity, total porosity and water porosity increase down to the toeslope area and then slightly decline at the base facet. Bulk density and air porosity behave in the opposite manner. All these properties, like their controlling factors, are statistically correlated with distance at significant level.

Soil structure improves downslope from 'single grain' at the summit to granular at the base with finer texture, greater organic matter and activities of earthworms. Soil consistence follows the textural pattern more closely. It changes from non-sticky, very friable and soft over the summit to sticky, friable and hard at the toeslope area and then becomes slightly sticky and slightly hard at the base facet.

The distribution of the chemical properties, except that of nitrogen, is somewhat different from that of the physical properties. Essentially they increase from the summit towards the base, but they do not reflect the decline of organic matter and relative coarseness of texture over the base facet (FIG. 4.9). Moreover, the distribution of some chemical properties such as available phosphorus is irregular. Apparently the chemical properties are mainly influenced by lateral flow of water and other complex factors controlling their availability.

Nitrogen has a similar distribution over the facets as organic matter (FIG. 4.9). But available phosphorus and potassium are erratic in distribution. They are generally at the low level which is probably due to very strong acidity of these soils. The irregular rise of phosphorus to medium level at the base facet probably results from fertilizer application.

Exchangeable bases increase towards the base facet but remain within the low level (FIG. 4.9). Exchange acidity also increases towards the base area and, except in the footslope, it is higher than the total exchangeable bases. As a result base saturation is low and accordingly, soil reaction is strongly acidic. The distribution patt-:erns of base saturation and pH are anomalous. Base saturation is higher at the lower facets but pH slightly declines in that direction. This may be due to influences of different types of colloids.

Cation exchange capacity, following exchangeable bases and acidity, increase from low level at the summit to medium level at the base area. The downslope increase of the exchange properties is mainly due to transport and deposition of exchangeable ions by lateral flow of water in solution and as complexes with clay and organic matter. All the exchange properties are positively correlated with distance.

In spite of high exchange acidity, exchangeable aluminium is very low in all facets. Exchangeable sodium is also very low. There is, therefore, no toxic threat to plant growth from them. These soils are also free from the problem of salination under heavier irrigation, for the amount of soluble salts is very low. The salts are thoroughly removed and only accumulate in very small quantity in the lower facets. Likewise calcium carbonates are also absent from the surface soils except in a very small amount at the toeslope area. This occurrence may be due to precipitation from groundwater. Free iron is also low at all facets. It increases towards the base facet despite poor drainage condition which most authorities agree would normally reduce the level.

In summary, most of the surface soil properties improve towards the lower facets. Organic matter, nitrogen and most of the physical properties are at their best over the toeslope area. The base facet, although relatively poorer in these properties, has the greatest content of exchangeable bases, cation exchange capacity and available phosphorus. The toeslope and base facets are, therefore, well suited to cultivated crops. Their nutrient status may be further improved by application of phosphorus and potassium at the toeslope and organic manures at the base area. The footslope facet would require greater input; organic manures may be more economic considering the low exchange capacity. The summit and shoulder areas are better suited to perennial trees and grasses so far as surface soil properties are concerned.

4.2.2 SOIL PROFILES

Five soil profiles representing five facets are discussed in this subsection. Some of the morphological characteristics are shown in FIG. 4.6. The profile diagrams of physical and chemical properties are presented in FIG. 4.10.

All the facets have deep soils. No petroferric horizon is encountered within depth of study (125 cm on average). The toeslope and base profiles, however, have a shallow water-table persisting for a greater part of the year which limited the depth of study. In this toposequence the proximity of ponded streamwater is partly responsible for the shallow water-table.

Soil colour at the summit and shoulder areas becomes increas-:ingly more reddish and darker with depth. There are no mottles. These suggest thoroughly good drainage in both these facets. The footslope profile, on the other hand, becomes more yellow with depth and finally grey in matrix colour with red mottles, indicating imperfect profile drainage by the influence of fluctuating water-table. Although the mottles increase in abundance and size, they do not meet the require-:ments of 'plinthite in continuous phase' for classification purpose (Soil Survey Staff, 1975). Probably the small extent and the slope angle of the footslope facet restrict the zone of groundwater fluctuat-:ion and thus a significant amount of mottle formation is prevented. The toeslope and base areas become neutral in hue and chroma 0 with depth, indicating strong gleying. Mottles are plentiful, but they decrease in size and abundance with depth as gleying intensifies. In the base area the gleyed horizons are deeper than in the toeslope because of relatively coarser texture of the upper horizons.

Soil texture becomes increasingly finer with depth in all profiles because of argillation. The summit and shoulder profiles are sandy clay loam in the lower horizons. The footslope, toeslope

Figure. 4.10 Soil profile properties of System B (source: laboratory work; see Appendix A).

Figure 4.10 (continued)

Figure 4.10 (continued)

Figure 4.10 (continued)

Figure 4.10 (continued)

and base have relatively coarser A2 horizons below which texture is finer. The lower horizons of the footslope are clayey. The toe-:slope and base are sandy loam and clay loam respectively at the limit of water-table.

Soil consistence increases in stickiness, plasticity, firmness and hardness with depth in response to argillation. It is probably modified by type of clay, for its change is greater in the lower facets where silicate clays may be dominant. The summit and shoulder areas show lesser change of consistence possibly because of hydrous oxide clays.

Roots are present in all horizons of all profiles. They, however, decrease in abundance in the gleyed horizons of lower facets. In the summit and shoulder areas, there are 'coarse' roots of the trees.

The summit and shoulder profiles are well worked by the acti-:vities of ants and termites. Soil fauna is limited in the gleyed horizons of the lower facets, but they have earthworms in the upper horizons.

The horizon boundaries of the summit and shoulder profiles are gradual to diffuse. This may be due to red soil colour which masks other features. In the footslope, toeslope and base profiles the boundaries between Ap and A2 horizons and between A2 and Bt horizons are 'clear'. Within Bt horizons the boundaries are gradual.

The gravel content is low in these soils. The gravels are mainly ironstone concretions of 'small' to 'medium' size. They increase in abundance with depth at the summit and shoulder facets but decrease in the gleyed horizons of the lower facets (FIG. 4.10).

The nature of argillation is clearly seen in the profiles of textural components (FIG. 4.10). With depth, sand decreases and clay increases in all facets. Silt remains uniform or increases slightly. In the summit and shoulder areas clay rapidly increases within 40 cm. In the footslope, toeslope and base facets there are A2 horizons between 15 and 40 cm, below which clay increases sharply within 60 cm depth. The picture is incomplete in the toeslope and base areas because of their limited depth of study. The absence of A2 horizons from the summit and shoulder areas is possibly due to truncation by erosion. The weighted profile means of clay increases from the summit to the footslope, indicating progressively intense argillation (Appendix C). It is suggested that availability of greater quantities of water and fine particles intensifies argillation. The toeslope and base facets have lower profile means because of their limited depth of study.

The profile behaviour of other physical properties is greatly influenced by that of texture. The effect of organic matter is comparatively less because of its decrease with depth. The activities of tree roots and termites, however, modify the effect of clay increase at the summit and shoulder areas. In these two facets air porosity increases with depth in spite of finer texture whilst water porosity decreases (FIG. 4.10). In the footslope, toeslope and base facets, on the other hand, porosities are strongly controlled by texture. Total porosity increases with depth in all profiles; in the summit and shoulder it is because of air porosity while water porosity is respons-:ible for its increase in the lower facets. Correspondingly bulk density decreases with depth in all facets.

Field capacity, as expected, follows the profile pattern of water porosity whilst wilting point is controlled by the clay profile (FIG. 4.10). In the footslope, toeslope and base facets, field capacity increases less sharply than wilting point and it decreases in the summit and shoulder areas. The net result is that available water capacity decreases with depth at all facets. In apparent relationship with clay, the weighted profile means of water porosity, field capacity and wilting point increase towards the footslope while that of air porosity decreases (Appendix C).

The influence of argillation is also evident in the profile behaviour of chemical properties (FIG. 4.10). In addition these properties are affected by conditions of drainage, leaching, pH and others. The chemical properties have, therefore, developed different profile patterns according to predominating controlling factors.

Organic matter and nitrogen profiles are strongly influenced by soil drainage, concentration of tree roots and argillation. They decrease to very low levels with depth in all profiles (FIG. 4.10). But the decrease is gradual in the well drained facets while the poorly drained facets are characterized by a sharp decrease below the surface horizon. In the summit profile there is a slight increase around 40 cm which is possibly due to abundance of tree roots. The footslope, toeslope and base profiles are also characterized by a secondary influx at the upper part of the argillic horizon which is probably due to illuviation of humus as complexes with clay. These irregularities of profile pattern prevent the weighted means of organic fraction from developing any regular trend across the slope (Appendix C).

Available phosphorus is apparently controlled by pH (FIG. 4.10). Like the latter, phosphorus increases with depth. In fact, each small irregularity of phosphorus profile may be related to that of pH. But available potassium has different profile pattern at different facets. The reason for its behaviour is not fully understood. Because of their irregularities neither of these two properties show regular trend across the slope (Appendix C).

The exchangeable bases apparently move down the profiles as dissolved ions and adsorbed on the colloid surfaces with water. They increase with depth at all facets (FIG. 4.10). Their weighted profile means also increase towards the lower facets (Appendix C), indicating greater leaching with increasing amount of water. It seems from the weighted means and profile diagrams that the toeslope and base profiles are lower in exchangeable bases than the footslope. But this is because of their limited depth of study. They show, in fact, a tendency towards greater increase than the footslope profile. In profile pattern, the exchangeable bases show a decrease in the A2 horizon of the lower facets where clay and humus which hold the bases are low.

In contrast to the exchangeable bases, exchange acidity as well as exchangeable aluminium decrease with depth in all profiles (FIG. 4.10). As a result base saturation and pH increase with depth. The cation exchange capacity also increases with depth because of increasing exchangeable bases. Its profile pattern and trend of weighted profile means are similar to those of exchangeable bases (FIG. 4.10 and Appendix C).

Electrical conductivity regularly decreases with depth at the summit area, indicating a thorough leaching out of the soluble salts. But in the remaining facets, electrical conductivity increases slightly in the lower horizons. Either some of the leached down salts are accumulating there or they are precipitated in the capillary fringe of groundwater. The quantity is, however, too small to cause any problem (FIG. 4.10).

Calcium carbonates are present only at the lower facets, partic-:ularly in their deeper horizons (FIG. 4.10). They are leached out of the upper facets and the surface horizons of lower facets and are deposited in the deeper horizons of lower facets. Precipitation at the capillary fringe of groundwater may also be responsible for their deposition. The quantity of the carbonates is, however, very low. Free iron also tends to increase towards the lower horizons of all facets (FIG. 4.10), but the reason for its increase in the gleyed horizons is not fully understood.

This discussion may be summed up by saying that processes of argillation, leaching and drainage condition are the main factors controlling profile behaviour of these soils. With argillation and leaching, total porosity, exchange capacity and plant nutrients, except nitrogen, improve in the lower horizons and also towards the lower facets. But increasingly poorer drainage restricts plant root activities in the deeper horizons of lower facets. These facets are, therefore, better suited to the shallow-rooted annual plants or those adapted to waterlogging. The upper facets, on the other hand, allow deep root penetration because of their deep, well drained soils with greater air porosity at depth. At present these facets are well suited to perennial trees and grasses, but with manuring they may support many plants which cannot be grown in the poorly drained lower facets.

4.2.3 SOIL CLASSIFICATION

All five profiles in this land system have argillic horizons where base saturation is more than 35%. Therefore, they belong to Alfisol order. The toeslope and base profiles have aquic moisture regime, indicated by low matrix chroma and presence of mottles. Since they do not have iso-temperature regime nor plinthite but have ochric epipedon, they are classified as Ochraqualfs. The profile at the base facet has a chroma greater than 2 at the A2 horizon (12 - 37 cm) where coarse texture allows aeration. This profile is, therefore, classified as Aeric Ochraqualf. The toeslope profile corresponds to the central concept of Ochraqualfs. Hence it is a Typic Ochraqualf.

The footslope, shoulder and summit areas have ustic moisture regime. These soils are, therefore, Ustalfs. The footslope profile has no plinthite. There is neither a very sharp increase of clay to be a Paleustalf nor the hue of the argillic horizon is red enough for Rhodustalf. It is, therefore, a Haplustalf. Since there is no calcic horizon, it is classified as Udic Haplustalf.

The Ustalfs at the shoulder and summit areas do not have plinth-:ite. They do not meet the requirements of Rhodustalf, but they have the right type of hue and clay distribution for Paleustalf. Both of them lack calcic horizon and have less than 75% base saturation in the argillic horizon. They are, therefore, classified as Ultic Paleustalf.

The soil classification clearly shows the change of moisture regime at the lower boundary of the footslope, The summit and shoulder areas have significant argillation and low base saturation. The foot-:slope has a better moisture regime (udic at the subgroup level) than these two facets. The base facet has better aeration than in the toeslope which prevents strong gleying near the surface.

4.3 LAND SYSTEM C (BULANPUR SYSTEM)

This system lies within the valley of a first order stream. The representative toposequence consists of the headstream area of R. Tamal. The toposequence is situated within the area of a village near Bulanpur (latitude 22 degrees, 44 minutes north and longitude 87 degrees, 6 minutes east). Its location is shown in FIG. 4.32 (in SECTION 4.9).

The form of the slope profile is rectilinear for the most part (FIG. 4.11). There is a more or less regular fall from the summit to the base. Most of the slope profile is occupied by the summit, shoulder and footslope facets. The toeslope and base areas are very narrow, each about 100 m in width. The summit area is gently convex. The shoulder, footslope and toeslope are gently sloping at an average angle of 1.0 degree. The shoulder is only slightly steeper than the footslope or toeslope. The footslope is subjected to moderate or severe gully erosion, probably because of its great slope length (FIG. 4.12; see also SECTION 4.7). There are many locally steep slopes where gullies cut through the land (FIG. 4.11). The base area is flat. The relative proportion and slope angles of the facets indicate a lesser valley flattening than in system B (SECTION 4.2).

In some places such as in the base facet and near stream channel in lower footslope, there are recent stream depositions occurring at various depths. Stratified deposits of sand, silt and clay are found. These layers have a marked influence upon drainage and profile pattern

Figure 4.11 Land System C: slope and soils (source: field work; see Appendices A and E).

1. Ironstone concretions; 2. Cemented pisolitic ironstone; 3. Mottles; 4. Strong gleying; 5. Argillic horizon; 6. Sand; 7. Stratified sand; 8. Stratified clay; 9. Water-table during field work.

of the soil properties. A site in the lower footslope has been studied to demonstrate this. The upper footslope area shows a grey colour in the soils near stream channel. A site has been studied here also (see SECTION 4.3.2 for explanation of colour).

This toposequence suffers from shallow water-table over a great:er part of the area during wet season (FIG. 4.12). Drainage becomes poorer and approaches closer to the soil surface towards the base facet. This is probably due to the presence of many channels of stream and gullies which raise the water-table of the area. Except:ing the summit, all facets have drainage problems. The shoulder area is moderately well drained. The footslope is imperfectly drained by the influence of fluctuating water-table which is evident from below 50 cm depth. In the toeslope and base, whole profiles below the Ap horizon are poorly drained. The water-table was encountered at 110 cm depth at the base area during the field study (winter, 1982). Poor drainage is modified by coarse depositional layers wherever they occur in the lower facets. For example, the profile at the lower footslope between 0 - 140 cm and the base profile between 38 and 70 cm depth are better drained than the other horizons (FIG. 4.11).

The land use pattern of the area with facet boundaries is shown in FIG. 4.13. The summit, shoulder and greater part of the foot:slope are covered with 'type D, relatively undisturbed natural vegetation' (SECTION 2.4 and TABLE 2.10). The growth is 'slightly dense' and the canopy is 'slightly close' in the summit. But they become more open towards the footslope. The settlements are situated at the edge of the forest. The remaining part of the footslope and

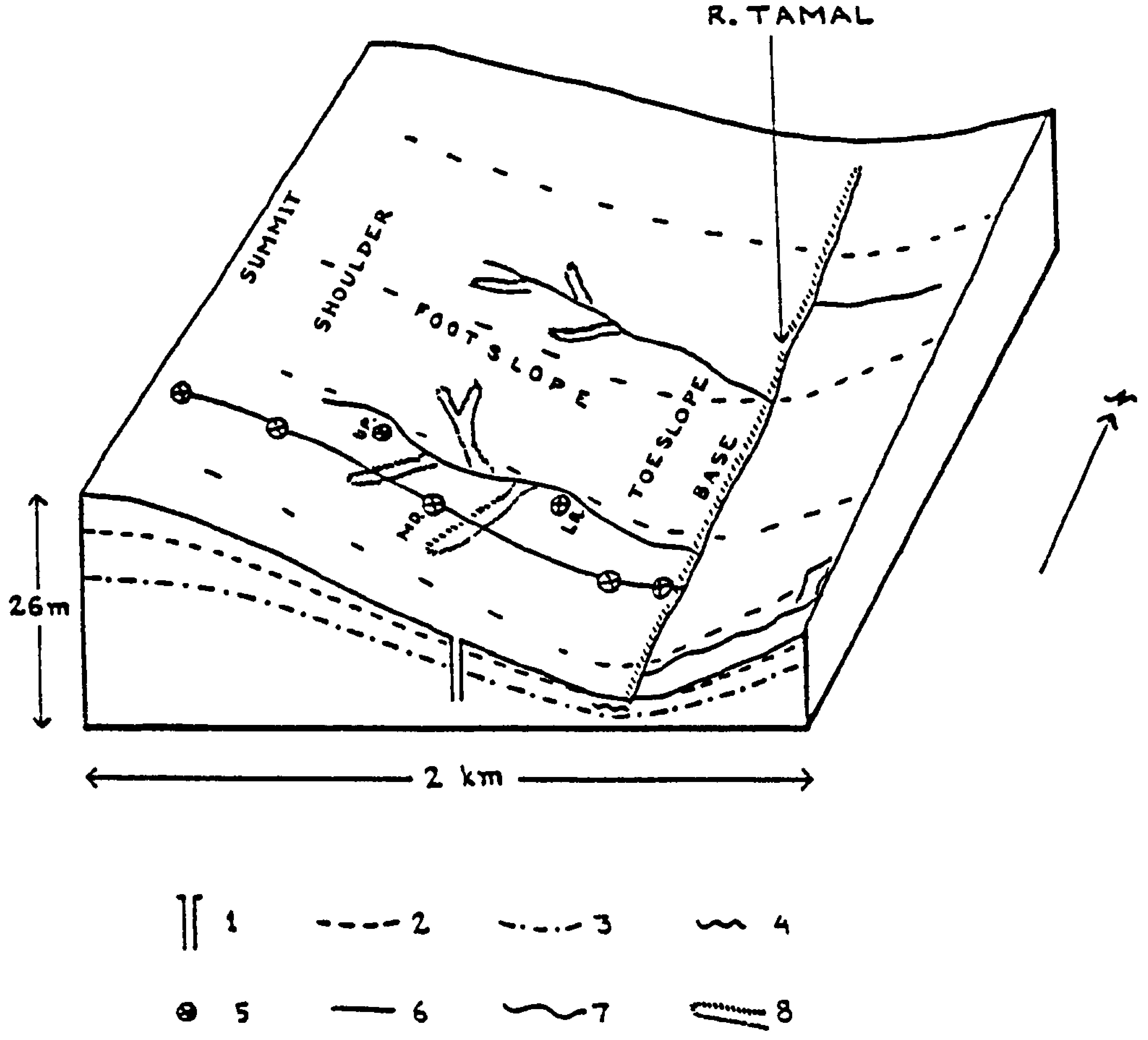


Figure 4.12 A schematic block diagram of System C.

1. Well where depth to water-table was measured; 2. Wet season water-table; 3. Summer water-table; 4. Water-table encountered in a pit during field work; 5. Soil sampling site; 6. Survey line; 7. Stream; 8. Gullies.
UP. = Upper footslope profile; MD. = Middle footslope profile, representing the footslope facet; LR. = Lower footslope profile.

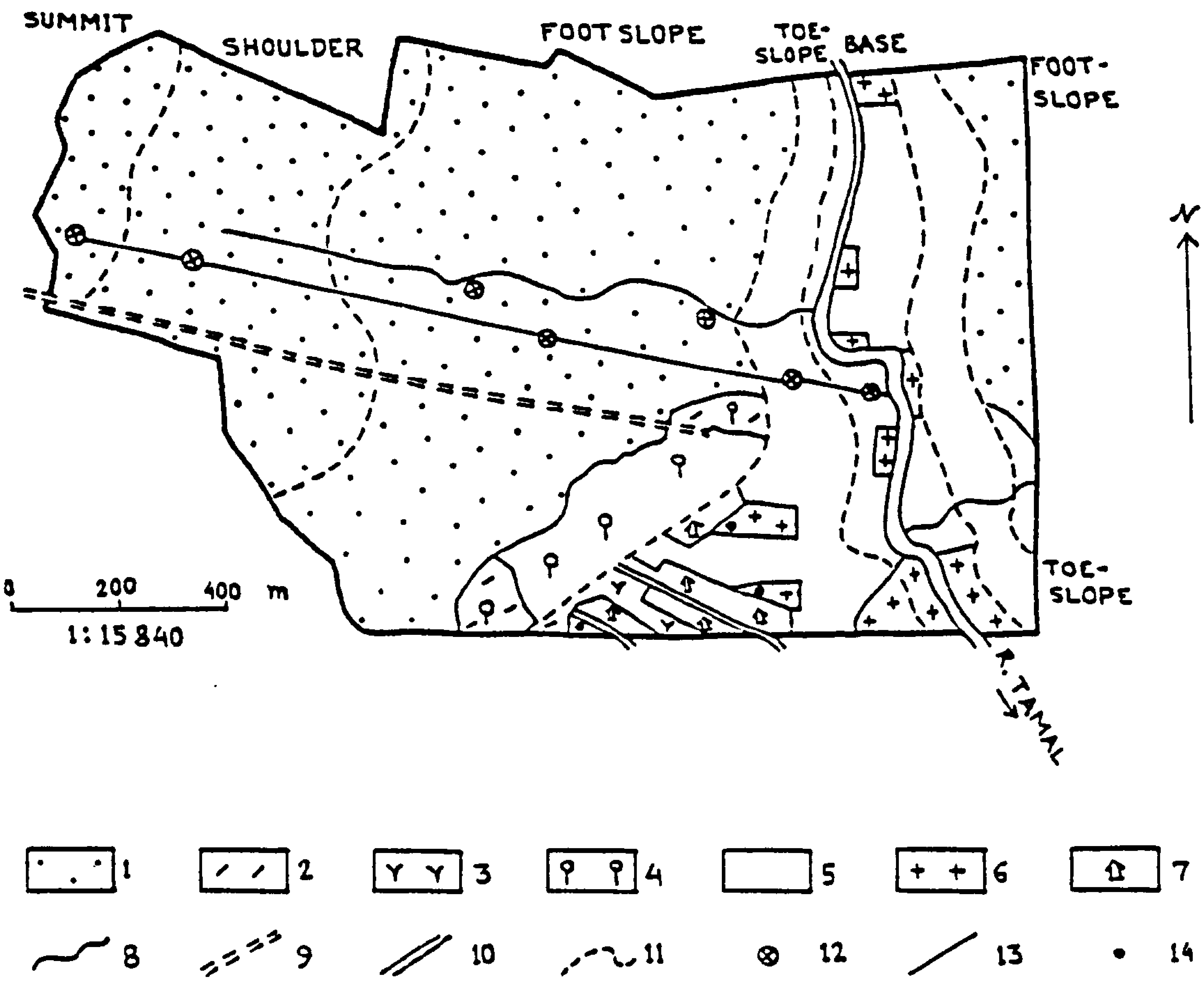


Figure 4.13 Land use pattern of System C (source: field mapping in Salbani and Balikhunia villages, 1981-82).

1. Forest; 2. Pasture; 3. Bamboo; 4. Trees; 5. Rice (single crop); 6. Multiple crops; 7. Settlements; 8. Stream; 9. Canal; 10. Road; 11. Land facet boundary; 12. Soil sampling sites; 13. Survey line; 14. Well.

the entire toeslope and base facets are under cultivation. Rice is grown during the wet season. Parts of these facets are also culti:vated with irrigation in winter and summer. Rice (at the base facet), wheat, oilseeds and vegetables are the main irrigated crops. There is little grass upon the forest floor, but the cultivated fields are occupied by grasses when left fallow.

The effects of these environmental factors upon the distribution pattern of soil properties are discussed in the following subsections.

4.3.1 SURFACE SOIL PROPERTIES

There are seven soil samples in this land system. Each facet is represented by one sample, except the footslope where three samples are studied for upper, middle and lower footslopes. The middle footslope is representative of the footslope facet. The upper and lower footslopes are included for their special features (see SECTION 4.3). The distribution of the physical and chemical properties over the facets is shown in FIG. 4.14.

Soil colour gradually changes from strong brown over the summit area to pale yellow at the base with increasingly poorer drainage. There is a progressive change of hue, value and chroma towards the base facet, but the characteristic grey colour of poor drainage is not achieved. Mottles are also absent from the surface horizon, except the reddish lines along rice roots in the lower facets. It seems that water does not remain stagnant for a long time in the surface horizon.

There are no ironstone concretions over the upper facets, but a few are found in the lower slope. They are probably depositional.

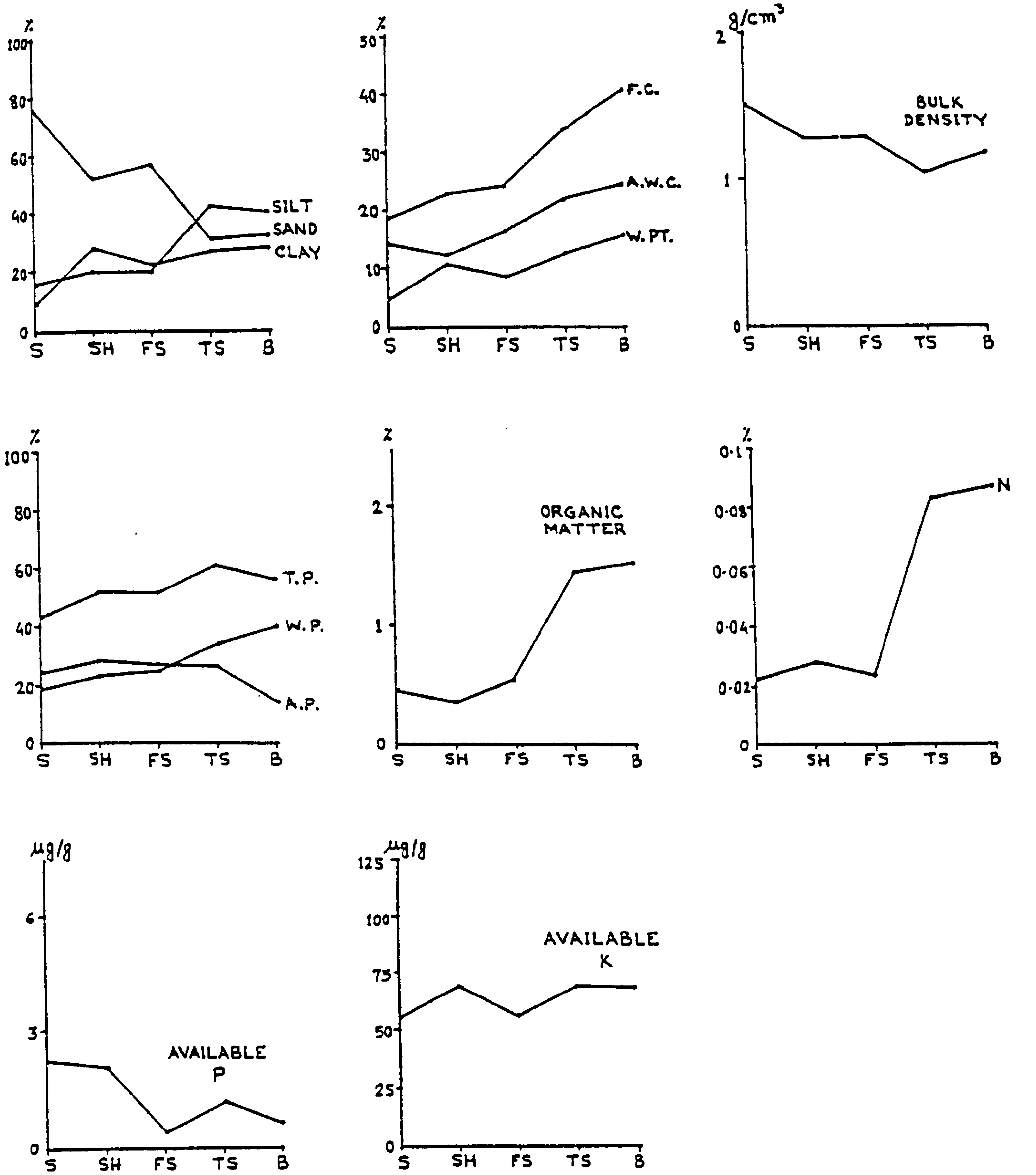


Figure 4.14 Surface soil properties of System C (source: laboratory work; see Appendix A).

S = Summit; SH = Shoulder; FS = Footslope; TS = Toeslope; B = Base. F.C. = Field capacity; W.PT. = Wilting point; A.W.C. = Available water capacity; T.P. = Total porosity; W.P. = Water-filled porosity; A.P. = Air-filled porosity.

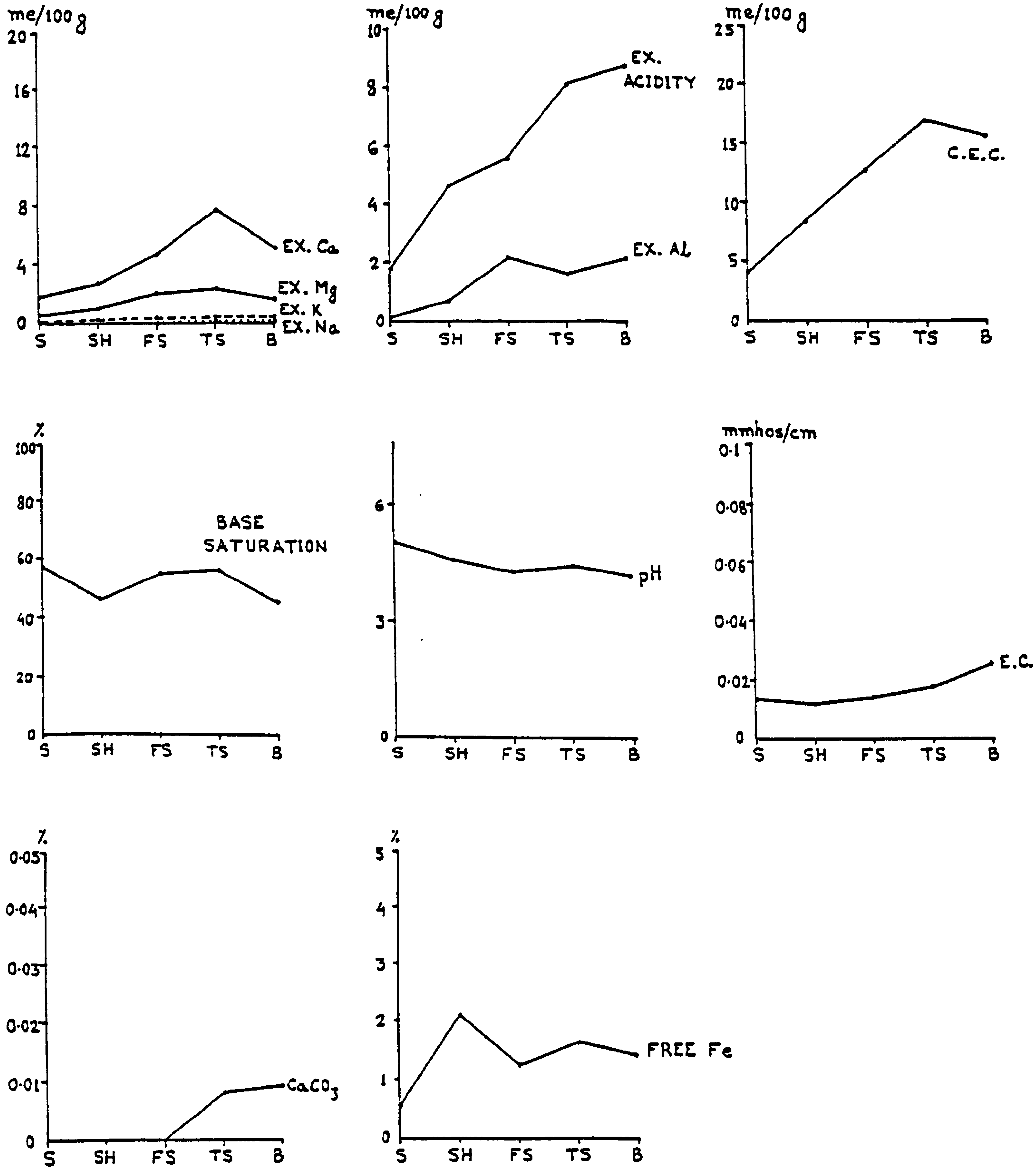


Figure 4.14 (continued)

EX. = Exchangeable; C.E.C. = Cation exchange capacity;
E.C. = Electrical conductivity.

Some calcium carbonate concretions are found strewn over the toeslope and base facets. According to the local people, these are brought up during digging for irrigation wells. But no such concretions were encountered in the studied profiles nor seen in situ in any natural section. They possibly occur below a depth of 2 m.

Roots and animals are abundant in the surface horizons of all facets. The type of animals, however, changes from termites to earthworms with increased moisture content at the lower facets.

The distribution of the other physical properties and, to some extent, chemical properties are controlled by texture and organic matter content. These two properties are, therefore, described first. The texture of the surface horizon becomes progressively finer down the slope from sandy loam over the summit to clay loam at the base facet. This is because of selective transport and deposition of fine particles by surface water flow. The downslope increase of silt is more regular than that of clay (FIG. 4.14) probably because the latter is transported into the stream instead of being deposited at the lower facets. This is why clay fails to show a significant statistical relationship with distance. As a corollary to the increase of fine particles, sand decreases towards the base facet developing negative relationship with distance.

The upper and lower footslope sites are relatively coarser in texture than the neighbouring areas. This is because of their locat-:ion close to the stream (FIG. 4.12) which is an agent of coarse alluv-:ial deposition.

The organic matter increases from low level over the summit to medium level at the toeslope and base (FIG. 4.14). This increase is due partly to downslope transport and deposition by surface flow and partly to greater moisture, finer texture and grassy vegetation over the lower facets. However, the distribution curve of organic matter is not regular apparently on account of vegetation type (FIGS. 4.13 and 4.14). There is a sharp increase of organic matter at the junction of forest and grassy cultivated fields i.e. between the footslope and toeslope. The influence of texture upon organic matter content is well demonstrated in the case of upper and lower footslope sites. These two texturally coarse soils are poorer in organic matter than the neighbouring areas despite having the same forest vegetation.

All the physical properties are strongly influenced by the distribution pattern of texture and organic matter. The non-sticky, friable and slightly hard consistence of the summit soils becomes sticky, firm and hard towards the base facet in close relationship with the texture. The structure is more influenced by organic matter and types of vegetation and animal. It remains massive throughout the humus-poor forest covered facets. But as the organic matter sharply increases at the toeslope accompanied by grasses and earthworms, a crumb structure is developed.

In response to finer texture, greater organic matter content and better structure, the field capacity, wilting point, available water capacity, total porosity and water porosity increase from the summit to the base area (FIG. 4.14). Their distribution curves are more or less regular. All of them are positively correlated with distance. Predictably the bulk density and air porosity decrease towards the base facet. The upper and lower footslope sites are not part of this general trend on account of coarser texture and lower organic matter content. They are lower in field capacity, wilting point and total porosity but higher in bulk density than the neighbouring sites.

Like the physical properties described above, most of the chemical properties show a trend pattern with distance. But some of them such as available phosphorus and pH decline towards the base facet. Still others like available potassium and free iron are very irregular in their distribution. Obviously they are influenced by various factors of chemical environment in addition to lateral flow, texture and organic matter.

The nitrogen behaves like the organic matter. It remains low over the three upper facets and then sharply rises to medium level in the toeslope and base facets (FIG. 4.14). The available phosphorus and potassium, on the other hand, are low throughout this land system. Moreover, phosphorus decreases towards the lower facets in response to a fall in pH (FIG. 4.14). But potassium does not show any clear trend.

The exchangeable bases are at low level over the summit area, but increase down the slope to medium level at the toeslope facet (FIG. 4.14). It is likely that exchangeable bases are transported by lateral flow and deposited over the lower facets where they are retained by texturally fine and humus-rich soils. There is, however, a decrease of calcium and magnesium at the base facet. This is not related to fine particles or organic matter, both of which continue to increase over the base facet. Possibly calcium and magnesium are partly transported into the stream and partly leached downward through the layers of sand (FIG. 4.11). Nevertheless they dominate the exchangeable bases in all facets and also show a positive correlation with distance.

Both the exchangeable aluminium and exchange acidity increase towards the base facet (FIG. 4.14). The aluminium saturation, however, remains below toxic level throughout the toposequence. The exchange acidity, averaging the values over all facets, is slightly less than the total exchangeable bases. The average base saturation is, therefore, just over 50%. It tends to decrease towards the base facet with the decline of exchangeable bases, but the pattern is not regular (FIG. 4.14). The soil reaction, as expected, is very strongly acidic over the summit and becomes extremely acidic towards the base facet (FIG. 4.14).

The cation exchange capacity, following the increases of exchangeable bases and acidity, shows a perfectly regular rise from the summit to the toeslope where it reaches medium level (FIG. 4.14). But then it decreases at the base facet, being weighted by calcium and magnesium. The humus-poor and texturally coarse soils of the upper and lower footslope sites are poorer in exchangeable bases and exchange capacity than the neighbouring areas.

The electrical conductivity is very low throughout the topo-:sequence. It increases towards the base facet (FIG. 4.14), but there is no threat of salination. The calcium carbonate is present in very small amount at the toeslope and base facets only. The accumulation of salts and carbonates over the lower facets may be due partly to poor drainage and partly to precipitation. The free iron is present at all facets in small amount, but it has no regular trend pattern (FIG. 4.14).

In summary, the surface soils of the land system C improve in physical properties and in most of the chemical properties towards the lower facets where they reach medium level. The toeslope area has the best nutrient status among the five facets. The lower facets, however, require application of phosphorus and potassium fertilizers. In addition, the exchange capacity at the base facet may also be upraised by organic manuring. So far as surface soils are concerned, the lower facets are better suited to cultivated crops than the upper facets.

4.3.2 SOIL PROFILES

As outlined in SECTION 4.3, there are seven profiles in this land system. Each facet has one representative profile. The foot-:slope facet has two additional profiles: upper and lower footslopes. These are included to study some interesting features (see SECTION 4.3). Some of the morphological properties of all profiles are shown in FIG. 4.11. The profile diagrams of the physical and chemical properties are presented in FIG. 4.15.

All facets of this toposequence have deep soils (FIG. 4.11). The middle footslope profile is, however, no deeper than 115 cm because of a petroferric contact (cemented pisolitic ironstone). It is unlikely that the ironstone at this depth significantly affects plant roots. The profile at the base area suffers from shallow water-table (SECTION 4.3) and also has deposits of sand between 38 and 70 cm depth which may inhibit root growth.

The summit profile becomes more reddish with depth and has no mottles (FIG. 4.11), implying good drainage throughout. There are only a few ironstone concretions in the lower horizons. The shoulder profile is yellowish red down to 90 cm and then faint mottles of pale

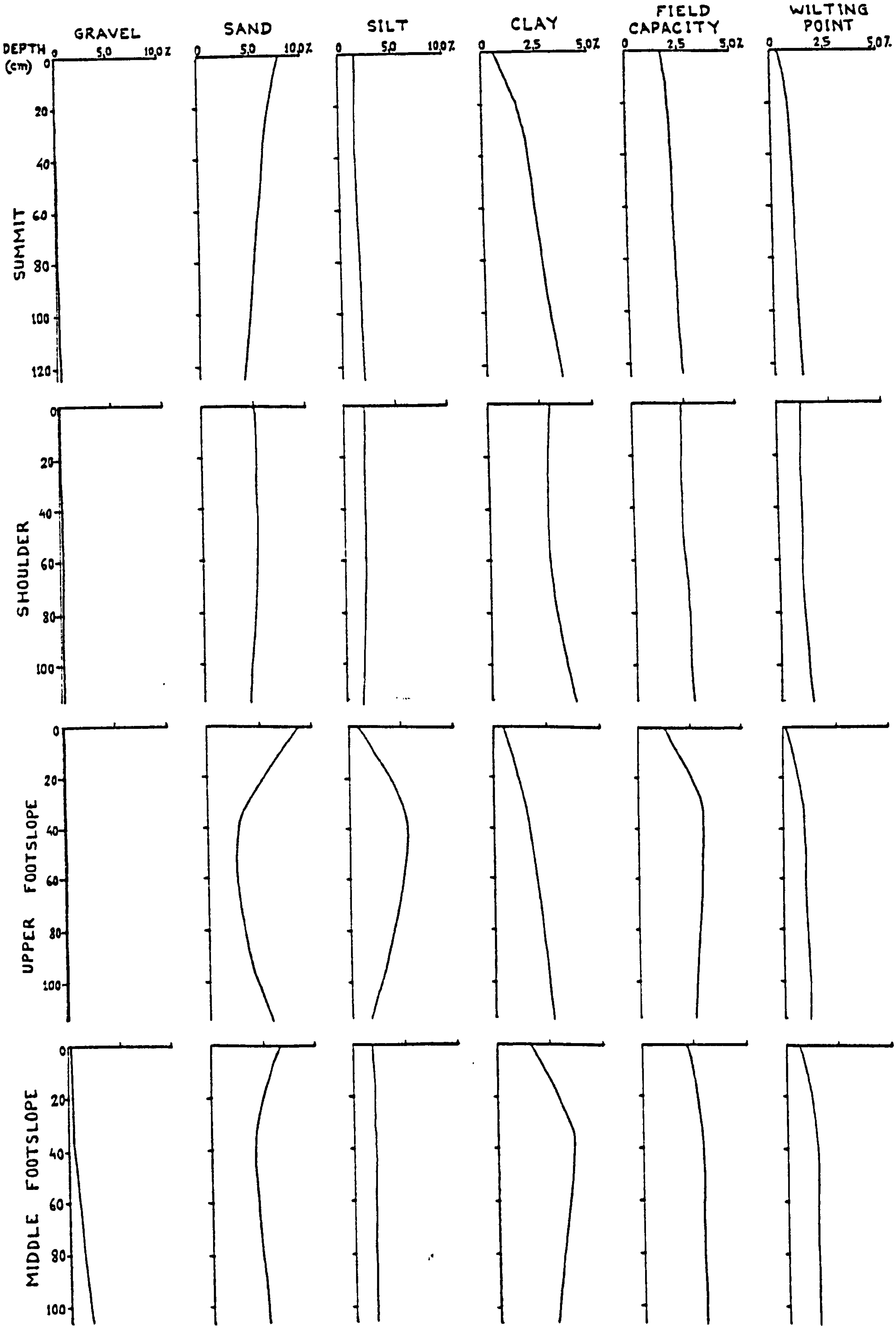
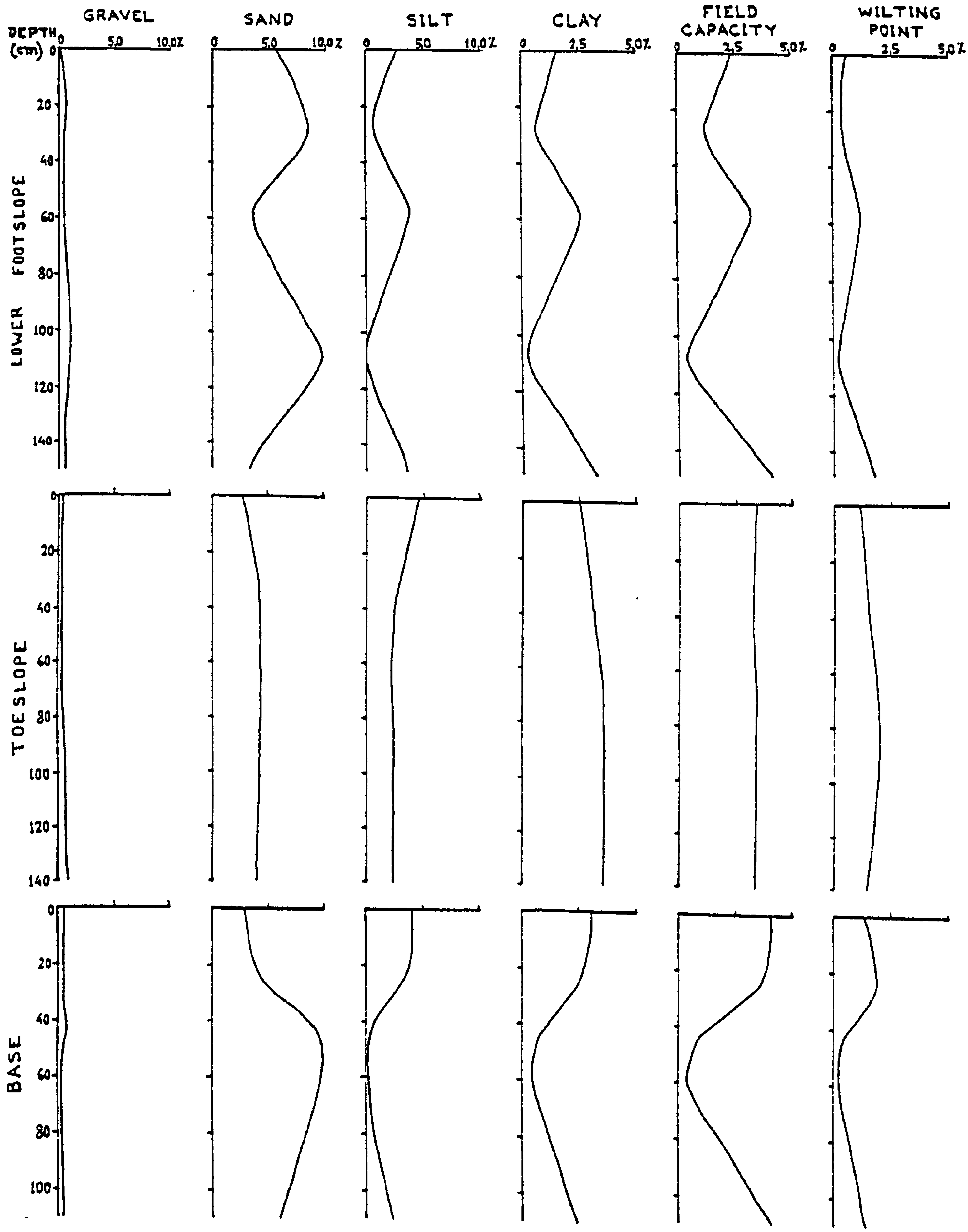


Figure 4.15 Soil profile properties of System C (source: laboratory work; see Appendix A).



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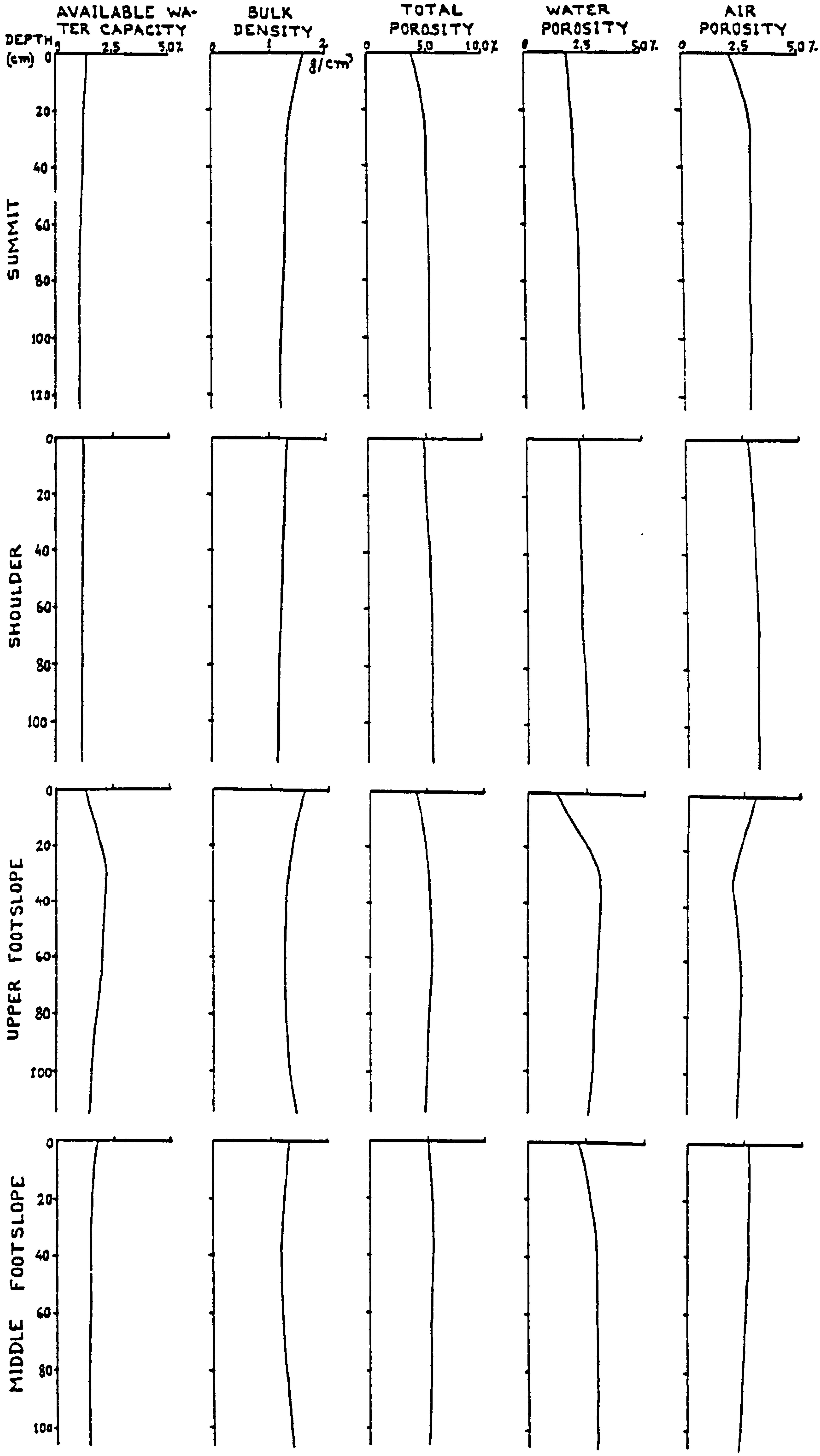

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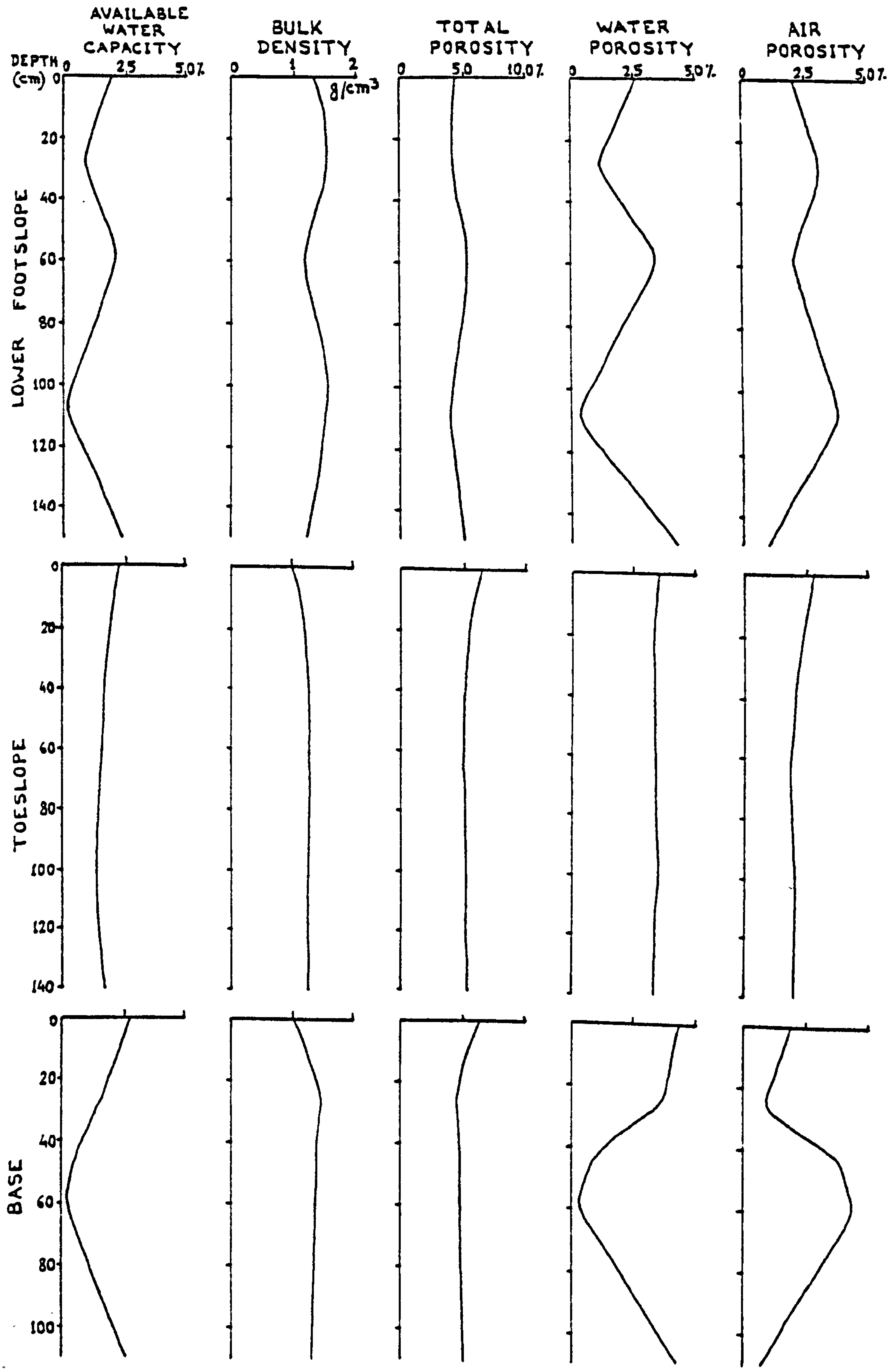

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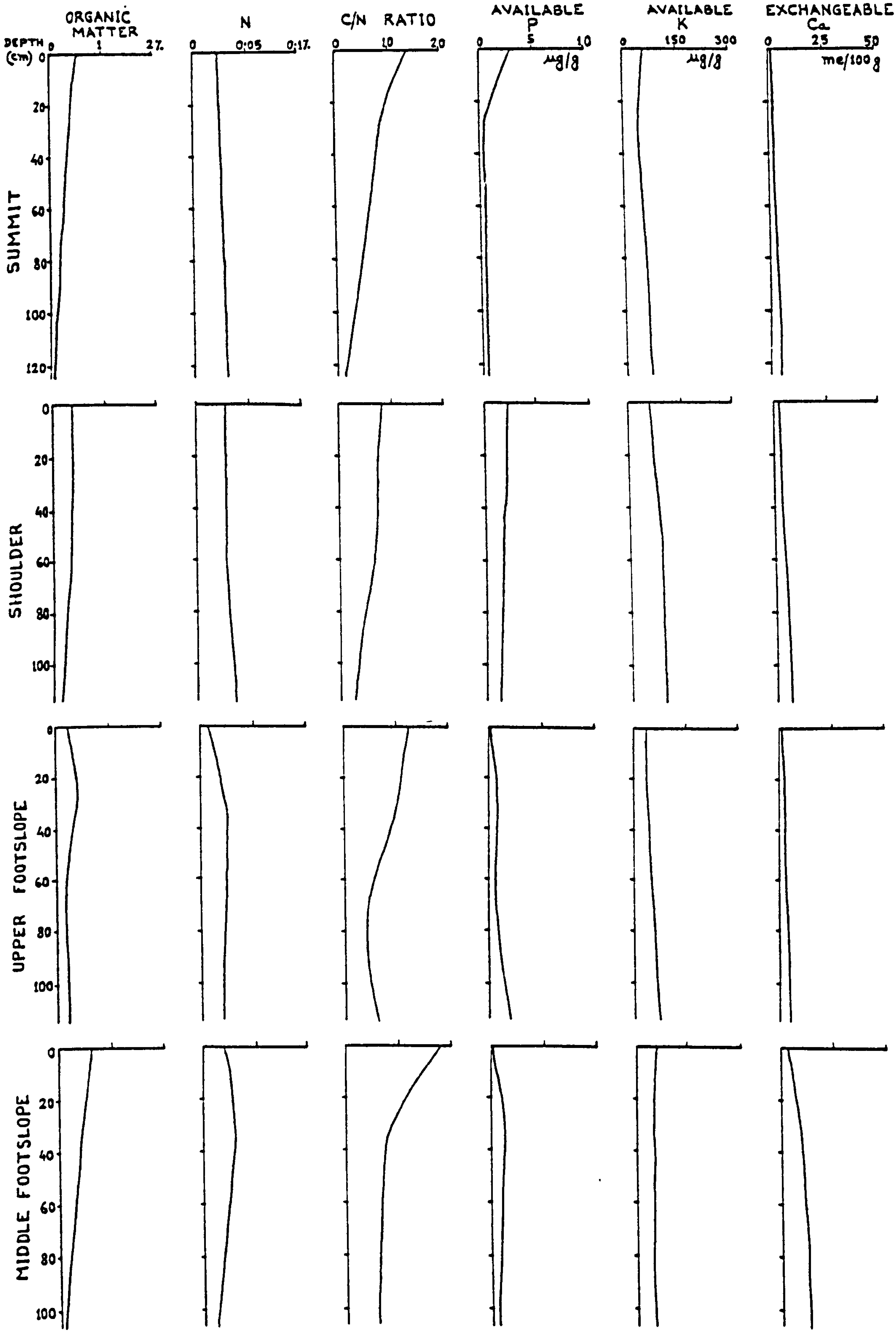

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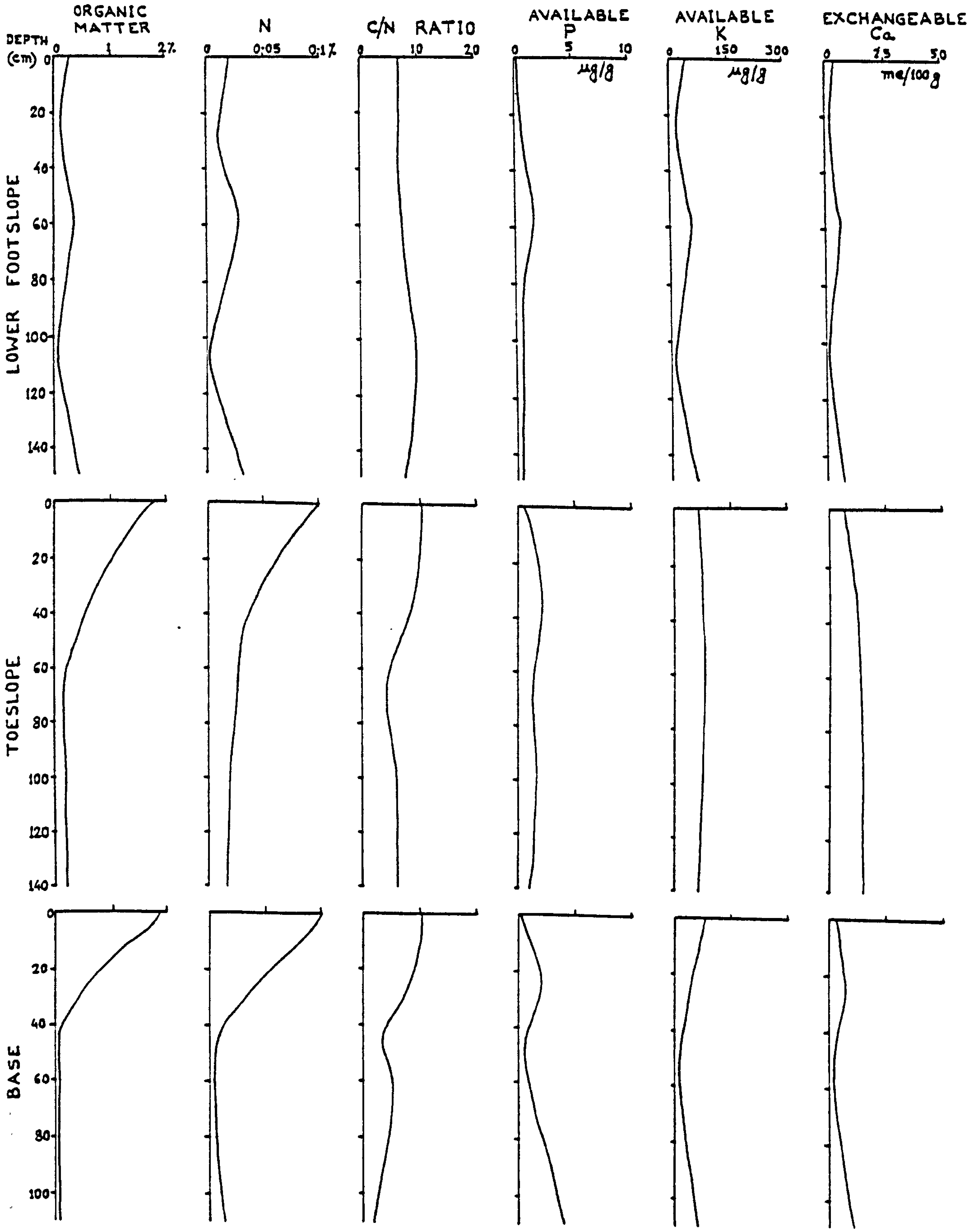

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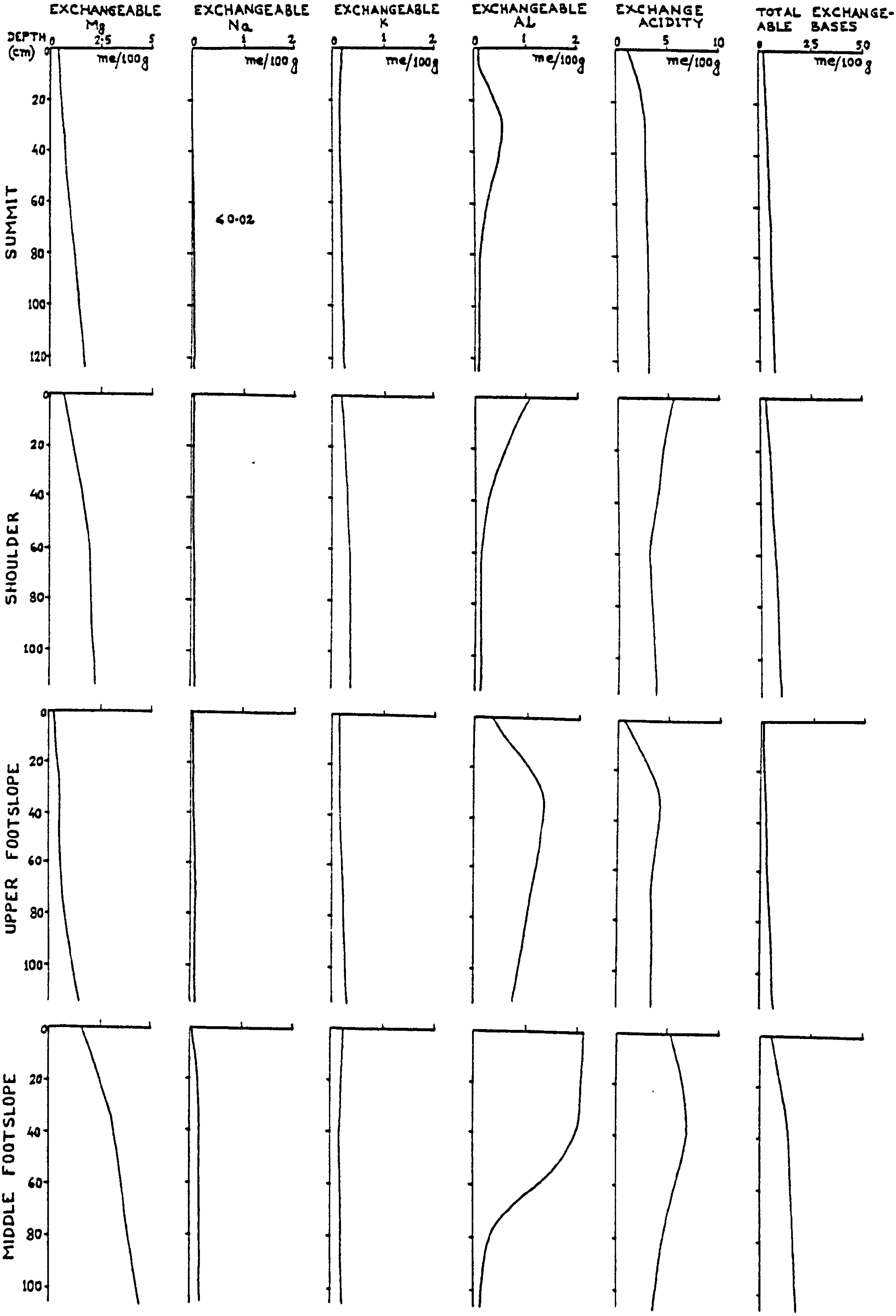

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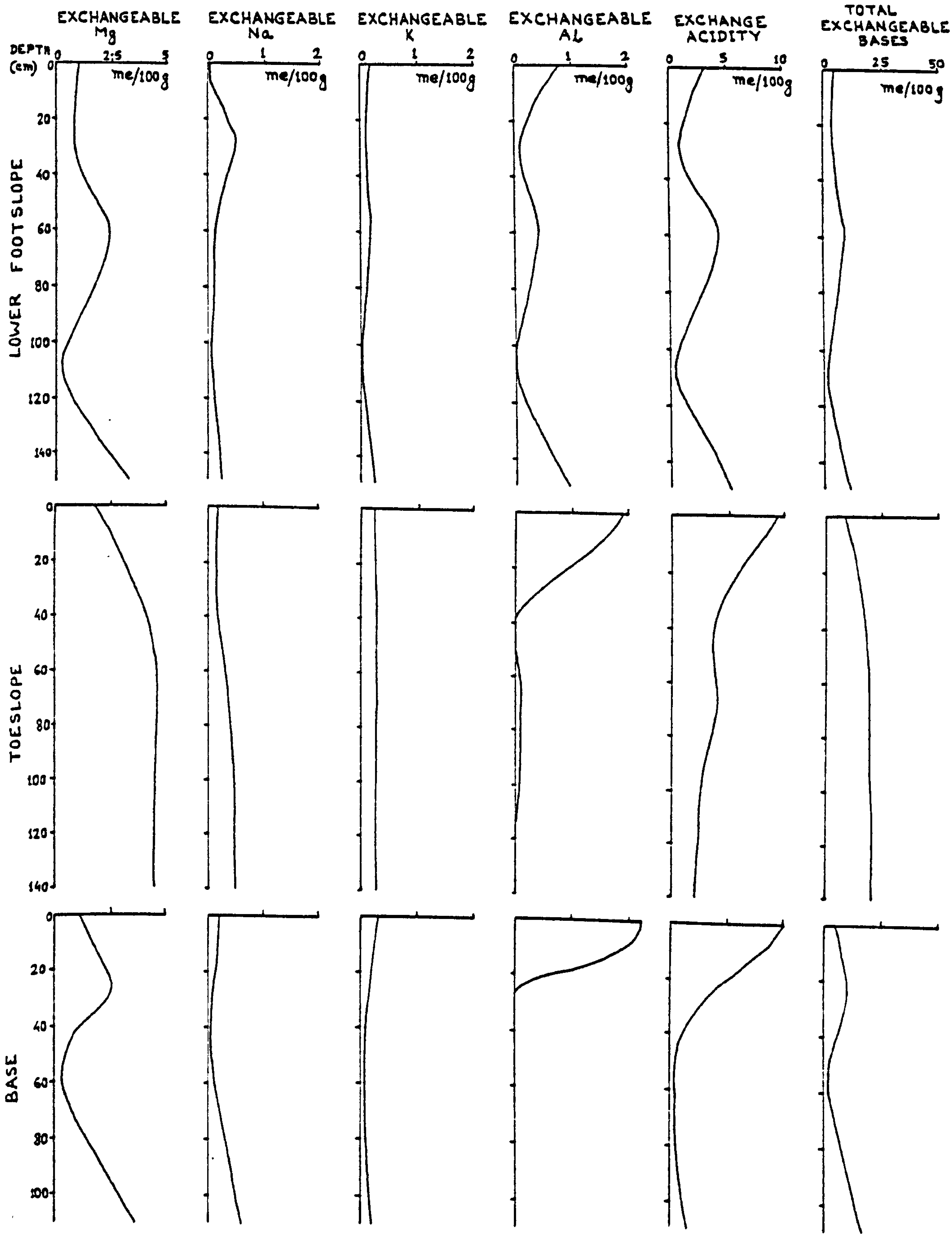

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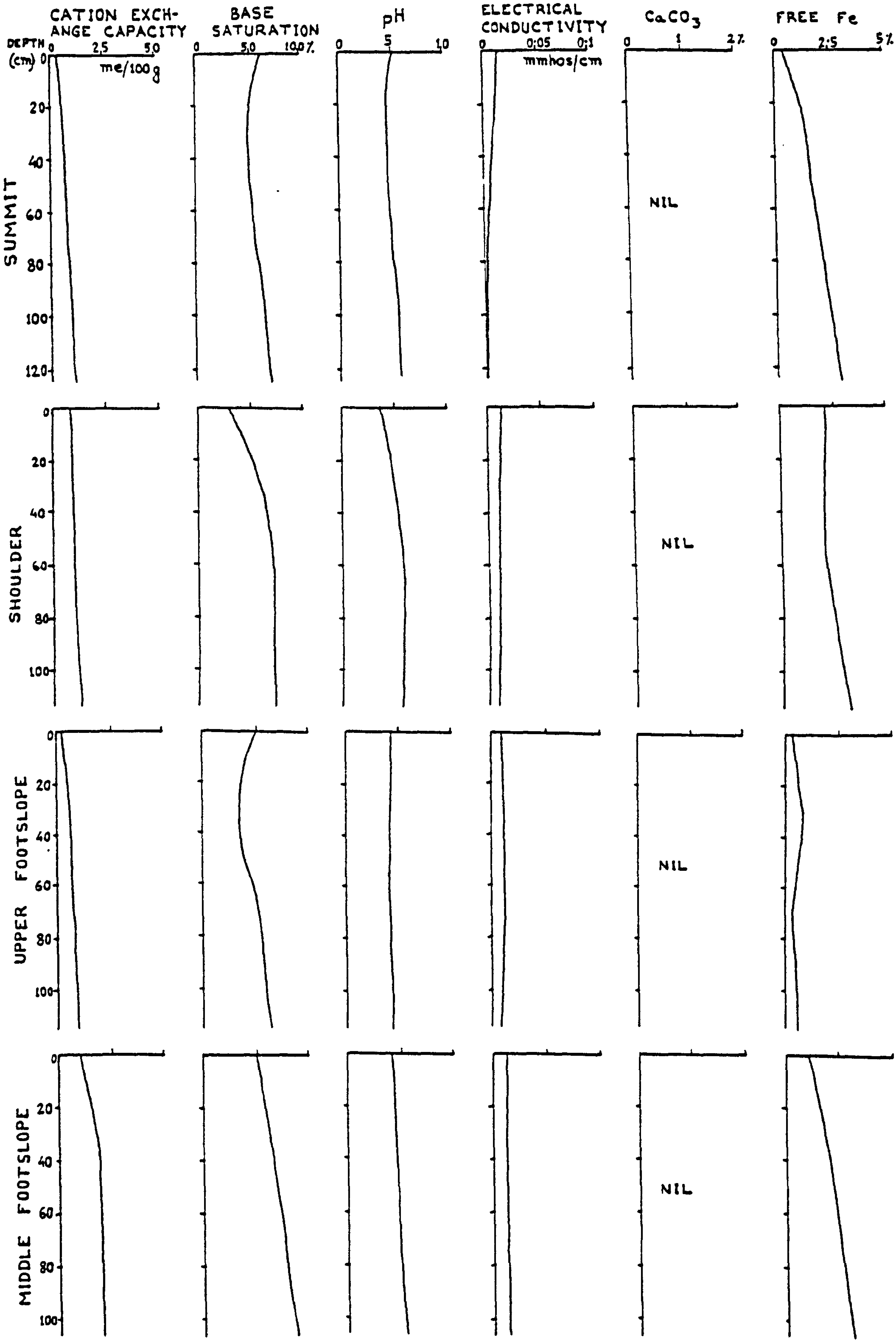

Figure 4.15 (continued)

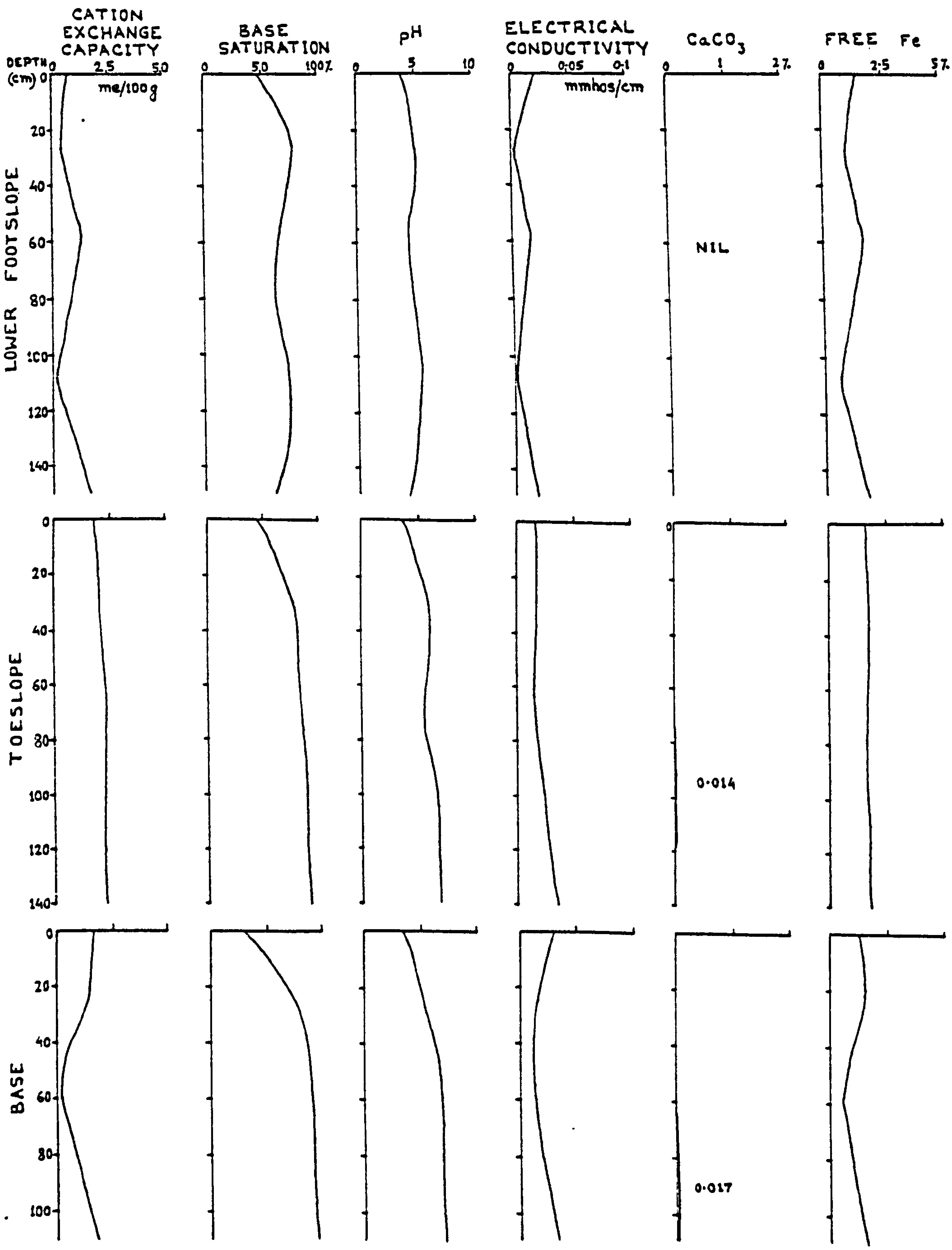

Figure 4.15 (continued)

brown colour appear over a dark red matrix. Apparently the wet season water-table or its capillary fringe rises to this level for a limited period. Ironstone concretions are few in the mottled zone, but they are common above it.

In the middle footslope site (representative of the footslope facet) soil colour changes from yellow to grey with depth, indicating strong gleying under the influence of fluctuating water-table. There are no mottles but many ironstone concretions. The concretions increase in abundance with depth and eventually pass into cemented pisolitic ironstone below 115 cm. Probably the mottles have passed through the soft plinthite stage into hard ironstone. The exposure of the lower horizons by gullies may augment the wetting-drying sequence at depth (FIG. 4.14) and may, thus, increase the rate of iron-:stone formation.

The toeslope profile is light grey in colour from below the Ap horizon under the influence of a shallow water-table persisting over greater part of the year. But it is not a totally reducing regime, for mottles are plentiful and increase in abundance with depth. Ironstone concretions, on the other hand, are common near the surface and decrease with depth. The base profile is like the toeslope in colour and mottle pattern, except in the layer of sand where the colour is dark brown.

The upper footslope profile has been studied for its colour. It has a light grey colour (hue 5Y, value 8, chroma 0). It stands out conspicuously in exposed sections on stream and gully-sides between the red coloured shoulder and the yellowish middle footslope areas. The grey colour is the result of intense gleying. Free iron which imparts red colour is also relatively lower here (FIG. 4.15). The soils of this colour are formed only near the channels of streams and gullies where water is concentrated. Mottles are absent from the intensely gleyed horizons. There are no ironstone concretions.

The lower footslope profile is of different nature. In the sandy layers between 0 - 140 cm it has good drainage and a brownish colour without mottles. Below this, there is a layer of silt and clay where the colour is light grey and mottles are common. Strati-:fied ironstone concretions are plentiful in the sandy layers.

The drainage conditions of the profiles control not only colour pattern but distribution of plant roots and soil animals as well. The frequency of both these features decreases as drainage becomes poorer. The layers of sand exert similar influence upon roots and animals. Thus the depth of root penetration and animal activity becomes shallower towards the base facet. The lower footslope profile shows alternating increases and decreases of roots.

The drainage conditions also influence the textural pattern in the profiles. In this land system, only the summit, shoulder and footslope facets have sufficient clay illuviation to form argillic horizons (FIG. 4.15). But the toeslope and base facets, in spite of having higher amount of clay in the surface horizon than in the other facets, do not show sufficient illuviation of clay. It is suggested that these two facets suffer from shallow water-table for a greater part of the year so that downward movement of clay is restricted. In fact, the toeslope where the water-table falls earlier than in the base facet has a relatively greater illuviation of clay.

According to the nature of argillation in this land system, the texture becomes finer with depth only in the summit, shoulder and footslope areas. But the whole toeslope profile and the base profile above the sand layer are uniform in texture. Between the summit and footslope, there is a progressive increase in the intensity of argill-:ation towards the latter, as indicated by the weighted profile means of clay (Appendix C). This increase is probably related to the availability of greater amount of water for illuviation towards the footslope facet.

The lower footslope profile is characterized by sequential deposition of sand and silt and clay indicated by typical sinuous profile diagrams (FIG. 4.15). The upper footslope profile shows argillation and increasingly finer texture with depth.

The profile pattern of the other physical properties is mainly controlled by texture as the influence of organic matter becomes limited with its decreasing amount towards depth. The activities of tree roots and animals, however, have a modifying effect over the textural control. In general terms the other physical properties change with depth at the summit, shoulder and footslope facets on account of clay increase. But they remain uniform with depth in the toeslope profile and in the base profile above the sand layer (FIG. 4.15). Between the former group of facets, the change of physi-:cal properties is less apparent in the summit and shoulder because of the modifying effects of tree roots, termites and ants. For example, water porosity does not increase appreciably with clay increase because the air pores at depth are kept open by organisms. As a result field capacity increases only slightly with depth, but wilting point which depends upon the amount of clay increases relatively more sharply.

Consequently, available water capacity gradually decreases with depth. In these two facets total porosity increases with depth because of increasing air porosity. The bulk density correspondingly decreases. In the footslope facet the physical properties change in the same direction but the degree of change is higher as the modifying effects of roots and termites are less. The latter are less abundant here because the forest is more open and the drainage is imperfect. The weighted profile means of water porosity, field capacity and wilting point increase, like that of clay, towards the footslope whilst that of air porosity decreases (Appendix C). The upper footslope site is comparable to the middle footslope in the distribution of physical properties. But at the lower footslope site the physical properties are characterized by the same sinuous profiles as those of the textural components. The base facet also shows sinuous curves in the deposit-:ional horizons below 38 cm (FIG. 4.15).

The organic matter decreases with depth in all facets, but the nature of decrease is controlled by drainage conditions. Over the relatively better drained summit, shoulder and footslope facets the decrease is gradual (FIG. 4.15). But in the poorly drained toeslope and base areas it decreases sharply below the surface horizon. The profile pattern of nitrogen is comparable to that of organic matter except in the summit and shoulder facets. There is a slight increase of nitrogen in the lower horizons of these two profiles. This is possibly due to better humification of organic matter or illuviation of nitrogen. The weighted profile means of organic matter and nitrogen increase downslope, but there is a decrease at the base facet (Appendix C). This is apparently because of the humus-poor sand layers in the lower horizons of the base profile.

The upper footslope site is comparable to the middle footslope in profile pattern of the organic fraction. The lower footslope site has typically sinuous profiles of organic matter and nitrogen, indicat:ing depositional sequences.

Available phosphorus does not show regular profile pattern in this land system, nor is it related to pH condition. Although the latter increases with depth at all facets, phosphorus decreases in the summit and shoulder areas and behaves irregularly over the remaining facets (FIG. 4.15). The profile pattern of available potassium is more irregular. These two properties are probably influenced by various factors resulting in a complex and at present inexplicable distribution.

In contrast to the available phosphorus and potassium, the exchangeable bases increase regularly with depth at all facets (FIG. 4.15). Apparently they are transported downwards by water in solution and adsorbed with clays. The rate of their increase declines in the lower horizons of the poorly drained facets, probably because of a shallow water-table. The weighted means of the exchang:eable bases increase towards the lower facets, indicating greater leaching of bases with the availability of more water (Appendix C). The base facet, however, has a lower profile mean for the exchangeable bases because of the sand layers.

As the exchangeable bases increase with depth, the exchange acidity and exchangeable aluminium decrease in all the profiles (FIG. 4.15). Consequently, base saturation and pH increase with depth at all facets. The cation exchange capacity also increases with depth at all the facets on account of the exchangeable bases. But its rate of increase declines with depth where the exchange acidity decreases (FIG. 4.15). In the distribution of weighted profile means over the land system, the base saturation, pH and cation exchange capacity show the same pattern as the exchangeable bases (Appendix C).

The amount of soluble salts (electrical conductivity), although low, shows a close relationship with the conditions of leaching and soil drainage. It decreases with depth in the freely drained summit area, but remains constant with depth in the shoulder and footslope facets where drainage is impeded. Finally it increases in the lower horizons of the poorly drained toeslope and base facets (FIG. 4.15). The same trend is also seen for the calcium carbonate. It is absent from the upper facets, but begins to accumulate in the lower facets, particularly at depth. The weighted profile means of these two properties increase towards the base facet (Appendix C).

The free iron increases with depth in all profiles, but only slightly in the poorly drained toeslope and base areas. Its weighted profile means increase towards the well drained upper facets, indicating its association with free drainage.

The upper footslope site behaves like the middle footslope in the profile pattern of exchange properties, salts, carbonate and iron. But the lower footslope site is characterized by sinuous profile pattern for all these properties, betraying its depositional origin.

This discussion may be summed up by saying that soil drainage conditions have a profound influence upon the profile pattern of soil properties in this land system. Soil drainage not only controls colour pattern and frequency of roots and animals but has a significant influence upon the rate of argillation as well. The toeslope and base facets have failed to develop an argillic horizon probably because of a shallow water-table persisting for the greater part of the year. The rate of downward increase of the properties of exchange complex is also reduced in these two facets for the same reason. Thus the upper horizons of these two lower facets offer relatively better nutrient status and drainage condition. Therefore, shallow-rooted annual crops are more suitable for these areas. The summit, shoulder and footslope facets, on the other hand, can support both annual and perennial crops by virtue of their relatively better drained deep soils with porous and humus-rich lower horizons. All the facets would, however, require application of phosphorus and potassium.

The upper footslope site, apart from its grey colour resulting from strong gleying, is comparable to middle footslope with respect to other soil properties. The lower footslope site is characterized by successive layers of coarse and fine particles which cause sinuous profile pattern of the soil properties. Although relatively better drained, such areas hinder regular root growth. They are, therefore, less suitable for cultivated crops. These areas are, however, restricted to the stream banks.

4.3.3 SOIL CLASSIFICATION

Seven soil profiles are studied in this toposequence. The profile at the base facet has lithologic discontinuities at 38 cm and at 70 cm depth (Appendix A). The profile above 38 cm consists of two horizons. The Ap layer is an ochric horizon. The horizon below it does not show extreme weathering nor has illuvial clay. But it has evidence of alteration by the presence of soil structure, low chroma of the matrix and regular decrease of organic carbon with depth. It is, therefore, a cambic horizon. The toeslope profile also has an ochric epipedon and a cambic horizon which is thicker. Both are, therefore, Inceptisols. Since they have aquic moisture regime and low chroma, they are Aquepts. In the absence of plinthite, iso-temperature regime and greater than 15% sodium saturation, they are classified as Haplaquepts. They conform to the central concept of the great group and are, therefore, Typic Haplaquepts.

There are three profiles upon the footslope facet (see SECTION 4.3). The lower footslope profile has no diagnostic horizon except an ochric epipedon. Rock structure (bedding plane) is seen over 64% of the whole profile. It is, therefore, an Entisol. The moisture regime is not aquic and the texture is not coarse in all horizons. The site has a low slope angle and the organic carbon decreases irregularly with depth. So it is a Fluvent. Since the moisture regime is ustic and the properties correspond to the central concept of the great group, it is a Typic Ustifluvent.

The middle footslope profile (representing the footslope facet) has an argillic horizon where base saturation is greater than 35%. Therefore, it belongs to Alfisol order. The moisture regime is ustic. There is no plinthite. The hue of the argillic horizon is not redder than 5YR nor even 10YR and there is no sharp increase of clay. It is, therefore, a Haplustalf. Since the base saturation of the argillic horizon is less than 75%, it is an Ultic Haplustalf. The upper footslope profile shows the same characteristics as the middle footslope. So it is also an Ultic Haplustalf.

The profiles at the summit and shoulder areas have argillic horizons with greater than 35% base saturation and an ustic moisture regime. There is no plinthite. Since there is no significant decrease of clay from the maximum and the hue of the argillic horizon is redder than 10YR, both of them are Paleustalfs. The shoulder profile is redder than 5YR in the argillic horizon. It is, therefore, a Rhodic Paleustalf. The summit profile has less than 75% base saturation in the argillic horizon. So it is an Ultic Paleustalf.

The distribution of the soil classes is graphically shown in FIG. 4.11. It demonstrates the distinction of soil moisture regime between the summit, shoulder and footslope on the one hand and the toeslope and base on the other. The latter group fails to develop argillic horizons probably due to the presence of a shallow water-table for the greater part of the year. It is also apparent that the profile development is more advanced in the former group (mainly 'Pale-') than in the latter ('Hapl-'). This view is supported by lower base saturation in the former group (Ultic). The upper foot-:slope profile apart from the conspicuous grey colour is comparable to the middle footslope and belongs to the same class. But the lower footslope profile is entirely different from the general trend. Such depositional profiles are restricted to places alongside stream channels in the lower facets.

4.4 LAND SYSTEM D (SONAMUKHI SYSTEM)

This system is a streamless valley, open only at one end (FIG. 4.17). The representative toposequence is situated within the area of a village near Sonamukhi (latitude 23 degrees, 14 minutes north and longitude 87 degrees, 22 minutes east). Its location is shown in FIG. 4.32 (in SECTION 4.9).

The form of the slope profile is convex-concave between the summit and the toeslope (FIG. 4.16). The base facet is separated from the rest of the slope profile by a distinct break of slope. The base has a very gentle longitudinal gradient towards the open end which eventually joins the head of a small stream at a distance of about 1.5 km (FIG. 4.17). Water can partly drain out of the valley as sheet wash along the base. As a result, a certain amount of water erosion occurs although there is no stream channel. The form-:ation of a narrow but flat base facet, the break of slope between the base and rest of the toposequence and downcutting producing a relief of 24 m are evidences of water erosion. However, in the absence of a stream, valley broadening is not advanced. The summit and shoulder areas occupy 60% of the slope profile. The summit facet is very gently sloping. The shoulder area is relatively steeper than other facets. Its average slope angle is 1.8 degrees, with local maximum of 2.7 degrees. Soil erosion is, however, limited to slight to moderate sheet erosion. But this facet is very stony (stoniness class 4) because massive ironstone occurs at shallow depths. The footslope and toeslope facets are very gently sloping whilst the base area is flat.

Upon such a topography, soil drainage should be free at the summit and shoulder and should be progressively poorer towards the base. But there are certain deviations from this simple hypothesis. Firstly, drainage is not 'very poor' (totally reducing regime) at the base facet although it receives water from both sides of the valley. Some of the water, as explained above, can move out following the long-:itudinal slope of the base. Nevertheless, some materials accumulate in significant amounts in this facet. For example, calcium carbonate

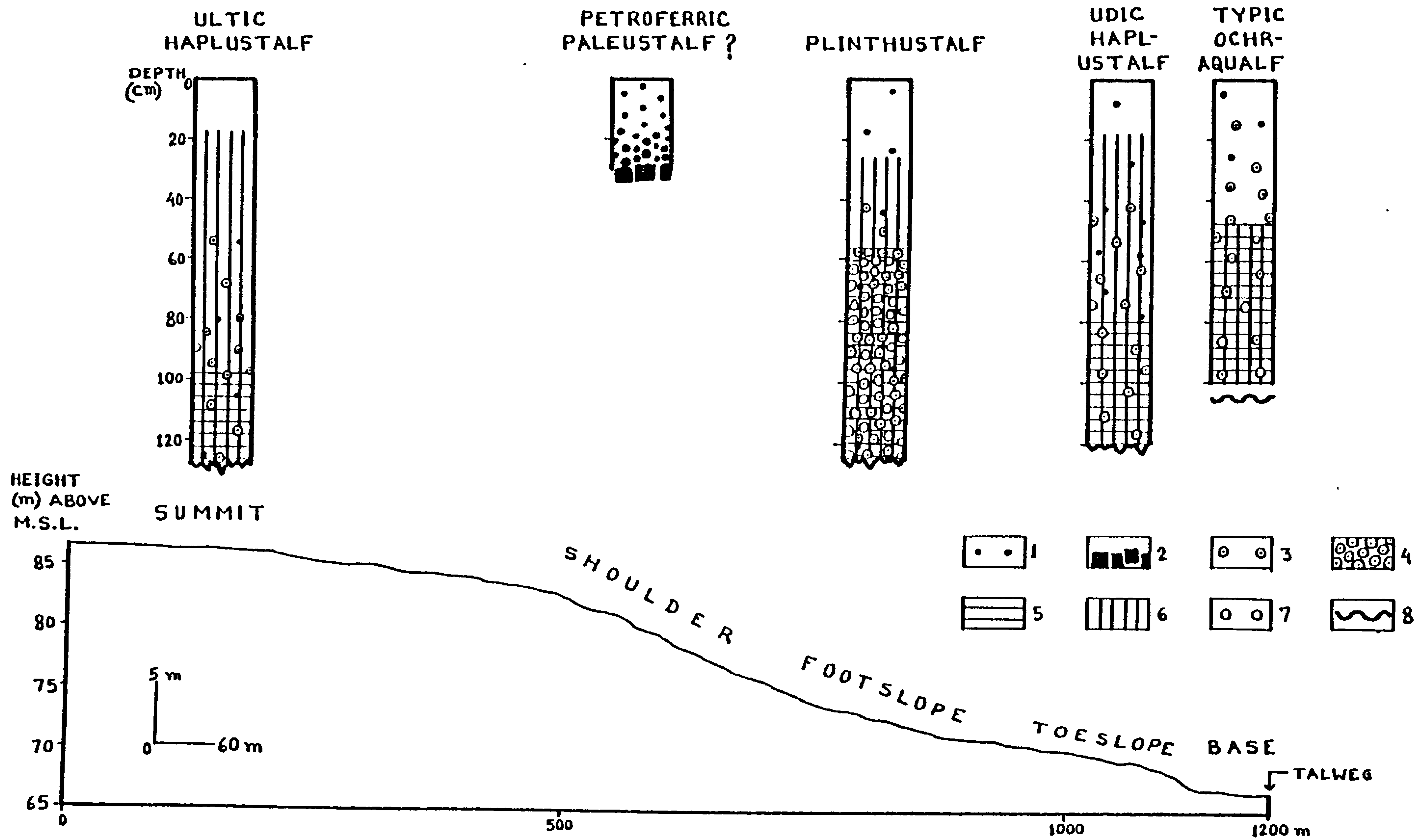

Figure 4.16 Land System D: slope and soils (source: field work; see Appendices A and E).

1. Ironstone concretions; 2. Massive ironstone; 3. Mottles; 4. Plinthite; 5. Strong gleying; 6. Argillic horizon; 7. Calcium carbonate concretions; 8. Water-table during field work.

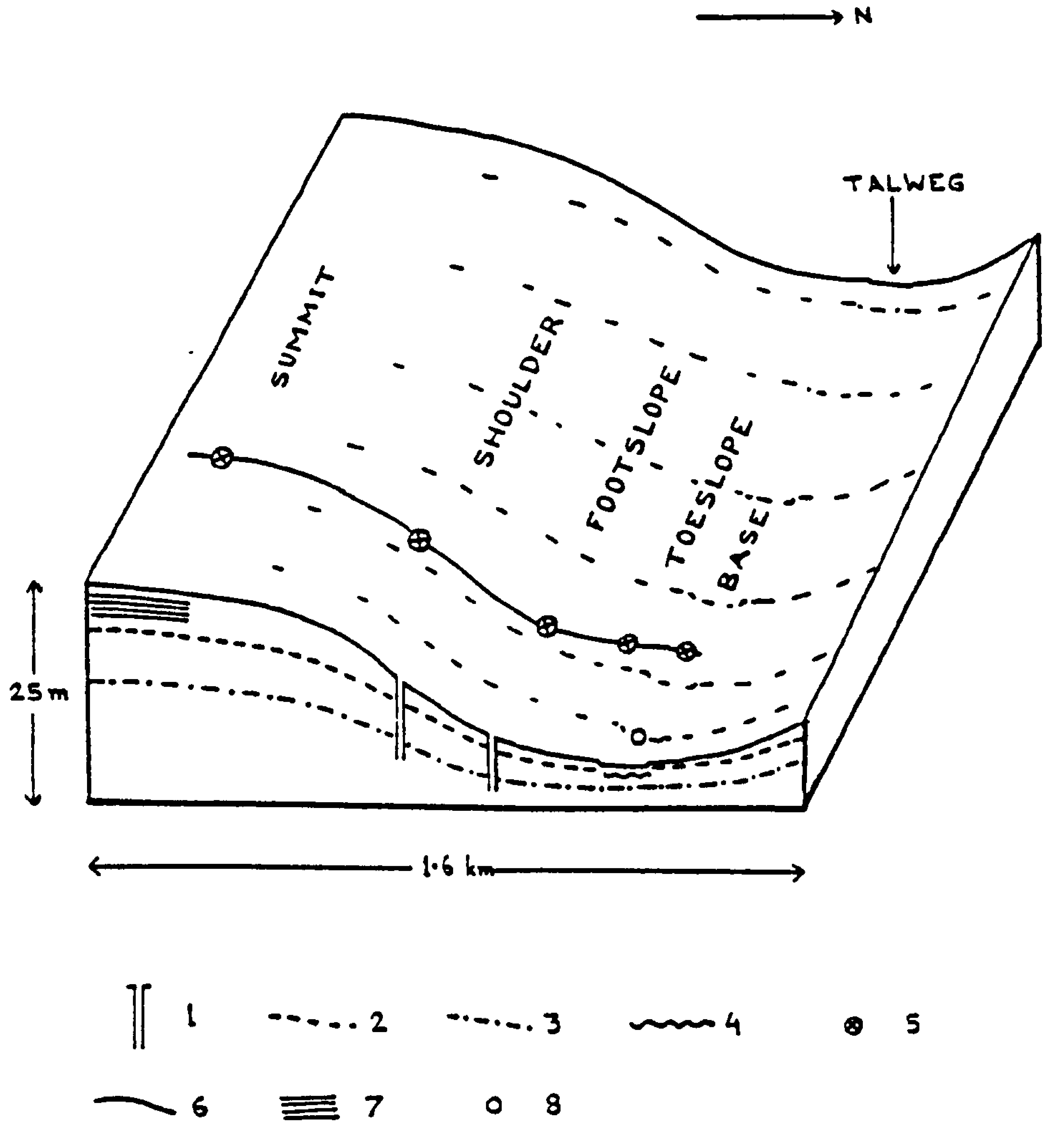

Figure 4.17 A schematic block diagram of System D.

1. Well where depth to water-table was measured; 2. Wet season water-table; 3. Summer water-table; 4. Water-table encountered in a pit during field work; 5. Soil sampling sites; 6. Survey line; 7. Clay bed; 8. Site where calcium carbonate concretions occur below 42 cm depth.

concretions occur at depth. Secondly, the shoulder facet is 'excessively' drained because of poor vegetation cover (see below), stoniness and presence of shallow ironstone at shallow depth. Lastly, the summit of this toposequence, unlike any other, suffers from impeded drainage below 53 cm depth (FIG. 4.16). This facet cannot be affected by the normal water-table at this depth even in the rainy season. It is a slowly permeable layer of clay which is arresting free drainage (FIG. 4.17). Such beds or lenses of clay have been reported to occur locally in the Southern Rarh Plain (Sinharoy, S.P. and Dutt, D.K., 1972 and Geological Survey of India, 1974).

The land use pattern of the village where the toposequence is located is shown in FIG. 4.18. The summit area is under 'type A' rotational coppice plantation of _Eucalyptus_ spp. and _Acacia auriculi-:formis_ (SECTION 2.4 and TABLE 2.10). The canopy is open. The stony and excessively drained shoulder facet carries only grasses and herbs. The plant growth is very poor, partly because of overgrazing. Settlements are situated in the lower part of the shoulder and at the upper part of the footslope. The rest of the footslope and the entire toeslope and base areas are cultivated. Rice is the main wet season crop. During winter and summer, parts of the footslope and toeslope facets are irrigated from a deep tubewell. Both annual and perennial crops like wheat, oilseeds, vegetables and sugarcane are grown intensively. The base facet is also cultivated during winter with shallow tubewell irrigation. Rice continues to be the main crop here because the water-table remains within shallow depth. The footslope, toeslope and base facets carry herbs and grasses when left fallow.

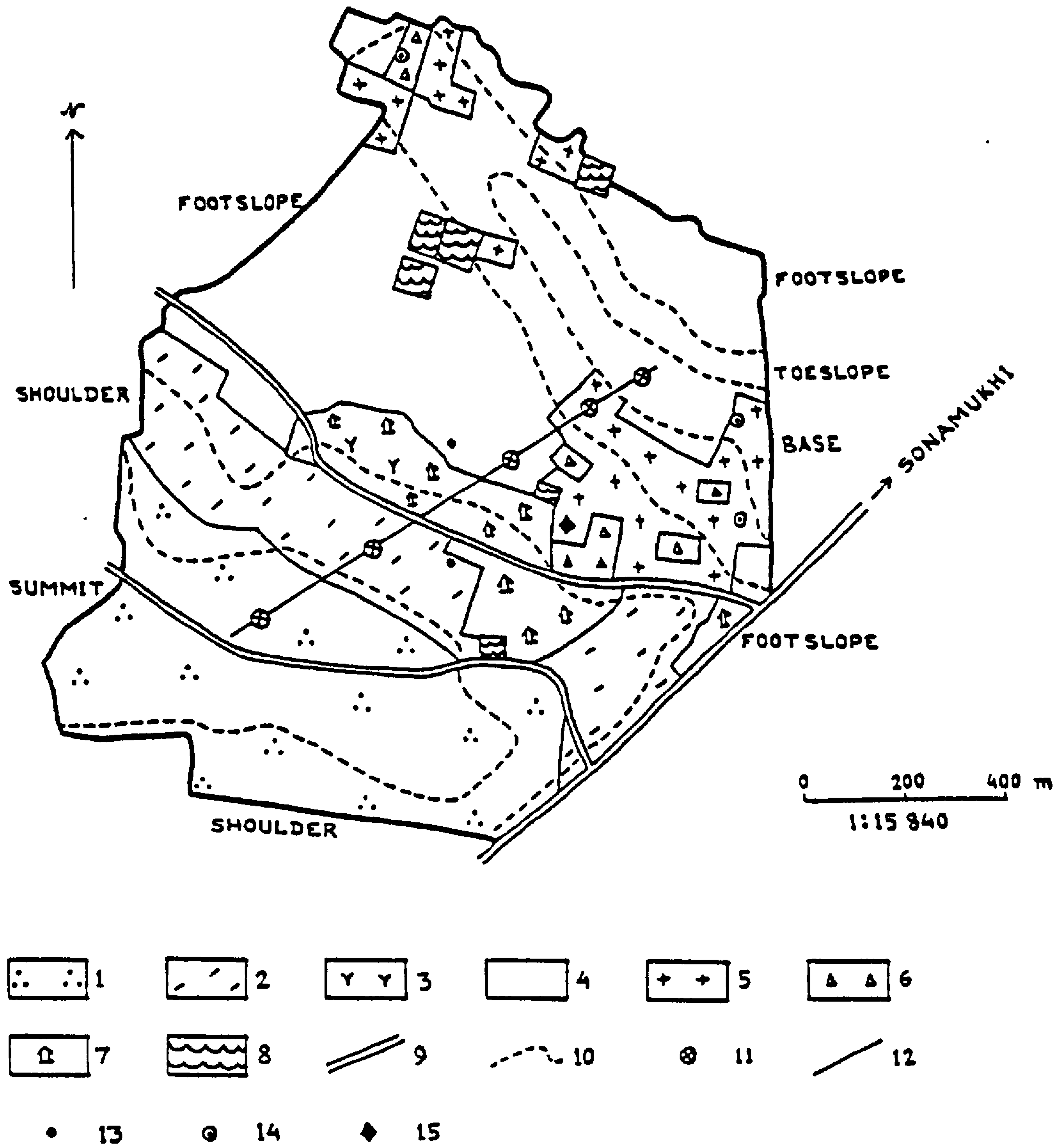

Figure 4.18 Land use pattern of System D (source: field mapping in Patharmara village, 1981-82).

1. Forest plantation; 2. Pasture; 3. Bamboo; 4. Rice (single crop); 5. Multiple crops; 6. Perennial crops; 7. Settlements; 8. Pond; 9. Road; 10. Land facet boundary; 11. Soil sampling sites; 12. Survey line; 13. Well; 14. Shallow tubewell; 15. Deep tubewell.

The soils of this toposequence have developed in close relation-:ship with the topographical and drainage conditions and then modified by agricultural practices. This relationship is analysed in the following subsections.

4.4.1 SURFACE SOIL PROPERTIES

There are five surface soil samples representing the five land facets of this toposequence. The distribution of their physical and chemical properties is presented in FIG. 4.19. These and the morpho-:logical properties are described below.

The morphological properties related with soil drainage, such as colour, are regular in distribution pattern over the toposequence. Soil colour changes from strong brown at the summit to light grey at the base as drainage becomes poor. The shoulder area which is better drained than the summit has a redder hue. Mottles do not appear in the surface horizon except those along rice root channels at the lower facets. Ironstone concretions are absent from the summit, but they are abundant, in all sizes, upon the shoulder where massive ironstone occurs at shallow depth. Ironstone concretions are present in small amounts at the lower facets. Some of the concretions may have been transported from the shoulder area by surface water flow. Roots are found at all facets, but they are less abundant in the shoulder area where soils are limited in depth. Ants are present at all facets. Termites are abundant in the well drained summit and shoulder areas whilst earthworms take over in the lower facets. In response to grassy vegetation, presence of earthworms and tillage, a coarse crumb structure has developed at the lower facets. The summit and

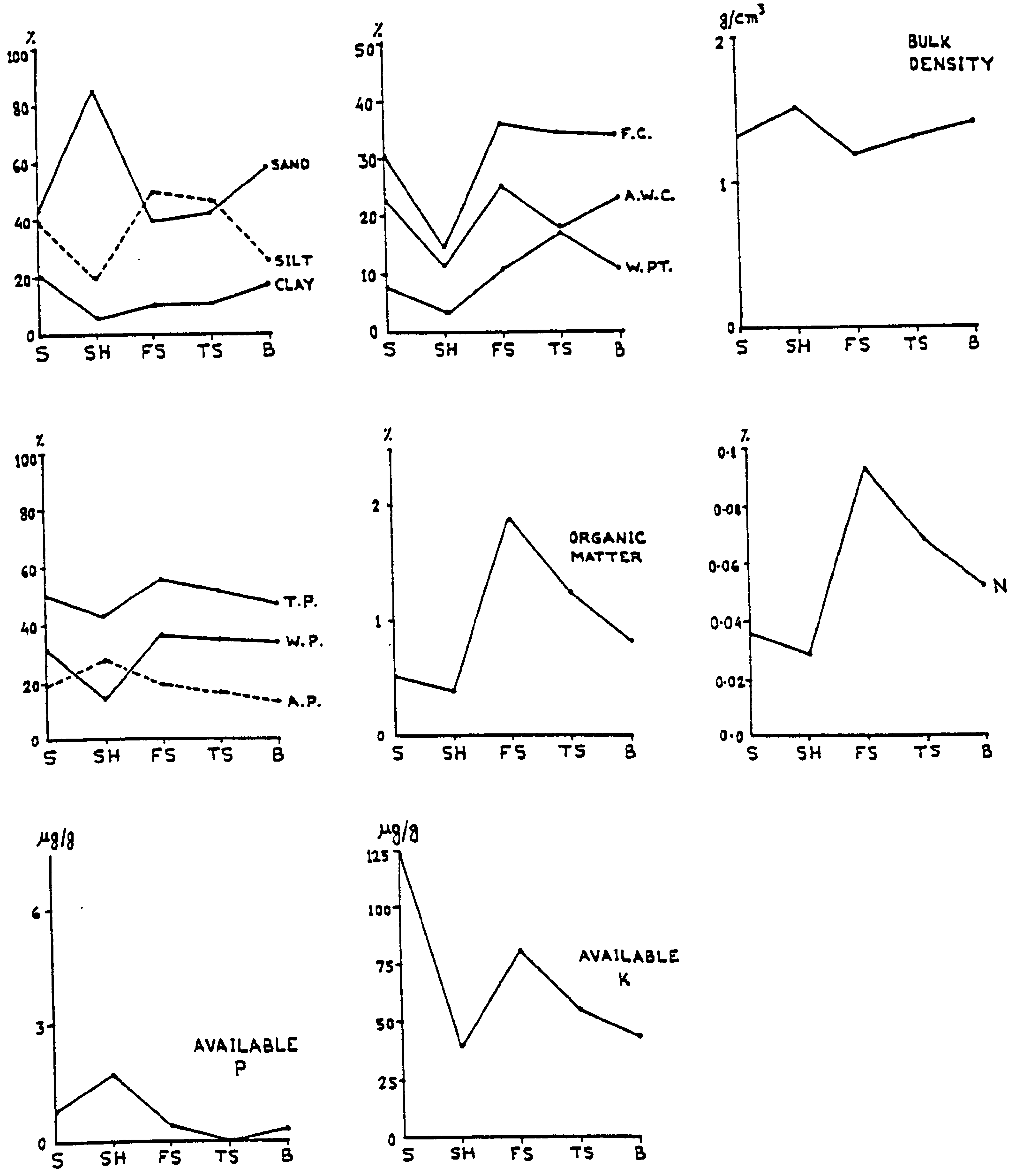

Figure 4.19 Surface soil properties of System D (source: laboratory work; see Appendix A).

S = Summit; SH = Shoulder; FS = Footslope; TS = Toeslope; B = Base. F.C. = Field capacity; W.PT. = Wilting point; A.W.C. = Available water capacity; T.P. = Total porosity; W.P. = Water-filled porosity; A.P. = Air-filled porosity.

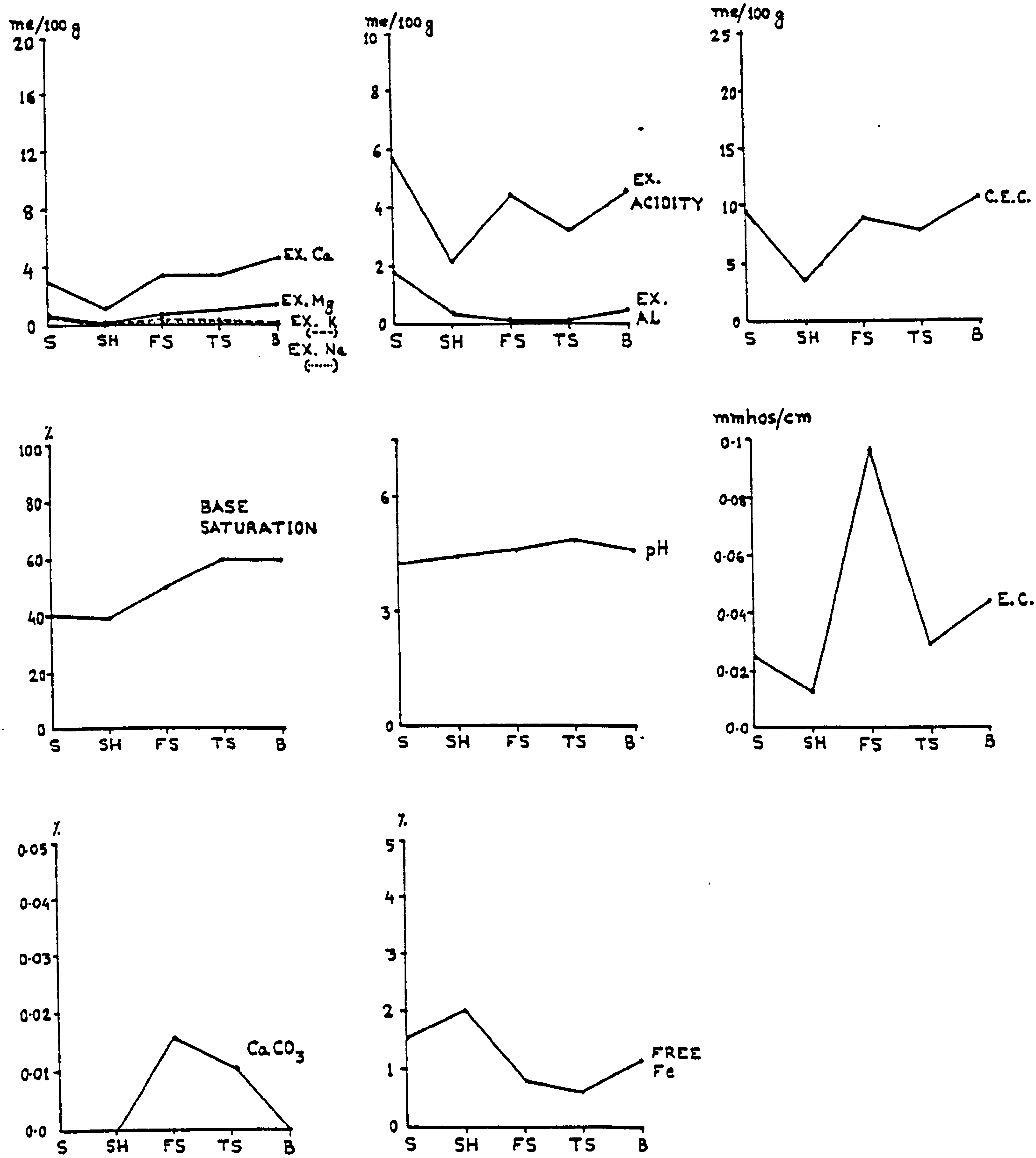

Figure 4.19 (continued)

EX. = Exchangeable; C.E.C. = Cation exchange capacity;
E.C. = Electrical conductivity.

shoulder have, on the other hand, a massive structure.

The physical and some chemical properties, unlike the morpho:logical properties described above, are not regular in their pattern of distribution over the toposequence (FIG. 4.19). No physical properties have statistically significant relationship with distance (Appendix B). Among the chemical properties only a few are corre:lated with distance. There are two sets of factors controlling the distribution of the physical and chemical properties: inherent and external. The inherent factors are length and angle of slope, stoniness, situation on the toposequence and vegetation cover. They modify the nature of lateral flow of water so that removal and accumu:lation of material across the slope are complex in this toposequence. The main external factors are irrigation and fertilization by man. They lead to the increase of certain properties at the site of application. The dominant factors at each facet are identified and their influence upon the distribution of two primary properties, texture and organic matter, is examined below.

The summit is a wide area with very gentle gradient and a cover of forest which reduces surface flow of water and favours accumulation of materials. Among the five facets it has the finest texture. But the organic matter content is low (FIG. 4.19) because of the reasons explained in SECTION 2.4. The shoulder, on the other hand, is a stony area with limited vegetation cover, sloping at an angle of 1.8 degrees. The surface flow of water is greatest among the five facets. It is a zone of removal. The texture is coarsest, with 86% sand. The organic matter content is also minimum (FIG. 4.19).

The footslope, being situated just below the shoulder, receives most of the material removed from it. The silt fraction is maximum at this facet (FIG. 4.19). The organic matter content is also maximum, but this is due partly to application of manures and irrigat:ion. This facet, in fact, receives maximum irrigation and manures because the deep tubewell is located here. Since less manure is applied at the toeslope, it is lower in the content of organic matter (FIG. 4.19). But the reason for decline of silt fraction is not apparent. The organic matter content is still lower at the base facet as less manure is applied. Its level is, however, greater than in the summit (FIG. 4.19). In texture the base facet exhibits unique characteristics. Through its function of draining water out of the valley, it behaves like a stream channel so that coarse materials are deposited upon it. It has the coarsest texture next to the shoulder only (FIG. 4.19).

The situation may be summed up with the following general state:ments:

(1) The texture is finest at the summit (loam) and coarsest at the shoulder (loamy coarse sand). The footslope is also loamy with the maximum amount of silt. Then the texture becomes coarser towards the base.

(2) The organic matter is highest at the footslope. It decreases towards the base. The shoulder has the lowest organic matter. In the summit area organic matter is lower than at the base.

The rest of the physical properties, which are controlled by texture and organic matter, have a similarly irregular distribution (FIG. 4.19). None of them has developed statistical relationship with distance at significant level (Appendix B). A few general statements may be made about the physical properties:

(1) The total porosity, water porosity, field capacity and available water capacity are highest at the footslope whilst bulk density is lowest. Apparently these properties are more influenced by better structure and higher organic matter content of the footslope than the finer texture of the summit area.

(2) The total porosity, water porosity, field capacity, wilting point and available water capacity are lowest whilst bulk density and air porosity are highest at the shoulder facet. This is because of the coarsest texture and lowest organic matter content of this facet.

(3) The values of these physical properties at the toeslope closely follow those of the footslope area.

(4) The summit and the base areas have comparable values for these properties although they have different texture and organic matter content. The lower organic matter of the summit is compensated by a finer texture while at the base higher organic matter counteracts coarser texture.

The control of the inherent and external factors is also apparent in case of the distribution of the chemical properties. These properties are, however, further influenced by various factors of the chemical environment. Under these combined influences some of the chemical properties have developed different distribution pattern from those of other land systems.

Nitrogen obviously behaves like organic matter (FIG. 4.19). Its quantity is minimum over the shoulder and maximum at the footslope. It decreases farther downslope but remains within medium level. In contrast, available phosphorus is highest at the shoulder facet where all other properties are at their poorest level (FIG. 4.19). It decreases over the lower facets to a very low level although they receive phosphate fertilizers and organic manures. This trend of decrease downslope is opposite to the distribution of pH. Available potassium is lowest at the shoulder, but its highest value is found at the summit area. It also decreases at the lower facets. The reason for such behaviour of the available phosphorus and potassium is not fully understood at present.

Excepting exchangeable potassium which behaves like available potassium, the exchangeable bases increase towards the base facet (FIG. 4.19). The exchangeable calcium and magnesium have a sharp drop at the shoulder facet like most properties, but they do not show any peak at the footslope area. Apparently these two properties are most strongly influenced by the lateral flow of water. The exchangeable magnesium has developed a statistical relationship with distance at significant level. But the calcium fails to do so because it has a sharper decline at the shoulder and a lower rate of increase over the lower facets. The exchangeable sodium has its maximum value at the footslope facet which is mainly a result of irrigation. The sodium saturation is, however, far below toxic level.

Both the exchangeable aluminium and exchange acidity behave differently in this toposequence. They decrease towards the base facet (FIG. 4.19). Their distribution pattern is also very irregular. The reason for such behaviour is not fully understood at present.

As the exchangeable bases generally increase downslope whilst the exchange acidity decreases, the cation exchange capacity has failed to achieve a trend pattern in this toposequence. It has the minimum value at the shoulder facet, but it does not have much variation over the other facets (FIG. 4.19). It is just above the medium level at the base area and slightly below this level at the summit, footslope and toeslope facets.

The base saturation, on the other hand, clearly increases towards the lower facets on account of increasing quantity of bases and decreasing acidity (FIG. 4.19). Accordingly, the pH also increases in the same direction. Both have positive correlation with distance (Appendix C). The pH values are very strongly acidic over the lower facets in contrast to extremely acidic values at the summit and shoulder.

The soluble salts do not show the same tendency of downslope increase as the exchangeable bases. They are very low at the shoulder facet, but rise with a sharp peak at the footslope area as a result of irrigation (FIG. 4.19). Their level is, however, too low to cause any problem. The calcium carbonates similarly have a peak at the footslope facet whilst they are totally absent from the upper facets.

The free iron has maximum value at the shoulder where ironstones occur. Apart from that it tends to decrease downslope probably because of poor drainage (FIG. 4.19). Its quantity is generally low even at the shoulder facet.

In summary, most of the surface soil properties do not show any regular trend pattern in this system. Their distribution is control-:led by distinct sets of factors at each facet. The surface soils of the summit area have the finest texture and, although the organic matter and nitrogen contents are low, they are comparable with the lower facets in other physical and chemical properties. Moreover, they have the highest quantity of available potassium. Therefore, with organic manuring, the summit area would be equally suitable for cultivation as the lower facets. The soils of the shoulder facet, on the other hand, are coarse in texture and poorest in the physical and chemical properties, except in available phosphorus. These soils are not suitable for cultivation, but may be useful for perennial trees and grasses by virtue of free drainage. The soils over the footslope, toeslope and base facets improve in their physical properties and con:tents of organic matter, nitrogen, phosphorus and potassium towards the footslope area. But their exchange properties, base saturation and the pH improve towards the base facet. At present the footslope facet is most suitable for cultivation. The toeslope and base facets may also be raised to the same status by organic manuring.

4.4.2 SOIL PROFILES

Each land facet is represented by one profile. Their propert:ies are listed in Appendix A. Some of the morphological features are shown in FIG. 4.16. The profile diagrams of physical and chemical properties are presented in FIG. 4.20.

Excepting the shoulder area, all the facets have deep soils. The base facet is, however, affected by a shallow water-table which was encountered at 100 cm during field work (winter 1981-82). The shoulder profile is shallow, only 14 cm in depth, due to the occurrence of massive ironstone. In fact, the shoulder profile has a surface horizon only. It is, therefore, not included in the following discussion of profile characteristics.

Soil colour, pattern of mottles and distributions of roots and animals are closely linked with soil drainage and, therefore, reflect

Figure 4.20 Soil profile properties of System D (source: laboratory work; see Appendix A).

Figure 4.20 (continued)

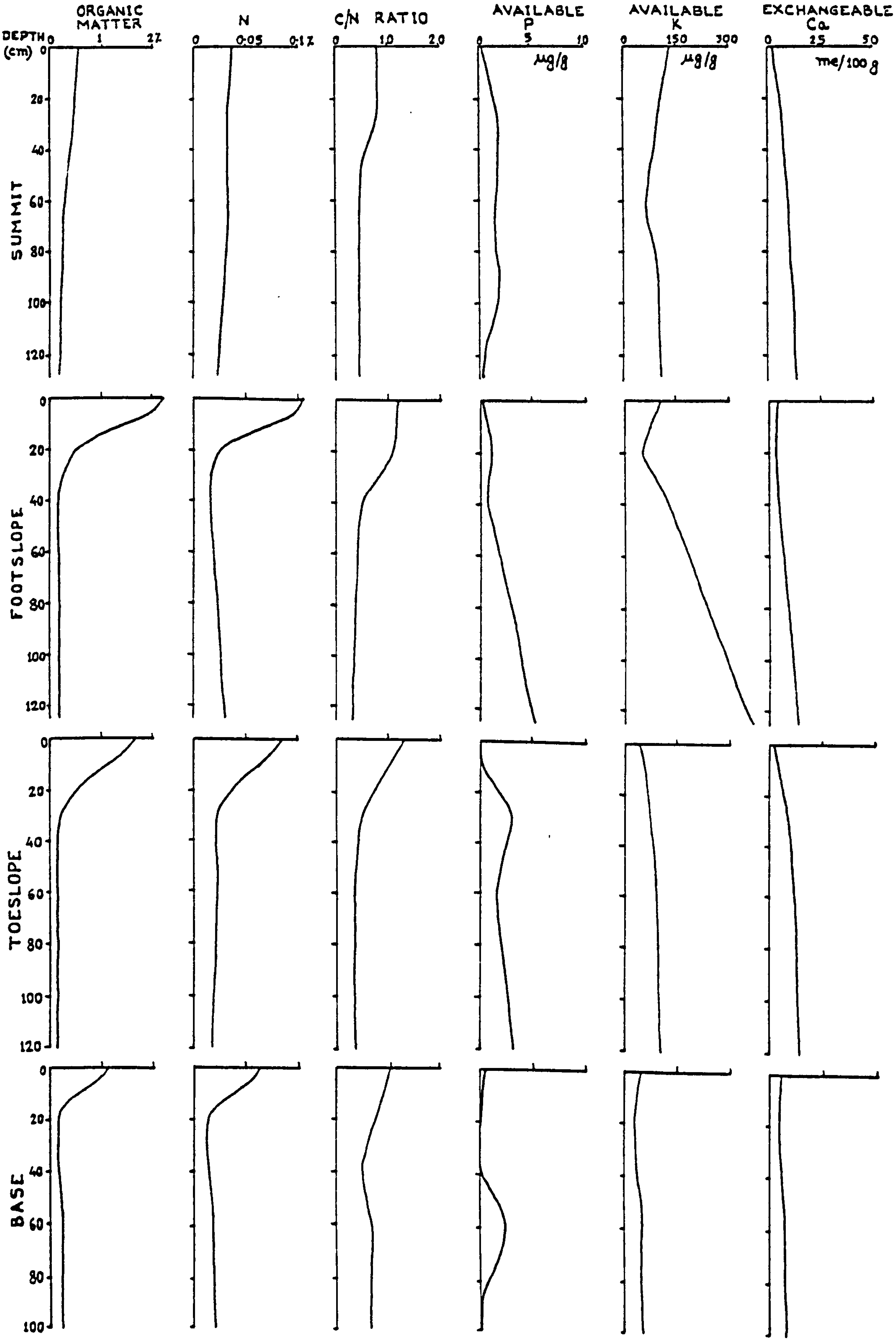

Figure 4.20 (continued)

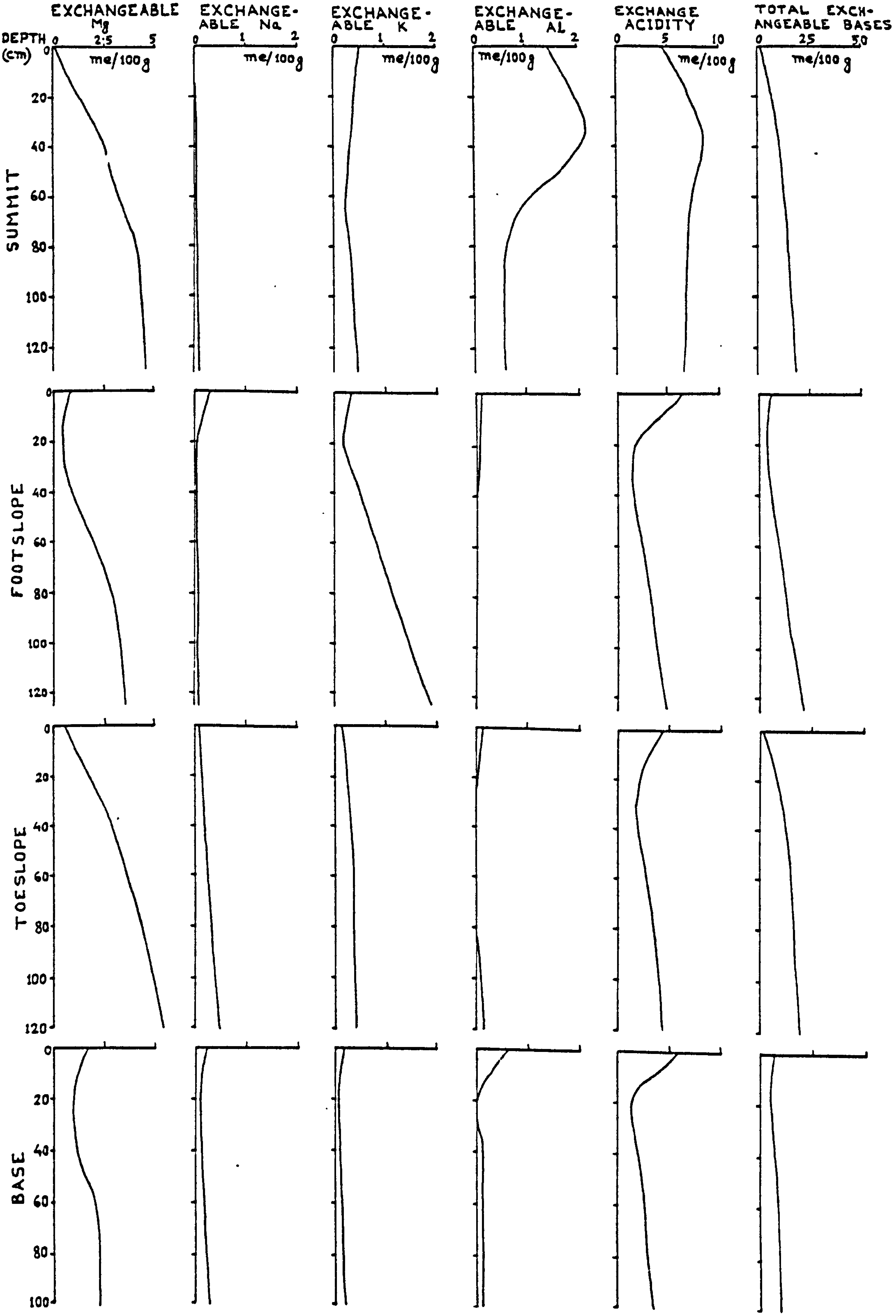

Figure 4.20 (continued)

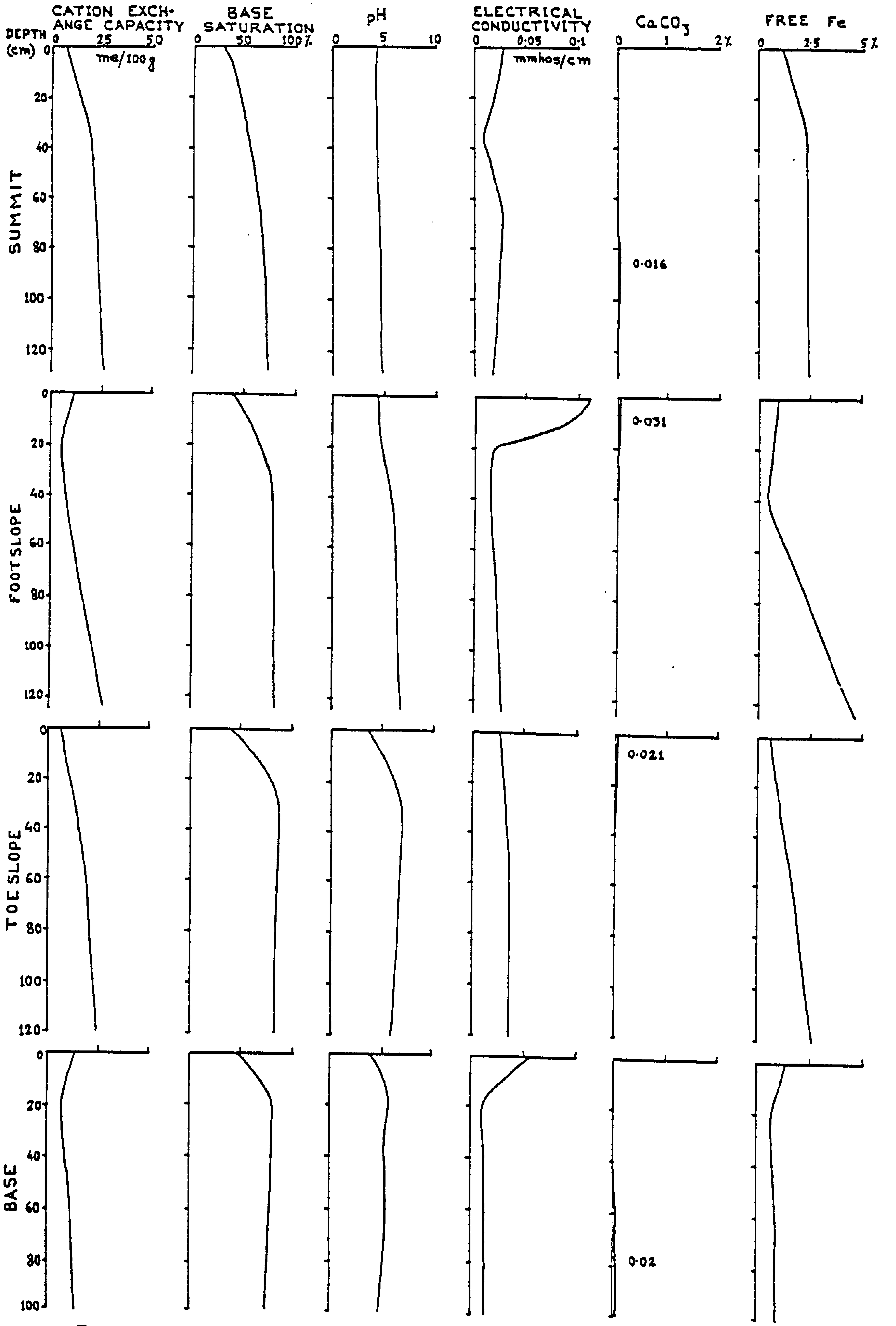

Figure 4.20 (continued)

its state in the profile. In the footslope, toeslope and base facets, colour becomes more greyish with depth. The hue changes towards 7.5Y, the value towards 8 and the chroma towards 1. This indicates increasingly poorer drainage with depth under the influence of water-table. The intensity of greyness is not, however, so strong in the footslope as in the toeslope and base. The footslope is under the influence of a fluctuating water-table. The development of mottles below 55 cm depth is prolific and they slightly harden on exposure. Therefore, they are classified as plinthite. In the toeslope and base, mottles are plentiful, but they decrease in abundance with depth as the permanently reduced zones are approached. Roots also decrease in abundance in the strongly gleyed horizons of the foot-:slope, toeslope and base facets. Soil animals are entirely absent from such horizons.

The summit profile, as explained in SECTION 4.4 suffers from impeded drainage below 53 cm. As a result, soil colour and mottling show a curious pattern. The profile becomes more reddish in colour and remains free from mottles down to 53 cm depth. Below this level, the matrix colour remains unchanged but 'distinct pale yellow' mottles appear and increase in abundance with depth. Below 98 cm, the mottles become light grey in colour and increase so much in abundance that they occupy 80% of the horizon. They are, therefore, described as the matrix and the red colour, which is represented as spots in this horizon, is described as mottles (Appendix A). The horizon below 98 cm is, therefore, strongly gleyed. Roots and animals decrease sharply as this horizon is reached.

Small amounts of ironstone concretions are found in all the profiles. In the base and toeslope, they disappear as the strongly gleyed horizons are approached (FIG. 4.16). In the footslope, they have an influx above the plinthite horizon where they are probably undergoing transformation at the present time. In the summit, they occur in small amounts in the mottled horizons only.

A few calcium carbonate concretions are found between 72 and 100 cm depth in the base profile. But in another pit at a distance of about 300 m towards the open end of the valley (FIG. 4.17), many concretions were found from below 42 cm depth during the reconnaissance surveys. It is suggested that calcium carbonates are removed in solution by water from all horizons of all facets into the groundwater. Subsequently the carbonates may be lost into a stream. But, in the absence of a stream i.e. proper drainage out of a valley, the carbon-:ates may be precipitated in the capillary fringe of the groundwater in the lower facets. The concentrically layered structure of the concretions and their occurrence above the dry season water-table support this hypothesis.

The profile patterns of the physical properties are dominated by that of texture and to a limited extent by organic matter. These two properties are, therefore, described first. In all profiles, texture becomes finer with depth as clay is transported from the upper horizons and deposited in the lower horizons (FIG. 4.20). It may appear from the weighted profile means that the summit area has maximum and the base facet has minimum argillation (Appendix C). As indicated in SECTION 4.4, the clay content of the lower horizons of the summit profile is not due solely to argillation. There is a local clay bed which is partly responsible for the clayey texture of these horizons. The relatively poorer argillation at the base profile may be due to a shallow water-table and income of coarse materials (SECTION 4.4.1).

The base profile has achieved only a loamy texture in the argillic horizon whilst the footslope and toeslope facets are clay loam in texture at depth. The base and footslope profiles have distinct eluvial horizons. But the toeslope, in a situation between them, lacks such a horizon. The reason is not fully understood at present. The patterns of the silt and sand profiles are opposite to the clay profiles i.e. they decrease with depth. There is an increase of sand in the eluvial horizons.

The organic matter profiles of the footslope, toeslope and base facets show typical patterns of poorly drained soils. They sharply decline to a very low level below the surface horizons and remain so with depth (FIG. 4.20). The depth of this sharp decline becomes shallower towards the base facet as drainage becomes poorer. The summit profile, although it has mottles from below 53 cm and is strongly gleyed below 98 cm, shows an organic matter profile of a thoroughly well drained soil i.e. organic matter decreases gradually with depth. This is because the horizons above 53 cm are well drained where organic matter accumulates. The profile pattern of nitrogen follow that of organic matter at each facet (FIG. 4.20).

Soil consistence is mainly determined by texture. It becomes more sticky, more plastic, firmer and harder with depth as texture becomes finer. This change of consistence is similar between the upper and lower facets (Appendix A). This fact suggests the presence of a similar type of clay, probably silicate clays, in the lower horizons of all facets. The absence of hydrous oxide clays from the summit area may be due partly to the profile development under impeded drainage and partly to the presence of a clay bed.

The influence of texture is also strong upon the other physical properties, but it may be modified by the activities of tree roots and termites. The water porosity tends to decrease with depth at all facets and in the eluvial horizons of the footslope and base facets in particular (FIG. 4.20). But as the argillic horizons are reached, it increases sharply in response to the finer texture. The air porosity has developed the opposite profile pattern. It has a particular increase around 50 cm depth of the summit profile. This is obviously due to the activities of tree roots and termites.

As a result of the opposite profile patterns of the water and air porosities, the total porosity remains uniform with depth (FIG. 4.20). Only in the summit profile thereis an increase of total porosity at about 50 cm depth by the weight of air porosity. The bulk density is also unchanged with depth, excepting the decrease at 50 cm depth of the summit profile.

The field capacity has a comparable profile pattern with the water porosity (FIG. 4.20) by which it is controlled. The wilting point has a profile pattern like its controlling factor, clay. The wilting point increases with depth at all facets and also shows a decrease in the eluvial horizons of the footslope and base facets. The available water capacity profiles, through the interaction of the field capacity and wilting point, are complex in pattern (FIG. 4.20). At the footslope and base areas, where wilting point increases relat:ively sharply with depth, available water capacity decreases. But it increases with depth at the summit and toeslope facets. There is a decrease of available water capacity just above the argillic horizon at all facets. This is because the field capacity is minimum in this zone. The weighted profile means show a progressive increase of available water capacity towards the base area (Appendix C).

The profile behaviour of the chemical properties are dominated by leaching processes. The influences of texture and root and animal activities are also apparent in case of certain properties. Moreover some of them are strongly influenced by complex chemical factors so that their profile patterns are irregular.

The available phosphorus increases with depth at the footslope and toeslope facets probably because of leaching and favourable pH in the lower horizons (FIG. 4.20). But at the summit and base areas, it shows an influx in the middle depth of the profiles only. Its decrease in the lowest horizons of these two profiles may be due to complex factors which are not fully understood at present. The available potassium increases with depth at all facets probably on account of leaching. It has the maximum increase at the footslope area where it reaches the high level of availability. The reason for such exceptional increase is not fully understood. There is a decrease of available potassium in the eluvial horizons of the foot-:slope and base areas and also around 60 cm depth of the summit profile. This is probably due to greater leaching encouraged by relatively coarser texture or higher air porosity of these horizons. Owing to the variations of profile patterns, the weighted profile means of available phosphorus and potassium do not show any regular trend across the slope (Appendix C). Both properties have their maximum means at the footslope area which is partly a result of fertil-:ization.

All the exchangeable bases increase with depth at all facets (FIG. 4.20) as they are leached down by water. They also show a reduction in the eluvial horizons of the footslope and base facets where leaching is relatively greater on account of a coarser texture. When the profiles of the total exchangeable bases of the four facets are compared, it is seen that the base facet has the least increase of exchangeable bases. The weighted profile mean is highest at the summit and lowest at the base facet (Appendix C). This pattern contradicts the surface pattern of the exchangeable bases (SECTION 4.4.1). The exchangeable bases are probably being removed from the base profile by leaching and drainage.

The profile behaviour of the exchange acidity is more complex than that of the exchangeable bases. It declines at the eluvial horizons of the footslope and base profiles and then increases with depth, as expected. But the reasons for its decline below the surface horizon at the toeslope facet and increase in the horizon of higher air porosity at the summit profile are not fully understood (FIG. 4.20). The profile pattern of the exchangeable aluminium is comparable to that of exchange acidity. The weighted means for both exchange acidity and exchangeable aluminium are highest at the summit area. The lower facets have comparable profile means between them (Appendix C).

As the exchangeable bases and exchange acidity increase with depth, the cation exchange capacity also increases at all facets (FIG. 4.20). It reaches 'high level' in the lower horizons of the summit, footslope and toeslope facets, but its level remains 'medium' at the base facet where the exchangeable bases are probably lost by leaching and drainage. The base area has the lowest profile mean for cation exchange capacity whilst the highest mean is found at the summit area (Appendix C).

Since the exchangeable bases are the dominating component, the base saturation is above 50% and increases with depth at all facets (FIG. 4.20). The weighted profile means of base saturation increase from the summit to the toeslope, but then decline at the base facet on account of lower quantity of exchangeable bases. The pH increases with depth at all facets in response to the increasing base saturation. The pH is comparable with the base saturation in profile pattern and distribution of weighted means. The total soluble salts are apparently leached out of the profiles, for their downward increase is very slight. They also decline sharply at the eluvial horizons of the footslope and base facets and at the horizon of higher air porosity of the summit profile. Their profile means increase from the summit to the toeslope facet, but then drops at the base area. They are probably removed from this facet, like the exchangeable bases.

The calcium carbonate is more thoroughly leached out than the salts. It is present only in the lower horizons. The presence of carbonates at the surface horizons of the footslope and toeslope areas is probably due to precipitation following irrigation. Although a few calcium carbonate concretions are found in the lower horizons of the base profile the percentage value of calcium carbonate in the soil sample is not high (only 0.02%). Apparently, the concretions are not easily soluble and all the carbonate is concentrated in them rather than being dispersed through the whole horizon.

The free iron increases with depth at all facets (FIG. 4.20) in spite of poorer drainage at depth. The weighted profile means, however, show a distinct pattern of decrease towards the base facet as drainage becomes poorer. There is a sharp increase of iron in the plinthite horizon of the footslope profile.

In summary, this toposequence is unique in having a clay bed at summit area which causes impeded drainage. Moreover the base facet suffers from a shallow water-table resulting in poor argillation. But the removal of soluble materials is quite effective at the base facet because of its longitudinal slope. These factors together prevent most of the physical and chemical properties from developing progressively improved profile characteristics down the slope. Among the five facets, the summit area offers the best conditions for deep rooted plants by virtue of its 'moderately well' drainage, higher level of exchange properties and comparable macro-nutrient status at depth. The footslope and toeslope areas, on the other hand, are well suited to shallow rooted plants on account of better drainage and higher nutrient status of the surface horizon. The base facet can only support shallow rooted annual plants, but it is less suitable than the footslope and toeslope areas because of poorer drainage and lower nutrient content. All these facets would require application of phosphorus for better crop production. The shoulder area can only support a few native trees and grasses which are able to grow upon such shallow and poor soil.

4.4.3 CLASSIFICATION OF SOILS

There are five soil profiles, each representing one land facet. The profile at the shoulder facet is too shallow for classification. It has a 14 cm thick ochric epipedon underlain by a petroferric horizon. The soil moisture regime is ustic. In the absence of any more data, the profile is provisionally designated as a Paleustalf, in conformity with the shoulder profiles of the other land systems. In the Ultisol and Oxisol orders, soils underlain by a petroferric contact at shallow depth are classified at the subgroup level using the adjective 'Petroferric' (Soil Survey Staff, 1975). But no such directives are put forward in the Alfisol order. This profile is, however, provis-:ionally classified as Petroferric Paleustalf.

The other four profiles have ochric epipedons and argillic horizons with greater than 35% base saturation. So all of them are Alfisols. In this toposequence, only the base profile has an aquic moisture regime. The break of slope between the base facet and the rest of the toposequence helps to drain the water out of the toeslope area. The base profile has mottles and low matrix chroma from below the Ap horizon. Since it has no plinthite nor iso-temperature regime but has an ochric epipedon, it is an Ochraqualf. It corres-:ponds to the central concept of the great group. It is, therefore, a Typic Ochraqualf.

The remaining profiles are Ustalfs. The toeslope profile has no plinthite. There is no sharp clay increase nor a hue redder than 10YR. It is, therefore, a Haplustalf. It deviates from the central concept of the great group by lacking a calcic horizon. So it is classified as a Udic Haplustalf. The footslope profile has plinthite below 55 cm depth, occupying more than 50% of the horizon. It is, therefore, a Plinthustalf.

The summit profile has no plinthite. The colour of the argillic horizon does not meet the requirements of Paleustalf or Rhodustalf, nor the clay increase is sharp enough. Therefore, it is a Haplustalf like the toeslope profile. Since the base saturation is less than 75% in the argillic horizon, it is an Ultic Haplustalf.

The distribution of the soil classes is schematically shown in

FIG. 4.16. Apparently the profile development is greatly influenced by the topography and drainage. From the base to the toeslope facet, the moisture regime changes from aquic to ustic, but there is still enough water (Udic, at subgroup level) so that the profile development is at the Hapl-stage. The footslope profile is water saturated in the wet season only and dry during summer. This wet and dry cycle has led to the formation of plinthite. Further up the slope in the shoulder area, ironstone has greatly developed in an oxidized regime. But the summit is under the influence of a slowly permeable clay bed. It is saturated with water in the lower horizons. As a result, the profile development has not progressed beyond the Hapl-stage. This profile is, however, more mature than the toeslope profile, as indicated by its Ultic nature.

4.5 LAND SYSTEM E (BINPUR SYSTEM)

This system, like land system D, is a streamless valley with one open end. But it has a unique topographical feature which disting-:uishes it from other systems (see below). The representative toposequence is within the area of two villages near Binpur (latitude 22 degrees, 36 minutes north and longitude 86 degrees, 53 minutes east). Its location is shown in FIG. 4.32 (in SECTION 4.9).

In contrast to the other land systems, this system has small mounds or convexities within the base facet (FIGS. 4.21 and 4.22). These convexities are not gilgai micro-relief features. There are no deep or wide cracks nor are there slickensides or wedge-shaped aggregates in the soil which are associated features of the gilgai. The convexities are few in number, usually two or three in one valley,

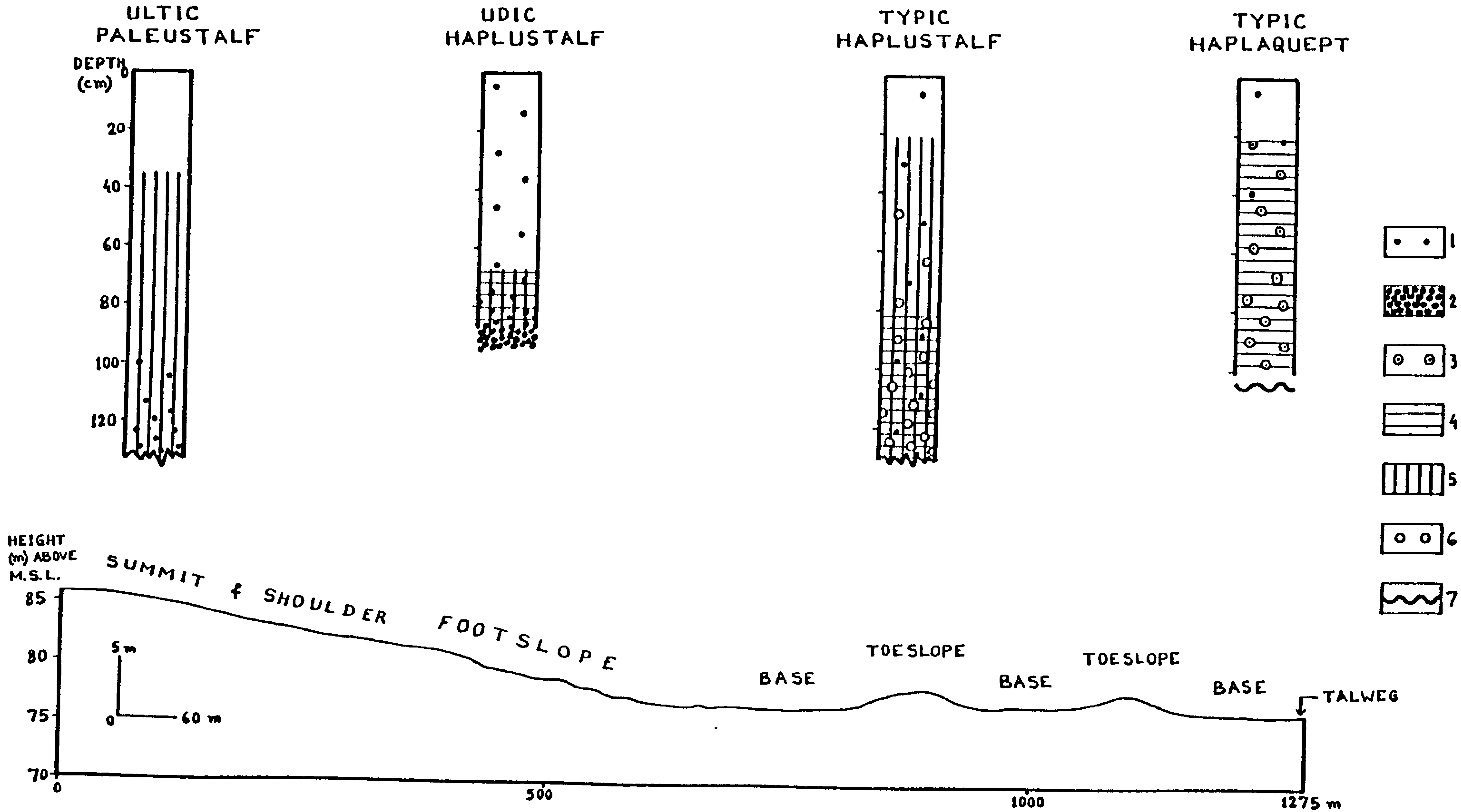

Figure 4.21 Land System E: slope and soils (source: field work; see Appendices A and E). 1. Ironstone concretions; 2. Cemented pisolitic ironstone; 3. Mottles; 4. Strong gleying; 5. Argillic horizon; 6. Calcium carbonate concretions; 7. Water-table during field work.

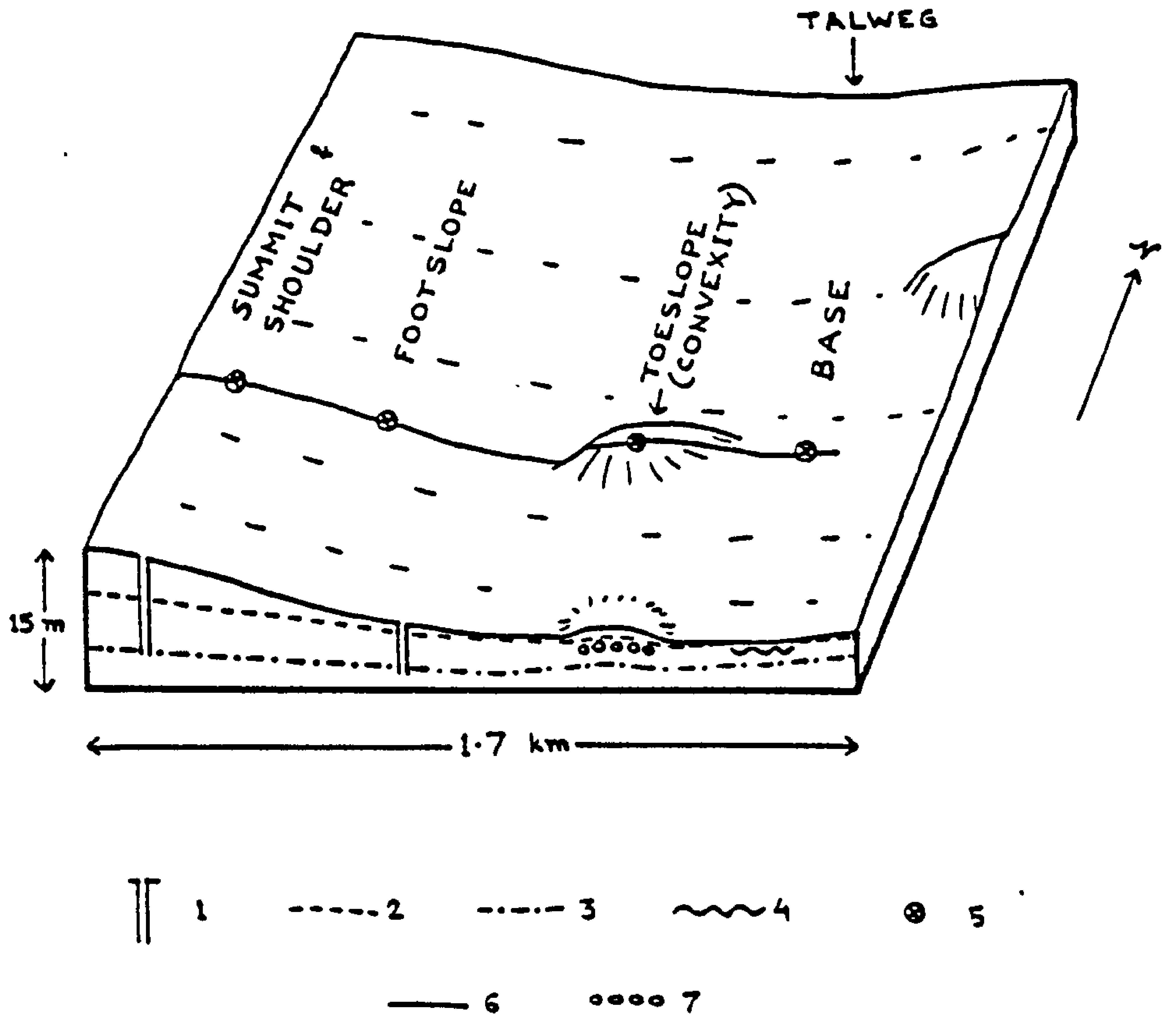

Figure 4.22 A schematic block diagram of System E.

1. Well where depth to water-table was measured; 2. Wet season water-table; 3. Summer water-table; 4. Water-table encountered in a pit during field work; 5. Soil sampling sites; 6. Survey line; 7. Calcium carbonate concretions.

and are big: 100 - 150 m in width and 1.5 - 2.0 m in height. The mode of origin of these convexities is not fully understood at present. They may be depositional inequalities of the parent material or they may be the result of selective water erosion or both. These convexities are distinguished from other facets by having abundant calcium carbonate concretions at depth. There may be a genetic relationship between the concretions and convexities. The concret-:ions may impart resistance to erosion to the convexities whilst the latter may favour precipitation of carbonates (see SECTION 4.5.2). The convexities are described as toeslope facets. There is no toeslope between the base and footslope facets (FIG. 4.21).

In the absence of valley cutting by a stream, the relative relief between the base and the summit is only 10 m. The footslope is not flattened and the shoulder is yet to attain the characteristic steepness (FIG. 4.21). In fact, the shoulder is so small and so similar in soil characteristics with the summit that no soil has been studied separately at the shoulder area. The summit profile may be considered as representative of both the summit and shoulder facets.

Since the basin has no stream (the nearest stream is 3.5 km away) and the longitudinal slope of the base facet has too low a gradient, water drains out of the basin very slowly. As a result, the base facet suffers from the influence of a shallow water-table for the greater part of the year (FIG. 4.22). The water-table was encountered at 100 cm depth at the base facet during field work (winter, 1981-82). The toeslope facet has a relatively deeper water-table because of its height, but its lower horizons are affected by the wet season water-table. The footslope has rapid surface drainage because of its gradient but the drainage of the lower horizons is impeded during wet season by the shallow water-table. The summit and shoulder facets have free drainage throughout.

The land use pattern of the villages around the survey line is shown in FIG. 4.23. A part of the summit and shoulder is under 'type C' open coppice wood of Shorea robusta and its associates (SECTION 2.4 and TABLE 2.10). There are small patches of orchard and bamboo. The rest of these two facets is bare except for poor grasses. The footslope carries poor pasture, orchard, bamboo and forest in the upper part. The lower part of the footslope is culti:vated for rice during the wet season. The settlements are located in parts of the summit, shoulder and footslope facets. The entire toeslope and base areas are cultivated. Rice is grown in the rainy season. Dry season cultivation is, however, limited by unavailability of irrigation. Only a small part of the base facet can be irrigated from ponds where wheat, oilseeds and potato are grown. The fallow lands support grasses and herbs.

The soil conditions of this toposequence are discussed and the influence of topography, drainage and land use upon them are analysed in the following subsections.

4.5.1 SURFACE SOIL PROPERTIES

Four surface soil samples are studied in this toposequence. The sample for the summit also represents the shoulder facet (see SECTION 4.5). The distribution of their physical and chemical properties is presented in FIG. 4.24. These and the morphological properties are discussed below.

The drainage-related morphological properties such as colour,

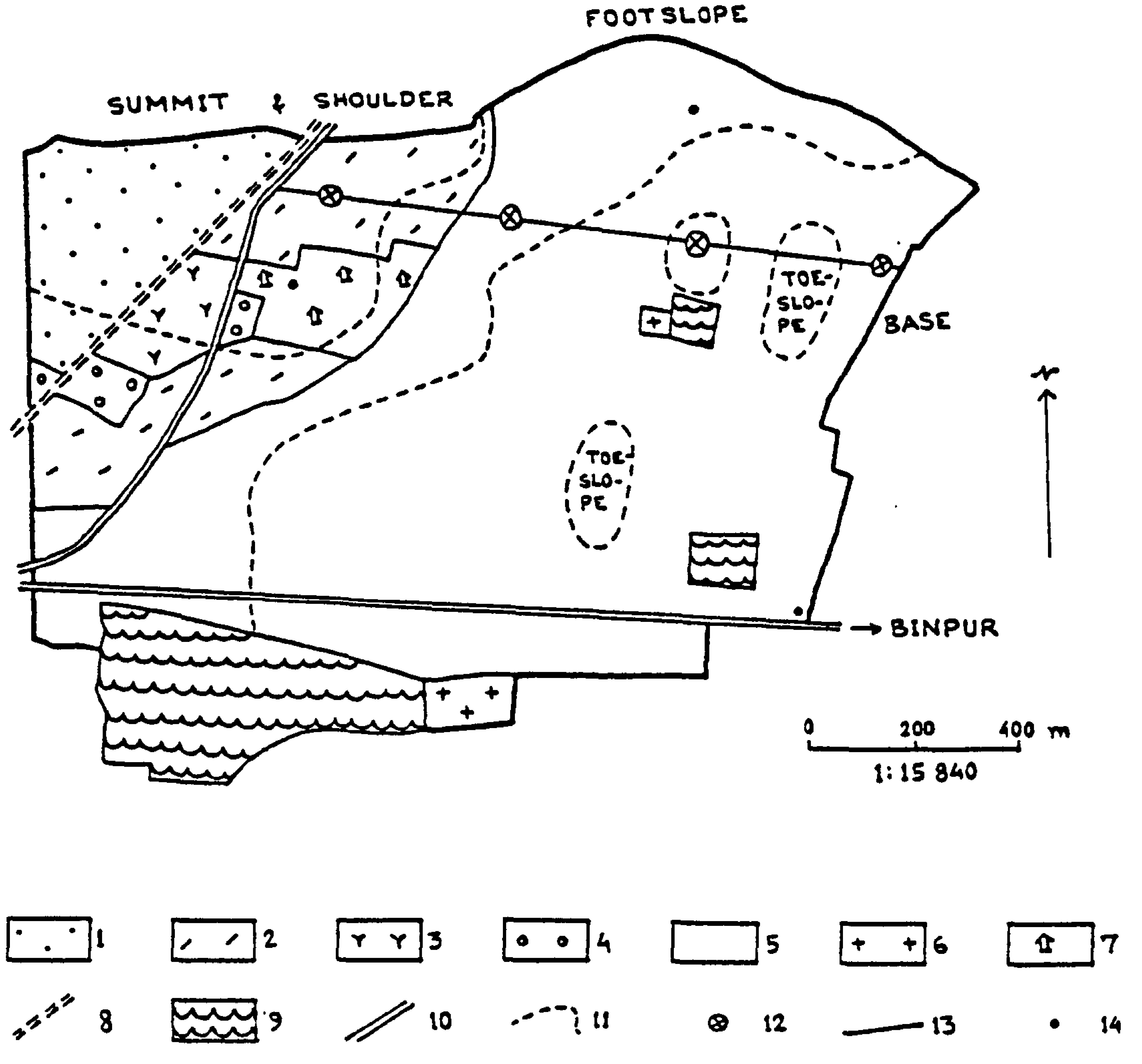

Figure 4.23 Land use pattern of System E (source: field mapping in Mohanpur and Ghoraisoli villages, 1981-82).

1. Forest; 2. Pasture; 3 Bamboo; 4. Orchard; 5. Rice (single crop); 6 Multiple crops; 7. Settlements; 8. Canal; 9. Pond; 10 Road; 11. Land facet boundary; 12. Soil sampling sites; 13. Survey line; 14. Well.

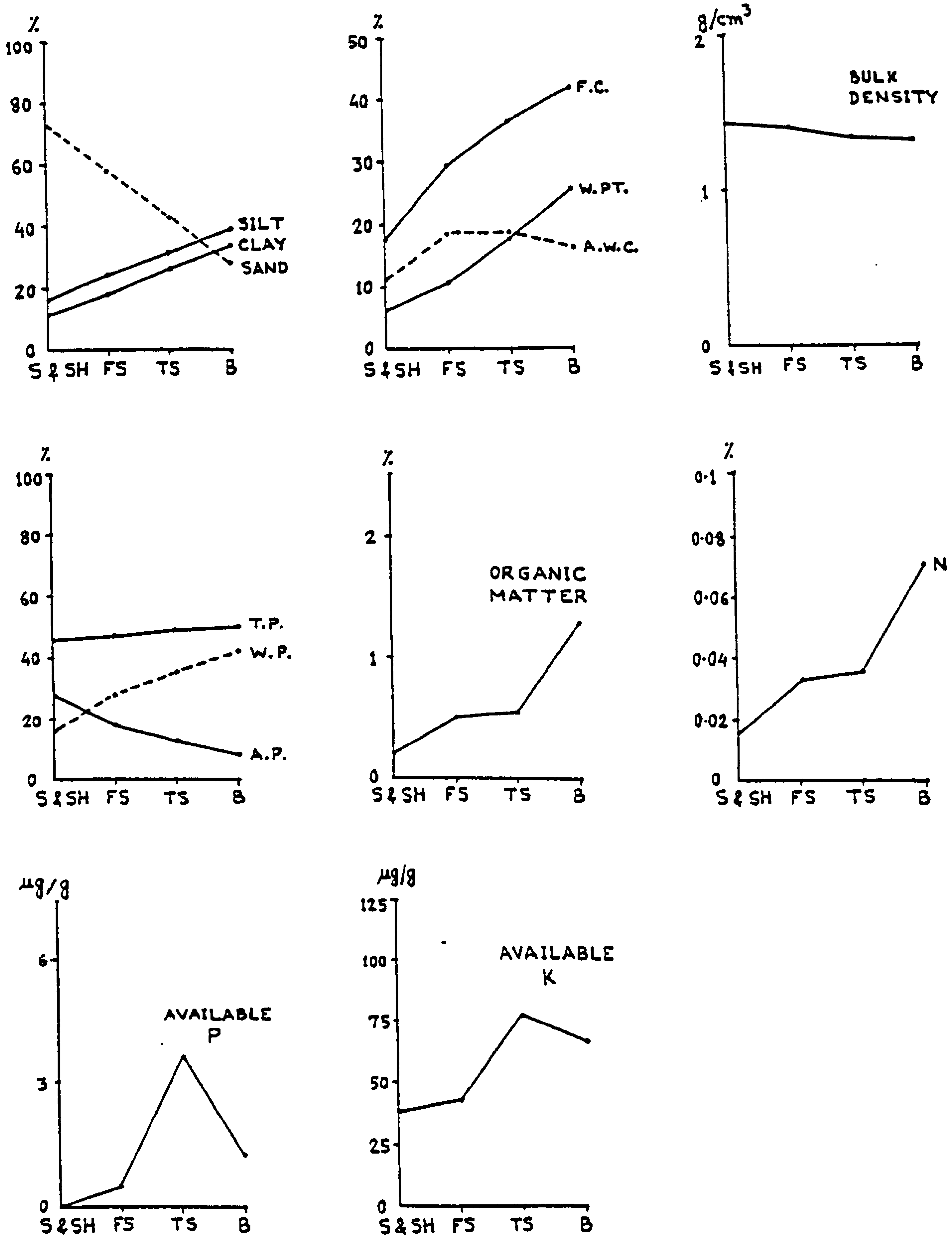

Figure 4.24 Surface soil properties of System E (source: laboratory work; see Appendix A).

S & SH = Summit and shoulder; FS = Footslope; TS = Toeslope; B = Base.
F.C. = Field capacity; W.PT. = Wilting point; A.W.C. = Available water capacity; T.P. = Total porosity; W.P. = Water-filled porosity; A.P. = Air-filled porosity.

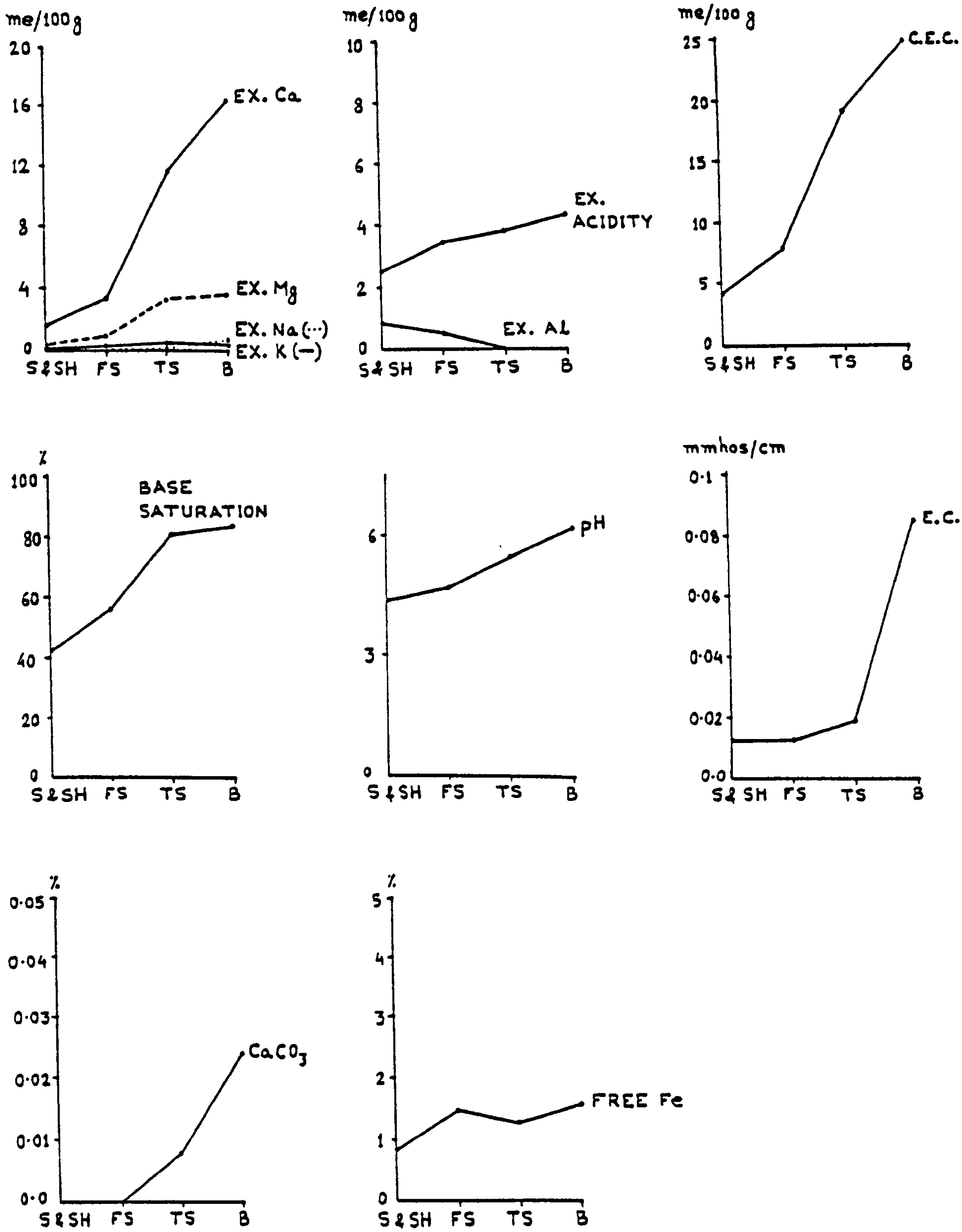

Figure 4.24 (continued)

EX. = Exchangeable; C.E.C. = Cation exchange capacity;
E.C. = Electrical conductivity.

mottles and animal activities change in a regular pattern from the summit to the base area as drainage becomes poorer in the same direction. Soil colour changes from red at the summit to light grey at the base facet. Mottles are absent from the well drained summit and also from the footslope area where surface run-off is rapid. They are found in the toeslope and base facets, mainly along the rice roots. The nature of activity of soil animals changes from ants predominant at the upper to earthworms at the lower facets. The frequency of roots does not change along the toposequence, but the types of plant vary between upper and lower facets. In contrast to these properties, ironstone concretions are irregular in their distribution. They are abundant at the footslope facet where a petroferric horizon occurs at depth. But they are absent from the summit area. They are present in small quantity at the toeslope and base which may be partly a result of transport from the footslope by surface water flow. Soil structure and consistence are determined by texture and organic matter content and are, therefore, described following them (see below).

The physical and chemical properties, the distributions of which are greatly influenced by lateral flow of water, show a regular pattern of change across the toposequence in spite of the convexities. There may be common causes behind the regularly changing values of soil properties and the origin of convexities, but they are not fully understood at present. The nature of the distribution is, however, described as follows.

In this toposequence, both silt and clay increase from the summit to the base area at the same rate (FIG. 4.24). The regular increase of clay is probably due to their deposition over the lower facets in the absence of removal by a stream. Clay and silt have positive relationship with distance at high level of significance (Appendix B). Sand correspondingly decreases towards the base facet. It has negative relationship with distance. The distri:bution of organic matter and nitrogen levels has a less regular pattern than that of the textural particles (FIG. 4.24). Organic matter and nitrogen increase more sharply from toeslope to base facet probably because of poorer drainage and application of greater amount of manures. Their relationship with distance is significant at a lower level than for the textural particles (Appendix B).

Soil consistence increases regularly in stickiness, plasticity, firmness and hardness towards the base facet as texture becomes finer. Soil structure also changes from massive at the summit to granular at the lower facets in response to finer texture, greater organic matter content and activities of earthworms.

The other physical properties are also controlled by the texture and organic matter content. Therefore, their distributions show a regular trend over the toposequence (FIG. 4.24). Their relationship with distance is significant at a high level (Appendix B). With finer texture and stronger structure, the water porosity increases regularly towards the base area whilst air porosity decreases. As a result, there is only a slight change in total porosity. It increases downslope and accordingly, bulk density decreases by a little amount. In response to the regular increase of water porosity, the field capacity similarly increases downslope. But the wilting point increases more sharply over the lower facets on account of clay increase. This is why the available water capacity decreases over the lower facets.

The exchangeable bases are also transported, like silt and clay, by lateral flow of water and deposited over the lower facets. All of them increase down the slope and have developed statistical relation- :ship with distance at significant level (FIG. 4.24 and Appendix B). The calcium and magnesium increase more sharply over the toeslope and base facets probably because their loss is minimum in the absence of a stream. Their quantity reaches 'high level' at the base facet. The exchange acidity increases more regularly than the exchangeable bases, but its level is low. The exchangeable aluminium, on the other hand, decreases towards the base facet. The reason for such behaviour is not fully understood at present. However, the level of aluminium saturation over the summit area and that of sodium saturation at the base facet are well below the toxic limit.

Since the exchangeable calcium and magnesium are the major components of the exchange complex, particularly over the lower facets, their distribution pattern is followed by the cation exchange capacity, base saturation and pH. All of them increase downslope and more sharply over the lower facets (FIG. 4.24). The cation exchange capacity and base saturation reach high levels of concentration over the base facet. The soil reaction improves from extremely acidic over the summit to slightly acidic at the base area. All of them have statistical relationship with distance at significant level.

The soluble salts and calcium carbonate also increase more sharply over the lower facets (FIG. 4.24). The reason is probably the same as for the exchangeable bases i.e. they are accumulating over the lower facets in the absence of stream removal. There may also be some contribution by precipitation from groundwater. However, their level is low. The concentration of salts is far below the level likely to cause an agricultural problem.

The available phosphorus and potassium are not so regularly distributed as the other properties. They are, however, less erratic here than in the remaining toposequences. Both of them increase from the summit to the toeslope facet but then decline at the base area (FIG. 4.24). The reason for such behaviour is not fully understood. The pH rises to 6.2 at the base facet and at the same time the aluminium becomes more scarce which should favour greater availability of phosphorus. It is doubtful whether the slight increase of free iron may be totally responsible for the decline of phosphorus. The available potassium should also have increased at the base facet like the exchangeable bases and salts in the absence of stream removal.

The free iron is the other property in this toposequence the distribution of which is not fully understood. It tends to increase towards the lower facets in spite of the increasingly poorer drainage (FIG. 4.24). The rate of increase is, however, low and the pattern is irregular. Therefore, it has no statistical relationship with distance at significant level (Appendix B).

In summary, most of the surface soil properties of land system E are distributed in a regular pattern over the facets. Excepting available water capacity and available phosphorus and potassium, the surface soil properties improve from the summit to the base facet where they reach maximum concentrations. The above three properties are at their highest level over the toeslope. Thus, both the toeslope and base areas are well suited for cultivated crops. The levels of exchange capacity and nitrogen of the toeslope facet may be improved by application of organic manures. The base facet and also the toeslope area would require application of phosphorus and potassium, for the concentrations of these two nutrients are low. The footslope facet is less suitable for cultivated crops on account of its poorer physical conditions and nutrient status. The summit and shoulder areas are even less suitable for cultivation, but may be more successful for tree crops by virtue of better drainage than the lower facets.

4.5.2 SOIL PROFILES

There are four soil profiles in this toposequence, representing the summit, footslope, toeslope and base facets. The summit profile also represents the shoulder area (see SECTION 4.5). Some of the morphological properties are shown in FIG. 4.21. The profile diagrams of the physical and chemical properties are presented in FIG. 4.25.

The summit and shoulder areas have deep soils. The footslope profile is limited to 87 cm depth by a petroferric contact of cemented pisolitic ironstone (see SECTION 4.5.3). The toeslope and base profiles are deep, but the base area is affected by a shallow water-table for the greater part of the year. During field work (winter, 1981-82) the water-table was encountered at 100 cm depth.

The colour and mottles show different patterns between the profiles of the base, toeslope and footslope facets. The entire base profile suffers from strong gleying which intensifies with depth, as indicated by its neutral hue. Yet the mottles increase in abundance and distinctness with depth (FIG. 4.21). This behaviour is probably due to deep penetration of roots and a medium fine texture which allows movement of oxygen. The toeslope profile is olive to yellowish brown

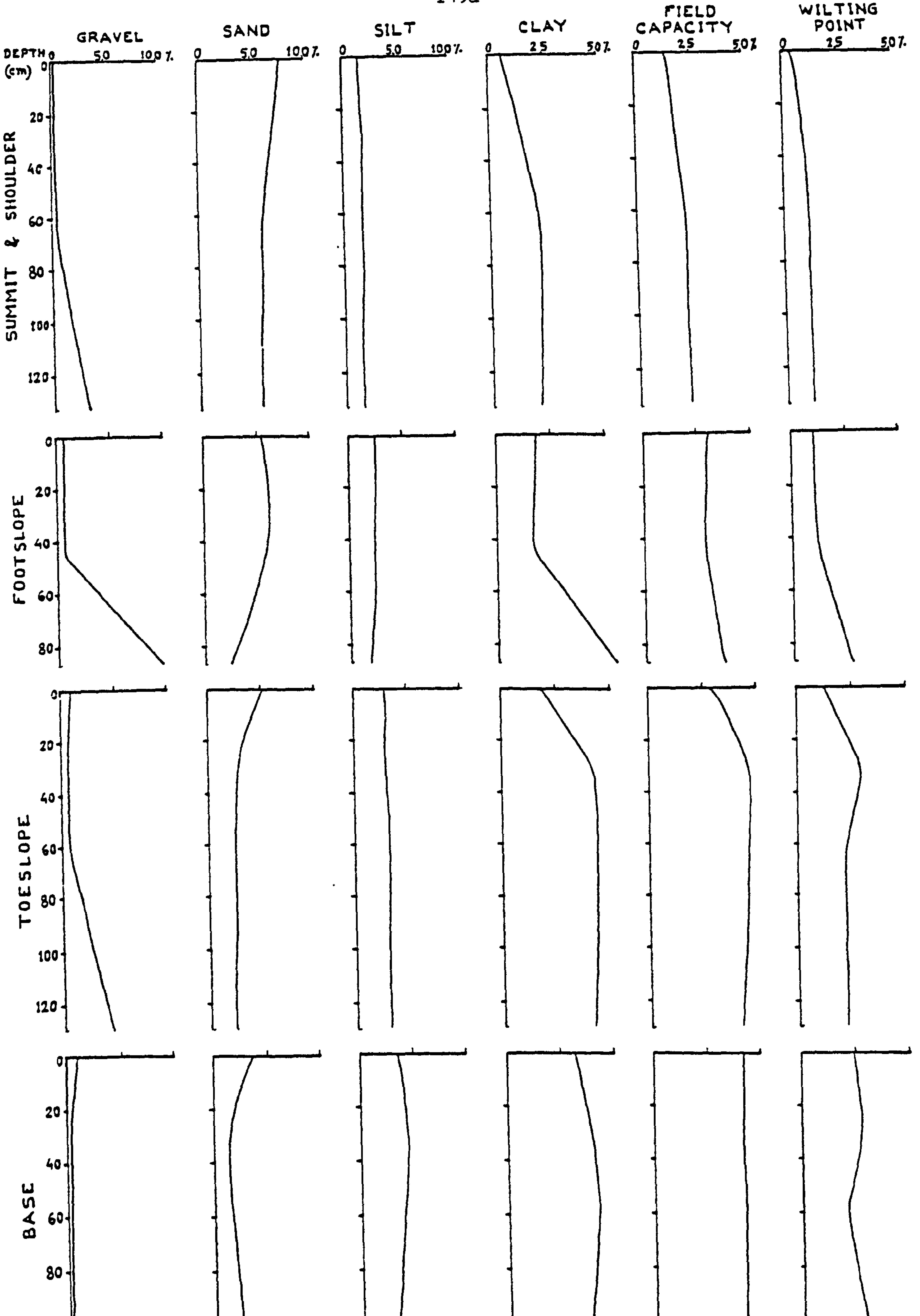

Figure 4.25 Soil profile properties of System E (source: laboratory work; see Appendix A).

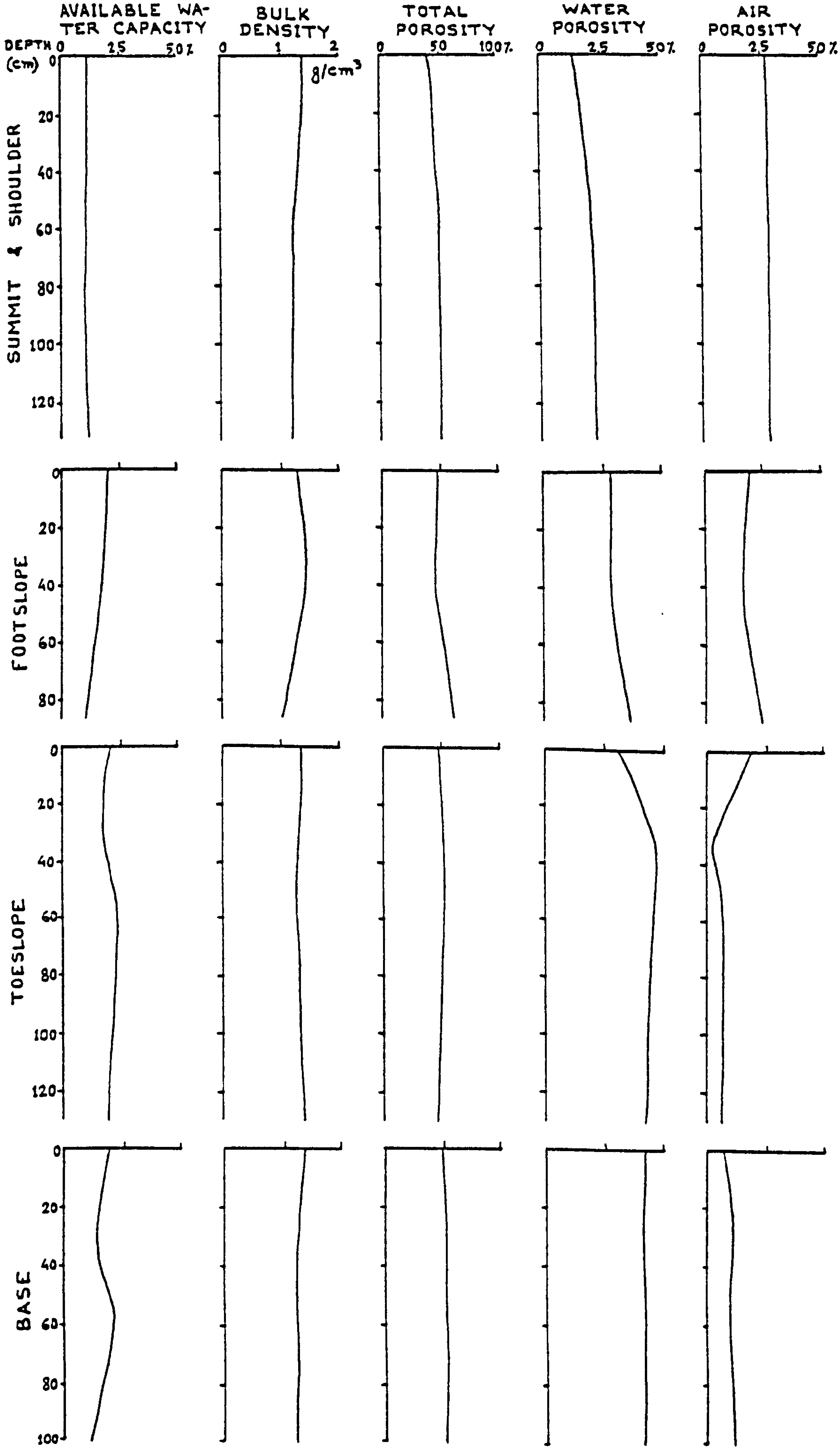

Figure 4.25 (continued)

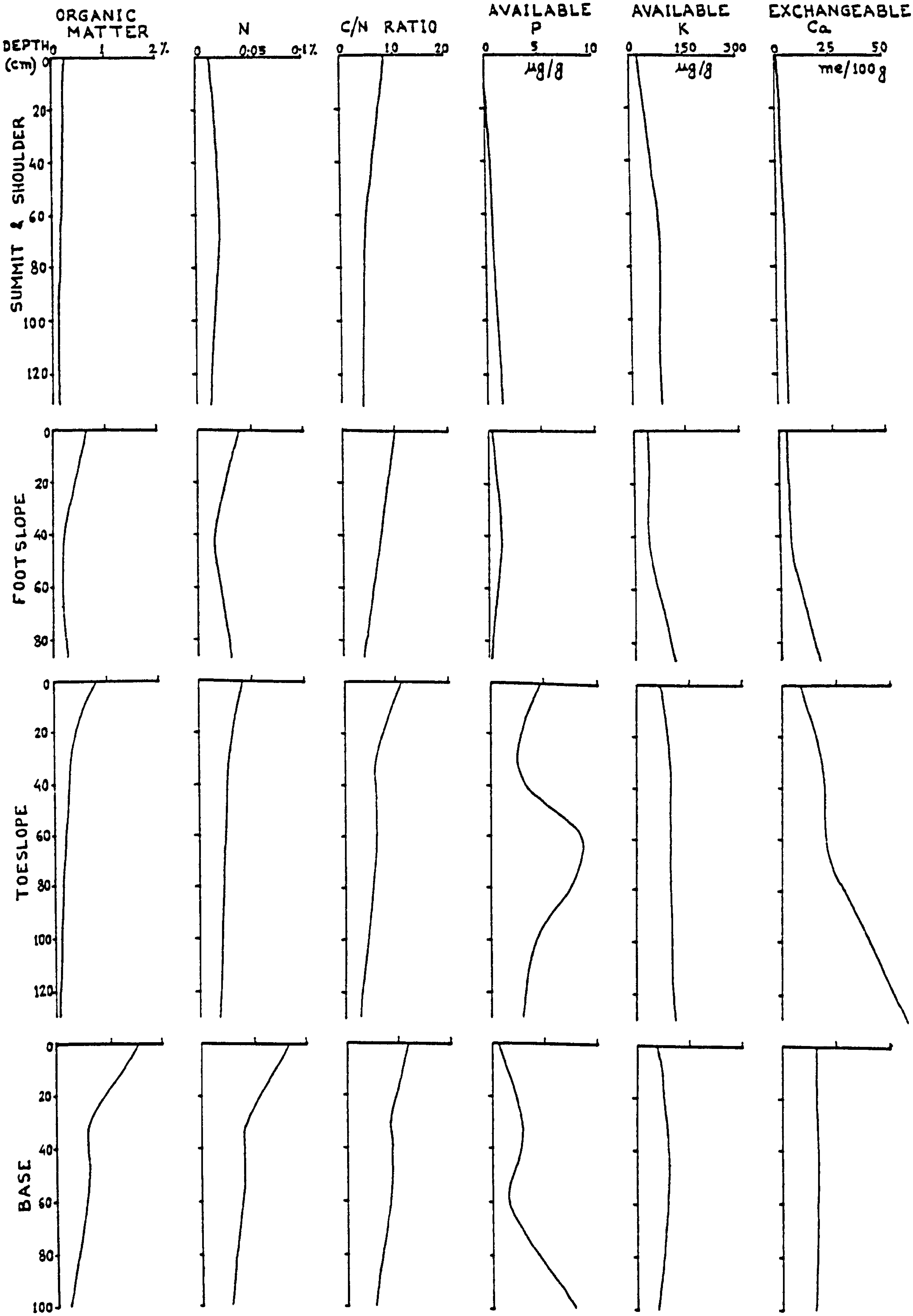

Figure 4.25 (continued)

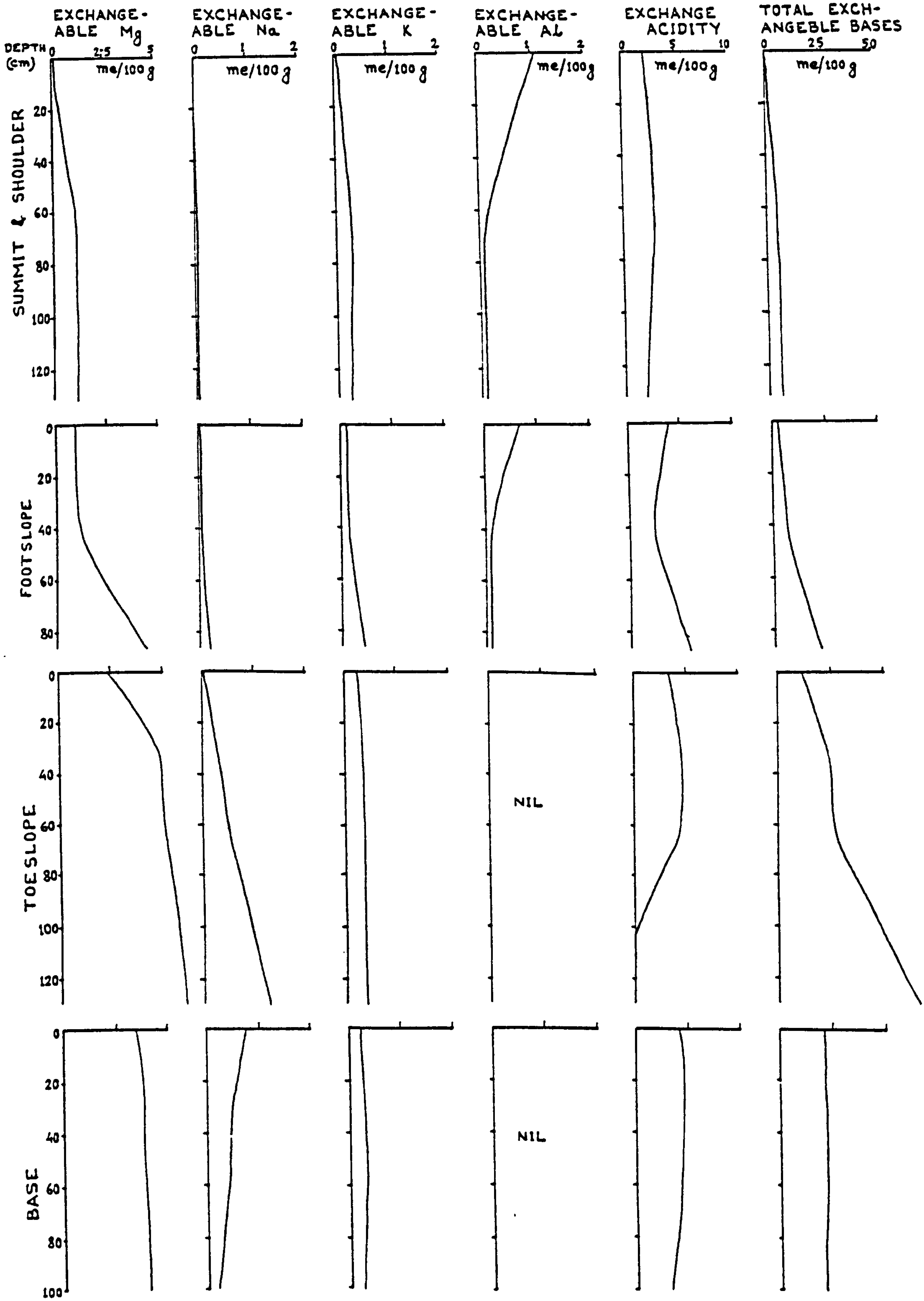

Figure 4.25 (continued)

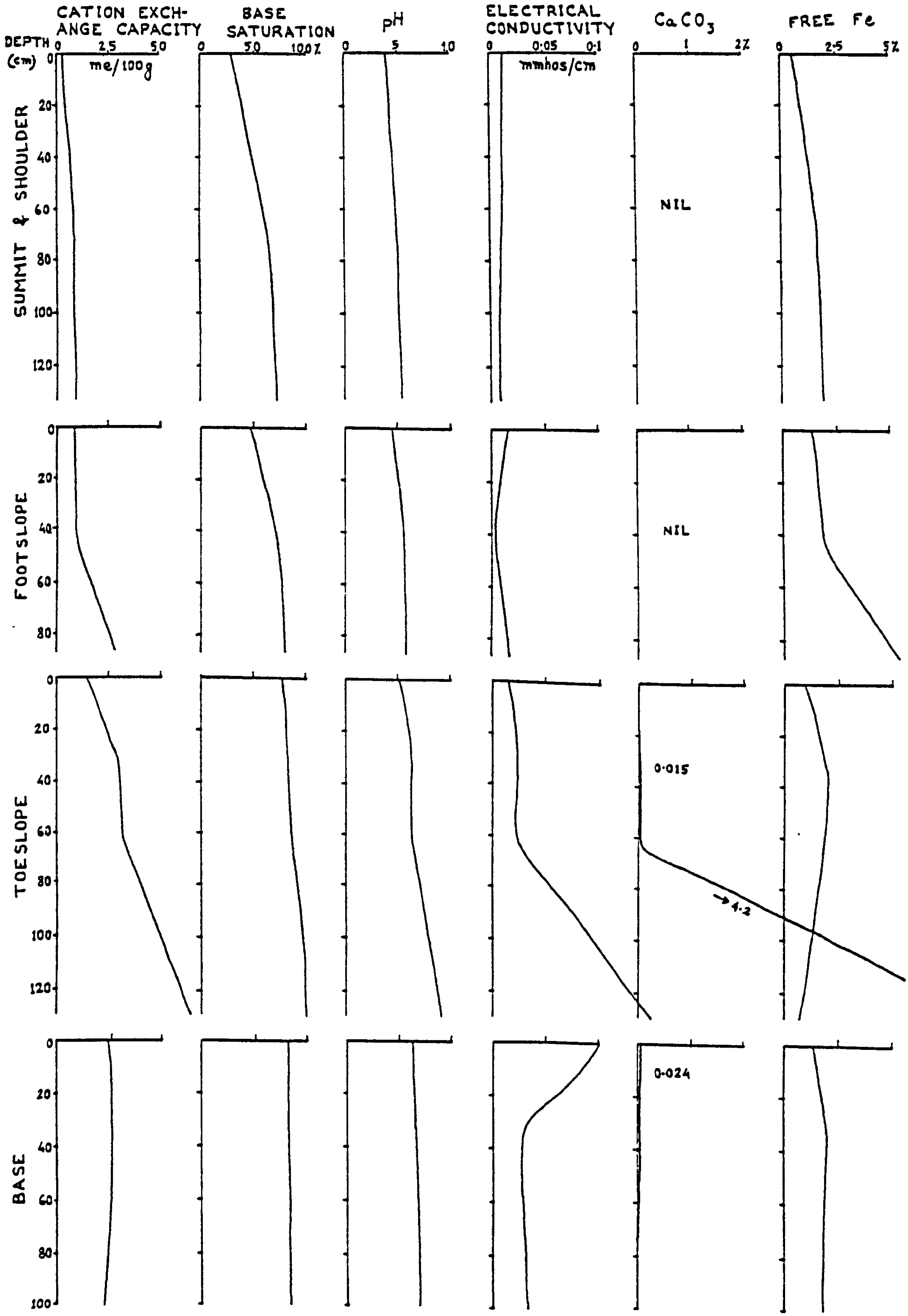

Figure 4.25 (continued)

for the greater part and changes to light grey colour of strong gleying only at depth. But there are no mottles in this profile except those along rice root channels in the surface horizon. The situation here is opposite to that of the base facet. A fine texture and lack of root penetration inhibit oxidation and limit the zone of mottling. The footslope profile also changes from yellowish colour to light grey at depth without any mottles. In this facet the mottles have already hardened into ironstone concretions (see SECTION 4.5.3). The concretions increase sharply with depth and pass into cemented pisolitic ironstone below 87 cm. The summit profile has a yellowish red colour throughout without mottles, indicating free drainage conditions. Ironstone concretions are found only at depth.

The unique feature of this toposequence is the abundant development of calcium carbonate concretions in the lower horizons of the toeslope profile i.e. within the convexities. The concretions are forming by precipitation of calcium carbonate from the capillary fringe of groundwater. As described in SECTION 2.2, the parent material is heterogeneous in composition which includes calcareous materials. Under a hot and wet-dry climate the calcareous components are thoroughly leached down into the groundwater from all facets. As the groundwater moves under gravity towards the centre of the basin, the calcareous materials may be lost into a stream. But in the absence of a stream, the outward drainage of the basin becomes limited and then the calcareous materials are concentrated in the groundwater below the lower facets. During dry season the calcium can move upwards from the water-table by capillary rise and may be precipitated after evaporation of the water. In this toposequence, the base facet remains moist throughout the year by the proximity of the water-table and, therefore, there is not enough evaporation to cause precipitation of carbonates. But since the toeslope (convexities) is elevated, the water-table is deeper and the soil dries out in summer. This is why calcium carbonate is precipitated here above the dry-season water-table. The concretions remain below the wet-season water-table (FIG. 4.22), but seem to be less readily soluble once they are formed.

The physical and chemical properties in profile are less regular in distribution over the toposequence than the surface soil properties. The weighted means of 120 cm profiles show that organic matter and some of the physical properties (sand and silt contents and wilting point) have a regular trend pattern across the toposequence (Appendix C). But the trends of the profile means of the other physical properties and all chemical properties are discontinued between the toeslope and base facets. There are two reasons for this behaviour. Firstly, the toeslope area is enriched with various materials in the lower horizons by means of capillary rise and preci:pitation. Thus, this facet has the highest profile means of exchangeable bases, cation exchange capacity, base saturation, pH, carbonates and soluble salts. The other reason is limited illuviat:ion of clay at the base facet because of a shallow water-table persist:ing over the greater part of the year. Thus the base facet is relatively poorer in the clay content of the lower horizons than the toeslope area. This factor accounts for the irregular trend of profile means of some physical properties. The behaviour of the physical and chemical properties in profile at each facet is described as follows.

All facets become finer in texture with depth because of clay illuviation and corresponding decrease of sand (FIG. 4.25). But the quantity of silt remains unchanged with depth. The base facet has a relatively lower illuviation of clay on account of a shallow water-table. An argillic horizon has not formed in this area. In the remaining facets, the clay increases sharply and sufficiently to form argillic horizons. The degree of argillation increases from the summit to the toeslope where the argillic horizon is clayey. But the lower horizons of the base area are clay loam in texture.

The organic matter content decreases gradually with depth in the well drained summit area (FIG. 4.25). The lower facets, on the other hand, are characterized by a sharp decline of organic matter below the surface horizon. The organic matter does not decrease to a very low level in the base area, probably because of deep penetration of roots. The slight increase of organic matter in the lowest horizon of the footslope profile may be due to the same factor. The profile pattern of the nitrogen content follows that of organic matter.

Since the lower horizons of the summit, footslope and base facets contain some amount of organic matter and are penetrated by roots, the air porosity slightly increases with depth in these three facets. But in the absence of roots and enough organic matter, the lower horizons of the toeslope profile show a decrease of air porosity. The water porosity increases in the argillic horizons of the summit, footslope and toeslope areas, but it remains unchanged with depth in the base facet where clay illuviation is limited. As a result of the opposite trends of the air and water porosities at the toeslope and base profiles, the total porosity remains unchanged with depth in these areas (FIG. 4.25). The summit and footslope facets, on the other hand, have an increase of total porosity with depth as both the air and water porosities increase in that direction. The profile behaviour of bulk density is opposite to that of the total porosity at each facet.

The field capacity obviously behaves like the water porosity in profile pattern (FIG. 4.25). It increases with depth in the summit, footslope and toeslope facets and decreases slightly in the lower horizons of the base area. The wilting point, on the other hand, does not correspond to the clay profile in all facets. It increases with depth following the clay illuviation in the summit and footslope facets, but decreases in the lower parts of the illuvial horizons of the toeslope and base areas. The reason for such behaviour is not understood at present. In consequence to the irregular profile pattern of wilting point, the available water capacity behaves irregularly in the toeslope and base profiles. In the footslope profile, however, the available water capacity decreases regularly with depth on account of wilting point increasing at a greater rate than the field capacity. The two latter properties increase at the same rate in the summit profile so that the available water capacity is unchanged with depth here.

As indicated earlier, the exchangeable bases, cation exchange capacity, base saturation and pH show different profile behaviour between the summit, footslope and toeslope on the one hand and the base facet on the other (FIG. 4.25). In the first group of facets, these properties increase with depth. The rate of increase becomes sharper towards the toeslope facet where the properties have maximum values. But at the base facet, these properties remain unchanged with depth. The process responsible for accumulation of exchangeable bases in the lower horizons of the first group of facets is mainly leaching. In addition, precipitation at the capillary fringe of water-table is a major process of accumulation at the toeslope area. In the base facet, on the other hand, both leaching and precipitation are limited by a shallow water-table and high soil moisture content.

Although the exchangeable bases and related properties do not increase with depth at the base facet, the exchangeable calcium and magnesium, cation exchange capacity and base saturation are at high level of concentration throughout the profile depth. At the toeslope and footslope facets, on the other hand, these properties reach the high level in the lower horizons only. The toeslope area, however, has the maximum increase for these properties among all facets. In the summit area these properties do not exceed the low level even in the deepest horizon. The pH also remains strongly acidic at this facet, but it reaches neutrality in the deeper horizons of the lower facets. The level of sodium is, however, well below the toxic limit in all horizons of all facets.

The exchange acidity slightly increases in the upper part of the illuvial horizon and then decreases with depth (FIG. 4.25). It occupies a lower proportion of the cation exchange capacity in all facets. The exchangeable aluminium decreases sharply with depth. It is totally absent from the toeslope and base areas.

The soluble salts and calcium carbonate do not increase with depth in the summit, footslope and base facets, indicating their thorough leaching. But there is a sharp increase of these two properties in the deepest horizon of the toeslope profile. This is due mainly to their precipitation from the capillary water rising from the dry-season water-table.

The free iron increases with depth in the summit and footslope areas corresponding to the increase of ironstone concretions. But it decreases with depth in the toeslope and base facets on account of poor drainage and scarcity of ironstones.

The available phosphorus and potassium tend to increase towards the lower horizons, but the profile pattern of phosphorus is irregular (FIG. 4.25). This irregularity is probably caused by the influence of different proportions of the pH, calcium, alluminium and iron at each horizon. The available potassium reaches the medium level of concentration in the lower horizons of all facets. The available phosphorus is at medium level in the lower horizons of the toeslope and base areas only. It remains within the low level throughout the summit and footslope profiles.

In summary, the profile behaviour of the properties is influenced by not only the leaching and drainage conditions but precipitation at the capillary fringe of water-table as well. The unique feature of this toposequence is the mounds or convexities (toeslope) associated with abundant development of calcium carbonate concretions and highest concentration of exchangeable bases at depth. The toeslope area, however, suffers from low air porosity and shallow water-table during wet season. Therefore, this facet is unsuitable for most deep-rooted perennial plants. The deep-rooted annual plants of the dry winter and summer may, however, utilize the greater fertility of the lower horizons. The base area has also high concentration of exchangeable bases and relatively higher air porosity and nitrogen content at depth than in the toeslope area. But the shallower and longer persisting water-table makes this area unsuitable for most deep-rooted plants.

The footslope area is under the influence of shallow water-table in the wet season only, but the soil is limited to medium depth by a petro-:ferric horizon. These three facets are, however well suited to shallow-rooted annual crops. The summit and shoulder areas have low levels of plant nutrients, exchange capacity and available water capacity throughout the profile depth. But the soil is deep, thoroughly well drained and high in air porosity. Therefore, these facets are better suited to deep-rooted plants and those requiring free drainage than the lower facets.

4.5.3 CLASSIFICATION OF SOILS

Four soil profiles have been studied in this toposequence, representing the summit, footslope, toeslope and base facets. The profile for the summit area also represents the shoulder facet (see SECTION 4.5).

All the profiles are characterized by illuviation of clay. But, in the base area, illuviation has not progressed enough to develop an argillic horizon. The subsurface horizons of the base profile are, however, sufficiently altered to have a fine texture, low matrix chroma and regular decrease of organic carbon. Yet, they have a cation exchange capacity greater than 16 me/100 g of clay. They are, therefore, cambic horizons and the base profile belongs to the Inceptisol order. The moisture regime aquic. There is no plinthite, iso-temperature regime nor a sodium saturation greater than 15%. So it is a Haplaquept. Since the profile conforms to the central concept of the great group, it is a Typic Haplaquept.

The other three profiles have argillic horizons where base saturation is greater than 35%. All of them have ustic moisture regimes. They are, therefore, Ustalfs at the suborder level. The toeslope profile does not have plinthite. The colour hue is not as red as 10YR nor is the clay increase sharp enough. It is, therefore, a Haplustalf. Since it conforms to the central concept, it is a Typic Haplustalf. The footslope profile is also a Haplustalf, but it deviates from the central concept by lacking a calcic horizon. Therefore, it is a Udic Haplustalf.

The profile representing the summit and shoulder area has no plinthite. The colour hue of the argillic horizon is redder than 10YR and the chroma is greater than 4. But it is no more red than 5YR. The amount of clay does not decrease by more than 20% from the maximum . Therefore, it is a Paleustalf. It deviates from the central concept by having less than 75% base saturation. So it is an Ultic Paleustalf.

The distribution of the soil classes over the toposequence is schematically shown in FIG. 4.21. The profiles are progressively more developed towards the summit area. The base profile is an Inceptisol while the profile at the summit is a mature Alfisol. The reason for the failure of the base profile to develop an argillic horizon is likely to be the presence of a shallow water-table for the greater part of the year, which inhibits illuviation of clay.

The development of a calcic horizon (horizon of calcium carbonate concretions) in the toeslope profile is unique among the studied profiles. It is the only "Typic" Haplustalf. It seems that calcium carbonate begins to accumulate in the lower facets of the toposequences as drainage becomes poorer from a third order stream basin (system A) to a streamless valley (system E) (see also SECTION

4.5.2).

The absence of mottles and abundant development of ironstone concretions in the footslope profile are also important features of this toposequence. The ironstone concretions look like mottles in the field, particularly since they are surrounded by light grey colour of the matrix. But the concretions are hard and brittle in consist-:ence. They have apparently transformed from the mottles (plinthite) into ironstone concretions. The lack of abundant vegetation upon the surface has augmented the wetting-drying cycle of this facet caused by the fluctuating water-table (cf. the footslope area of system C in SECTION 4.3.2). Otherwise, the profile could have been a Plinthustalf. The ironstone concretions gradually pass into cemented pisolitic iron-:stone with depth (i.e. in the middle part of the fluctuation zone of the water-table) as greater amount of iron becomes concentrated.

4.6 LAND SYSTEM F (FLOOD PLAIN SYSTEM)

This system is the flood plain of fourth order streams (Strahler order; Strahler, 1952). There are four such flood plains in the Southern Rarh Plain, formed by the Darakeswar, Silai, Kasai and Subarnarekha (SECTION 2.1 and FIGS. 2.1 and 4.26). The length of the flood plains within the limits of the region is comparable. But their width varies directly in proportion to the size of the upper catchments (TABLE 4.1 and FIG. 4.26).

The regime of these rivers is irregular because of the monsoon rainfall (TABLE 2.2). During summer the stream flow is minimal, but in the rainy season, the rivers overflow their channels. Such floods are regular and mild. They result in the deposition of particles,

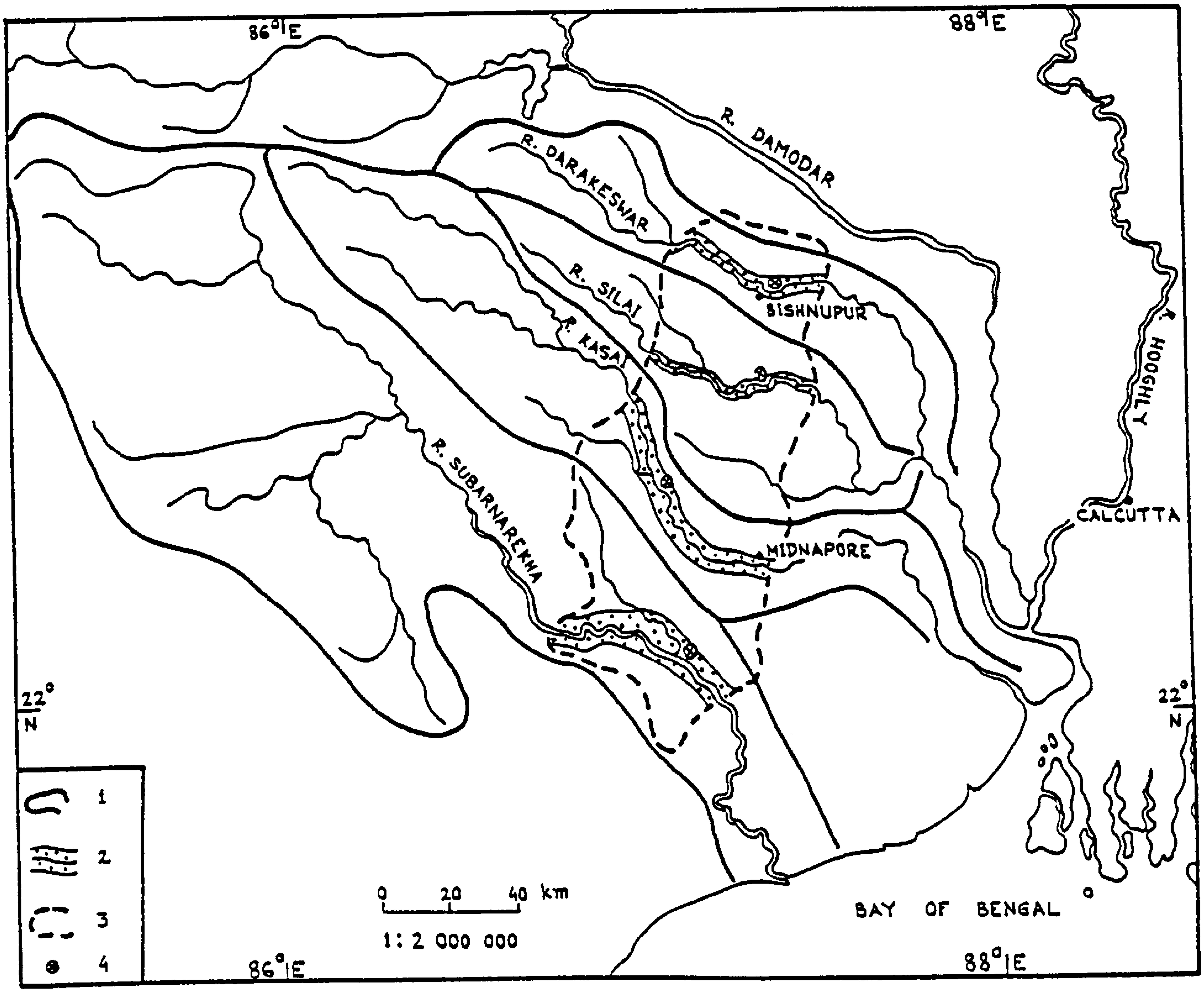

Figure 4.26 Land System F: the flood plains (after Survey of India and National Atlas Organization maps).

1. Catchment boundary; 2. Flood plain; 3. Approximate boundary of the Southern Rarh Plain; 4. Site of soil and land use studies.

TABLE 4.1 FLOOD PLAINS AND UPPER CATCHMENTS OF THE FOURTH ORDER STREAMS

NAME OF THE STREAMS	CATCHMENT AREA BEFORE ENTERING THE REGION (sq. km)	AVERAGE WIDTH OF THE FLOOD PLAINS WITHIN THE REGION (km)	LENGTH OF THE FLOOD PLAINS WITHIN THE REGION (km)
Darakeswar	1,800	5.0	46
Silai	1,200	2.5	57
Kasai	4,200	7.0	68
Subarnar-:ekha	15,200	10.0	56

source: calculated from topographical maps of Survey of India.

mainly silt and also organic matter. They hardly harm the rice crop. In the years of excessive rainfall, the floods are more extensive, but except in the case of R. Silai, they are not severe. The narrow flood plain of the Silai bordered by cliffs gives rise to devastating floods. It was very severely flooded during the rainy season of 1978.

The flood plains are generally flat, excepting the depressions along old channels, natural levees, etc. Soil drainage is poor in the rainy season because of shallow water-table and flood. Drainage improves during dry winter and summer when water-table falls. In the rainy season, rice is grown over most of the area. A great proportion of the area is also cultivated during winter with irrigation from rivers, shallow tubewells and wells. Summer cultivation is restricted to small patches by the rivers or around the wells. The main winter crops are wheat, oilseeds, potato, cabbage and other vegetables. Only oilseeds and vegetables are grown during summer. Sugarcane is an important perennial crop of the flood plains. Both organic manures and chemical fertilizers are liberally applied to the flood plains, particularly for the irrigated crops.

The soils and land use of each of the four flood plains were studied at a representative area which is a village as defined by the village maps i.e. settlements and fields. They were selected at about the middle of the length of the flood plains as far as permitted by ease of access and availability of village maps (FIG. 4.26). Only surface soil samples to the depth of plough layer were examined. In each village, ten to twelve samples were collected at random from plots of different types of crops (FIGS. 4.27, 4.28, 4.29 and 4.30). Land use pattern was mapped at a scale of 1:3960. The morphological, physical and chemical properties of each soil sample and the mean values for each village representing the flood plains are tabulated in Appendix D. In the following subsections, the soil properties of each flood plain as revealed by the representative village area are described separately and then, a general discussion is made in sub-:section 4.6.5.

4.6.1 FLOOD PLAIN OF R. DARAKESWAR (KATNA VILLAGE)

The Darakeswar is the northernmost river of the Southern Rarh Plain. Its flood plain is only 1 km wide at the edge of the Chotanagpur plateau, but widens to 6 km during its course in the plain. The representative area is Katna village (latitude 23 degrees, 6 minutes north and longitude 87 degrees, 22 minutes east). It is situated on the left bank of the river in the inner side of a meander (FIG. 4.26). The land use pattern of the village and the soil sample sites are shown in FIG. 4.27. About 50% of the area is multiple cropped with river lift and tubewell irrigation. In addition to rice, the important crops of this village are wheat, oilseeds, vegetables and potato.

This village is mildly flooded every rainy season. The mineral particles of the soils are essentially deposits of these floods, as evidenced by their size and spatial distribution. Silt is the major component of the texture (48% on average). It is uniformly distributed over the village (CV, 7%). But most of the sand is deposited near the river while clay is more abundant away from it. The soil texture, therefore, changes from loam to silty clay as one goes away from the stream.

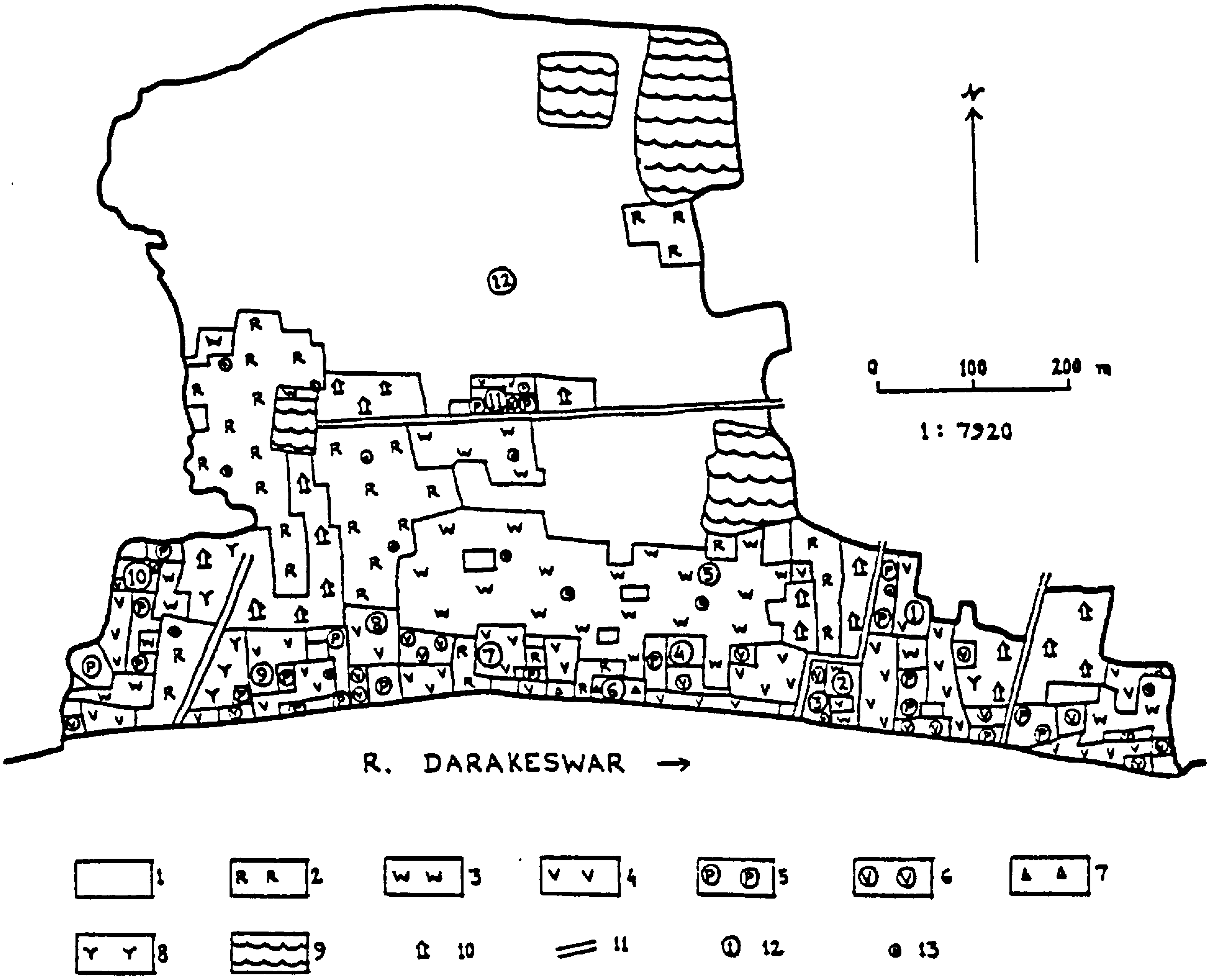

Figure 4.27 Land use pattern of Katna village, flood plain of R. Darakeswar (source: field mapping, 1981-82).

	Wet season	Winter	Summer
1.	Rice	-	- ;
2.	Rice	rice	- ;
3.	Rice	wheat	- ;
4.	Rice	oilseeds/vegetables	- ;
5.	Rice	potato	oilseeds/vegetables;
6.	Rice	oilseeds/vegetables	oilseeds/vegetables;

7. Sugarcane; 8. Bamboo; 9. Pond; 10. Settlements; 11. Road; 12. Soil sampling sites; 13. Shallow tubewell.

The distribution pattern of texture is not reflected in the pattern of other physical properties due to the influence of organic matter. The latter has no regular distribution pattern but varies from plot to plot depending upon the input of organic manures. The highest and lowest values of organic matter are found between neigh-:bouring plots (sites 6 and 4). As a result, the other physical properties are irregularly distributed. They are, however, 'medium' on average values owing to a medium texture and moderate content of organic matter (1.1% on average).

Three nutrients - nitrogen, phosphorus and potassium are applied to these soils as chemical fertilizers. The amount added to each plot varies according to the peasant's capital and cropping pattern. Available phosphorus and potassium are at the medium level of concent-:ration on average values, but vary enormously from one plot to another (CV 103% and 56% respectively). Nitrogen is also at the medium level (0.07% on average) but less variable (CV 13%). The nitrogen content is closely linked with the quantity of organic matter, as indicated by the range of C/N ratio between 8 and 12. The fert-:ilizer nitrogen is apparently not enriching the nitrogen reserve of the soil. The former is partly used up by the plants and partly lost by denitrification and leaching.

The other chemical properties, such as the properties of the exchange complex, are inherited from the soil. But their values also vary from one site to another without any regular pattern by the combined influence of texture and organic matter. On average values, the exchangeable calcium, magnesium and potassium, cation exchange capacity and base saturation are at the high level of concentration.

Accordingly, the pH is medium acidic. The exchangeable sodium and electrical conductivity are very low. Exchangeable aluminium is present only in traces. There is, therefore, no toxic threat from sodium or aluminium nor is there a susceptibility to salination upon heavier irrigation.

The morphological properties are less variable in distribution pattern than the physical or chemical properties because the former depend mainly upon drainage conditions and texture. Soil colour is various shades of brown. The hue is either 10YR or 2.5Y. Both value and chroma are medium. Mottles are few except those along the rice root channels. These indicate a 'moderately well' drainage in the surface horizon. Roots, ants and earthworms are plentiful, but there are no termites. At the presence of earthworms, medium texture and moderate content of organic matter, a strong granular to crumb structure has developed. The consistence is hard, firm, slightly sticky and plastic although these soils are only medium in texture. Probably some 2:1 clays are present and responsible for this. A few ironstone nodules are found in these soils. They are probably deposit-:ed by the floods.

4.6.2 FLOOD PLAIN OF R. SILAI (BHIKNAGAR VILLAGE)

The Silai has the narrowest flood plain among the four rivers. It is, therefore, prone to severe flood in years of excessive rainfall. The representative area is Bhiknagar village (latitude 22 degrees, 52 minutes north and longitude 87 degrees, 20 minutes east). It is situated on the inner side of a meander (FIG. 4.26). The village was severely flooded in 1978. Most of the area was covered with deposits of sand, varying in depth from 15 cm to 1 m. The thin deposits have been mixed with the buried soil by ploughing. But the thick deposits have to be dug out and removed. The removal is in progress. About 16% of the area was under sand at the time of field work (winter, 1981). The land use pattern of the village and the soil sample sites are shown in FIG. 4.28. Most of the cultivable area is multiple cropped with river lift and well irrigation. Rice is the main crop of the wet season. Potato and oilseeds are the most important crops of this village which are grown in winter and summer.

The thickness of the sand decreases away from the stream. Thus the sites beside the stream are sand or loamy sand in texture while those farthest from the stream are loam or sandy loam. There are only a few gravels. Most of them are ironstone concretions. Owing to recent sand deposition, the structure is not developed (single grain) and the consistence is non-sticky, non-plastic, very friable and soft throughout the area. Ants and other insects are the dominant soil animals. Earthworms are few. Soil colour is yellowish brown. The hue is between 10YR and 2.5Y. The value and chroma are medium. Only the sites 9 and 10, which are located in a linear shallow depress-:ion (probably an old channel), are light grey in colour with red mottles. The soil colours indicate that apart from a limited area of poor drainage, the surface soils are moderately well drained.

The high amount of sand (72% on average) and very low clay con-:tent (6%) strongly influence other physical as well as chemical pro-:perties. The field capacity is low (22%) because of poor structure, but wilting point is also low (5%) for the lack of clay. As a result, the available water capacity is medium. As the quantity of sand

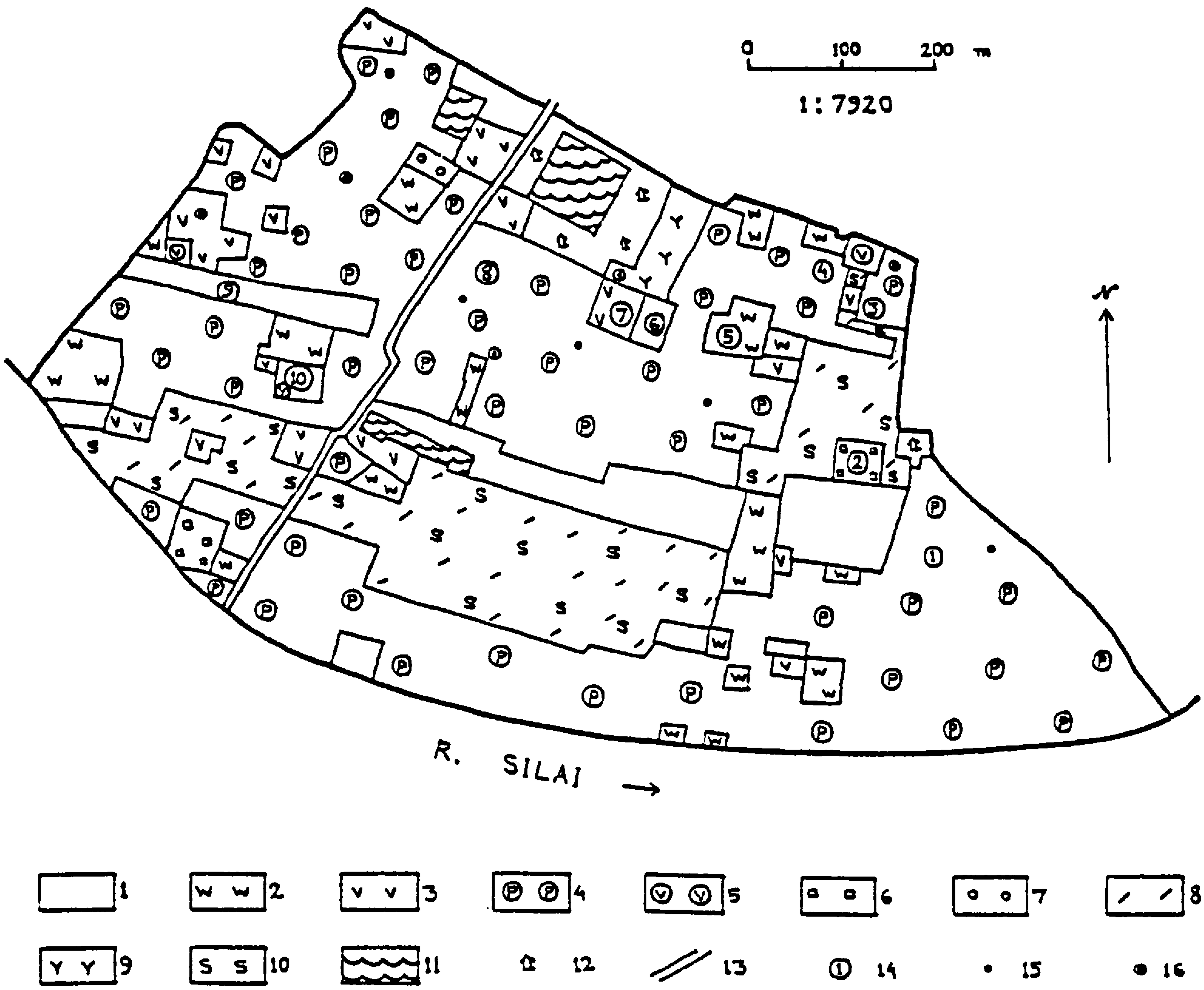

Figure 4.28 Land use pattern of Bhiknagar village, flood plain of R. Silai (source: field mapping, 1981-82).

	Wet season	Winter	Summer
1.	Rice	-	- ;
2.	Rice	wheat	- ;
3.	Rice	oilseeds/vegetables	- ;
4.	Rice	potato	oilseeds/vegetables;
5.	Rice	oilseeds/vegetables	oilseeds/vegetables;
6.	-	Vegetables	vegetables;

7. Orchard; 8. Pasture; 9. Bamboo; 10. Sand; 11. Pond; 12. Settlements; 13. Road; 14. Soil sampling sites; 15. Well; 16. Shallow tubewell.

decreases away from the river, these three properties increase in value in the same direction. The bulk density of these structure-:less sandy soils tends to be high (1.4) as the total porosity is low (48%). Their values also change with distance from the river. A greater proportion of the total porosity consists of air pores because of the coarse texture and single grain morphology of these soils.

The organic matter content of these sandy soils is naturally low. Although organic manures are liberally applied, the more ready oxidation in these sandy soils inhibits the accumulation of organic matter. It tends to increase away from the river as the sand content decreases, but the pattern is made irregular by variable inputs of organic manures. Nitrogen is also low although it is added as a fertilizer. It closely linked with the organic matter as indicated by an average C/N ratio of 8.4. Obviously, the part of the nitrogen fertilizer not utilized by the plants is getting lost by denitrificat-:ion and leaching. Phosphorus and potassium are also applied as fertilizers. A part of the phosphorus is apparently retained by the soil, for the concentration of available phosphorus is at the medium level. But the level of available potassium is low, probably because of the uptake by potato crops and loss by easier leaching through the sands.

The properties of the exchange complex, which are essentially inherited from the sandy soils poor in organic matter, have a very low status. The average values of the total exchangeable bases and cation exchange capacity are only 3.5 and 6.2 me/100 g respectively. The exchange acidity is nearly as high as the exchangeable bases. The base saturation is, therefore, only medium and accordingly, the pH is very strongly acidic. Such pH, however, helps to reduce the activit:ies of actinomycetes affecting the potato crops. The saturation levels of aluminium and sodium and the electrical conductivity are very low. There is, therefore, no toxicity problem nor threat of salination under heavier irrigation.

4.6.3 FLOOD PLAIN OF R. KASAI (PAYARABILA VILLAGE)

The Kasai has the longest flood plain within the Southern Rarh Plain. The flood plain is also considerably wide. The area selected for the study is Payarabila village (latitude 22 degrees, 36 minutes and longitude 87 degrees, 2 minutes). It is situated among the alluvial creeks on the left bank of the river. The land use pattern of the village and the soil sample sites are shown in FIG. 4.29. About 50% of the area is under multiple cropping with irrigat:ion from the river, creeks, ponds and wells. Apart from rice, the important crops of this village are cabbage, potato, oilseeds and vegetables.

The floods of the Kasai are regular and mild. The mineral particles of the soils are essentially deposited by such floods, as evidenced by the high proportion of the silt (59% on average). But there is no regular pattern in the spatial distribution of silt nor sand and clay. This is probably because of the further deposition by the creeks. The silt and clay fractions dominate the soil producing a fine texture. Their range is not very wide (CV 14% and 27% respect:ively). So the soils are rather uniformly silt loam in texture.

This uniformity of texture strongly influences the spatial distribution of the other physical properties. The latter are more

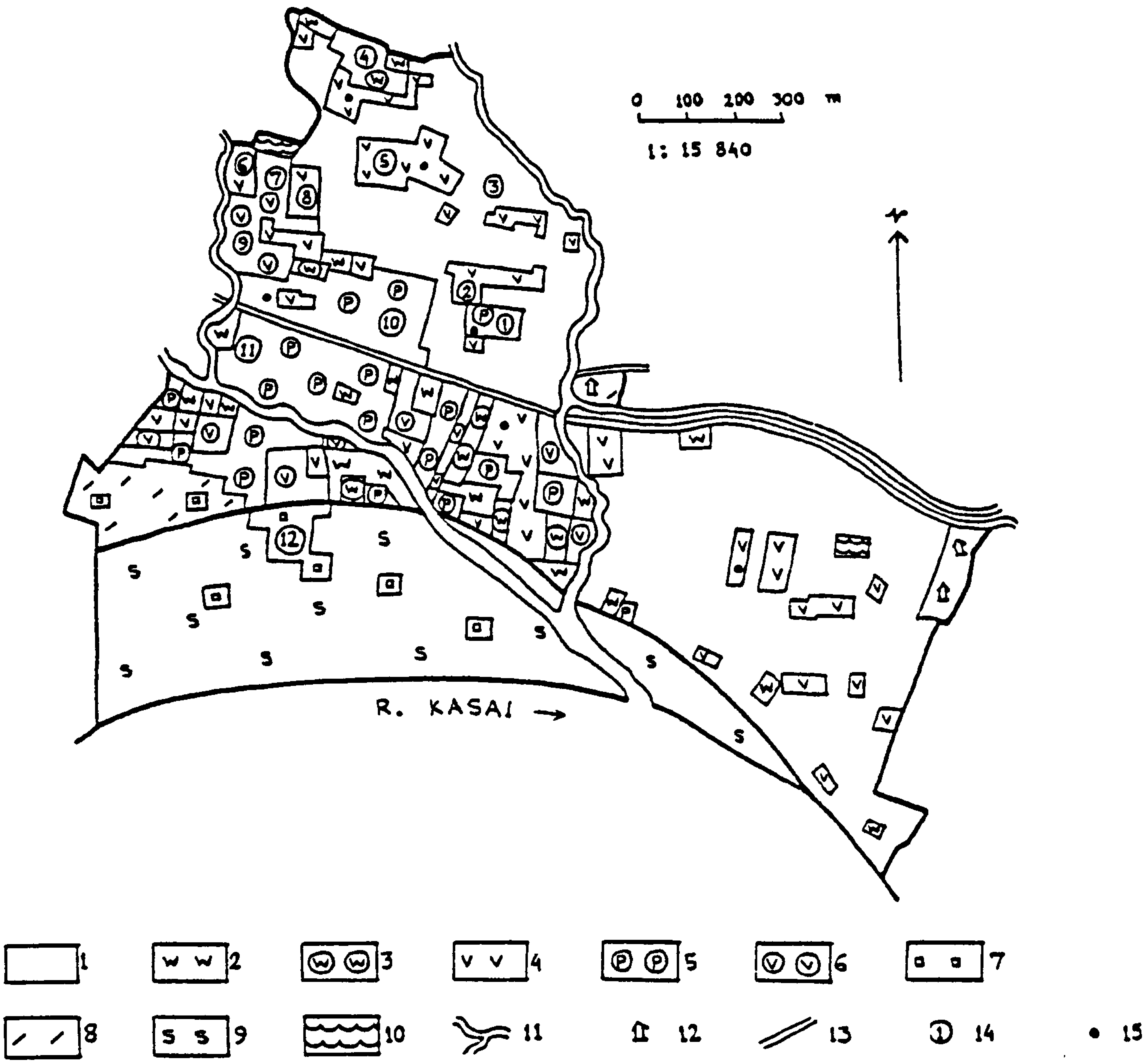

Figure 4.29 Land use pattern of Payarabila village, flood plain of R. Kasai (source: field mapping, 1981-82).

	Wet season	Winter	Summer
1.	Rice	-	- ;
2.	Rice	wheat	- ;
3.	Rice	wheat	oilseeds/vegetables;
4.	Rice	oilseeds/vegetables	- ;
5.	Rice	potato	oilseeds/vegetables;
6.	Rice	oilseeds/vegetables	oilseeds/vegetables;
7.	-	Vegetables	vegetables;

8. Pasture; 9. Sand; 10. Pond; 11. Stream; 12. Settlements; 13. Road; 14. Soil sampling sites; 15. Well

or less uniformly distributed over the village, as indicated by a low CV among the samples. In average values, both field capacity and wilting point are medium, resulting in medium available water capacity (22%). The bulk density is low owing to a strong crumb structure. For the same reason, the total and water porosities are well developed (58% and 38% respectively).

Among the morphological properties, the soil colour varies little between the samples. It is various shades of brown. The hue is either 10YR or 2.5Y. Both value and chroma are medium. Mottles are few, except the red lines along rice root channels. The colour and scarcity of mottles indicate a moderately well drainage condition in the surface horizon. The consistence is rather variable from sample to sample. It increases in hardness, firmness, plasti:city and stickiness with increase in the amount of clay. Roots, ants and earthworms are abundant in these soils. A few ironstone nodules are also found.

On the average, the organic matter, nitrogen, available phos:phorus and potassium are at the medium level of concentration in these soils. It is not only because these nutrients are applied as manures and fertilizers but the texturally medium fine soil can retain them also. There is obviously no regular distribution pattern of these properties, for the quantity of their input depends upon the capital of individual peasant and the type of crop. For example, the site 2 is exceptionally high in available phosphorus (265 kg/ha) and potassium (798 kg/ha) whilst the site 1 contains only 4 kg/ha of phosphorus and 213 kg/ha of potassium.

The cation exchange capacity, on the average, is at the high level although the average clay content is only 23%. It is likely that there are some 2:1 clays in these soils. The exchangeable bases are the predominant components of the exchange capacity, resulting in an average base saturation of 71%. Accordingly, the soil reaction is medium acidic. The concentration of soluble salts is highest here (electrical conductivity 0.1 mmhos/cm) among the flood plains. But it is still well below the level of any salination problem. The satur-:ation levels of aluminium and sodium also contain no toxic threat to plants.

4.6.4 FLOOD PLAIN OF R. SUBARNAREKHA (KUTISAI VILLAGE)

The Subarnarekha has the largest upper catchment area and has developed the widest flood plain in this region. The area of study is Kutisai village (latitude 22 degrees, 9 minutes north and longitude 87 degrees, 5 minutes east). It is situated on the left bank of the river, near the confluence of R. Dulung (FIG. 4.26). The land use pattern of the village and the soil sample sites are shown in FIG. 4.30. About 65% of the cultivable area is under multiple cropping with river lift irrigation. The water is supplied through pipelines from a pump-house located on the bank of the Subarnarekha. Wells provide a small proportion of the irrigation. The major crops of this village, apart from rice, are sugarcane and wheat.

Although severe floods do not occur in this flood plain, the major component of the river deposition is sand. On average, sand occupies 54% of the soil texture. Silt is only of secondary import-:ance in the textural composition. This is because the load of the Subarnarekha is mainly sandy during its course through this region. The sand is acquired from an area of 'Tertiary gravel and sand' form-

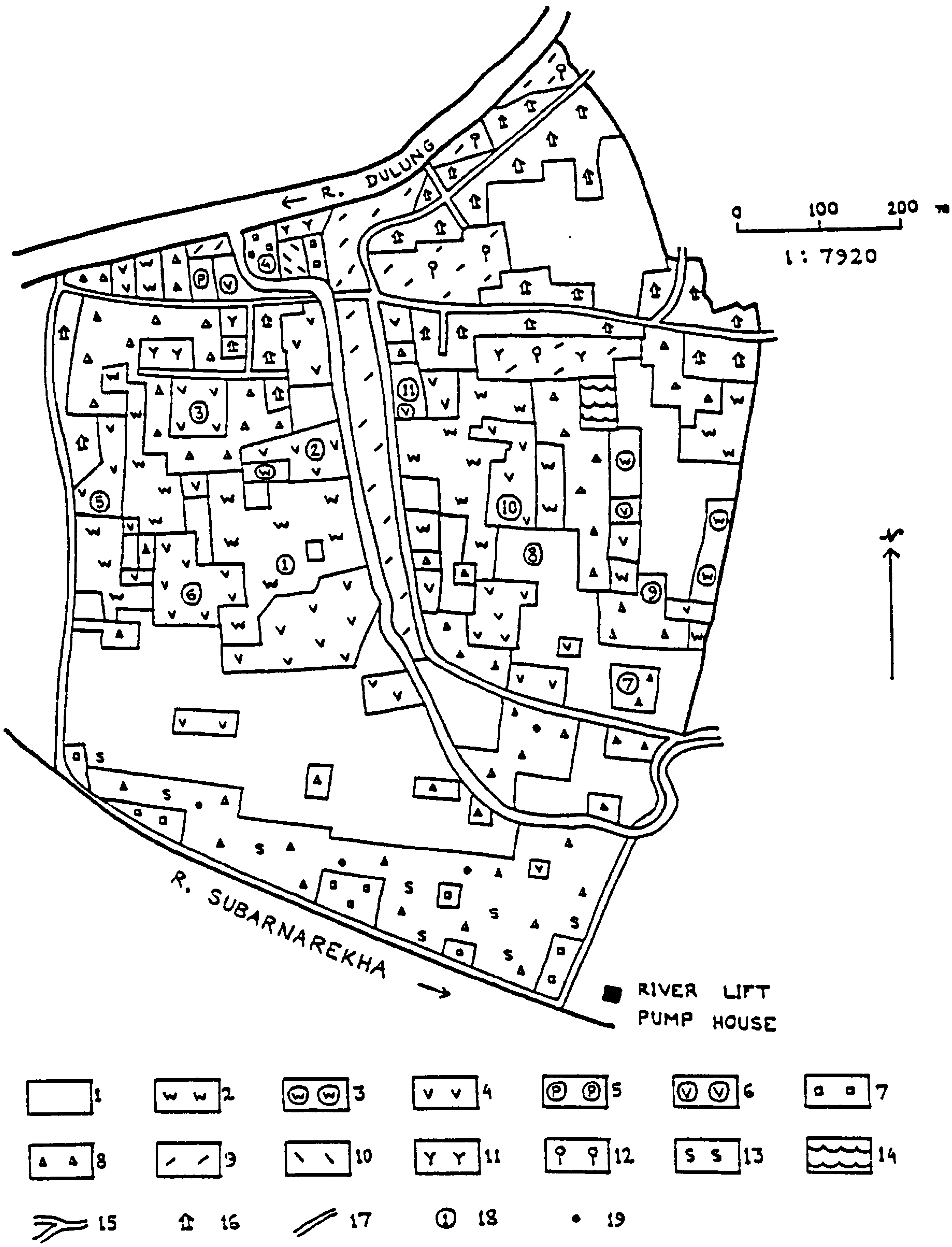

Figure 4.30 Land use pattern of Kutisai village, flood plain of R. Subarnarekha (source: field mapping, 1981-82).

	Wet season	Winter	Summer
1.	Rice	-	- ;
2.	Rice	wheat	- ;
3.	Rice	wheat	oilseeds/vegetables;
4.	Rice	oilseeds/vegetables	- ;
5.	Rice	potato	oilseeds/vegetables;
6.	Rice	oilseeds/vegetables	oilseeds/vegetables;
7.	Vegetables	vegetables	- ;

8. Sugarcane; 9. Pasture; 10. Planted grass; 11. Bamboo; 12. Trees; 13. Sand; 14. Pond; 15. Stream; 16. Settlements; 17. Road; 18. Soil sampling sites; 19. Well.

:ation across which the river flows for 35 km before entering the Southern Rarh Plain (FIG. 2.5). The proportion of sand in the soil is higher nearer the streams where the texture is loamy sand or sandy loam. The rest of the area is uniformly loamy in soil texture.

The other soil properties have been influenced, to a greater or lesser extent, by the predominance of sand in the texture. The soils have developed only a weak crumb structure. The consistence is generally friable and slightly sticky and becomes very friable and non-sticky nearer the streams. The bulk density is 1.3 and increases nearer the streams with greater content of sand. The total porosity is moderately developed (52% on average). The air porosity is dominating nearer the streams, but away from them water porosity occupies the greater part of the total porosity. The spatial distribution pattern of field capacity is obviously identical with that of water porosity. On the average, the field capacity is 32% owing to the crumb structure, but the wilting point is low on account of the poor clay content. As a result, the available water capacity has developed to medium level (24% on average).

The concentration levels of organic matter, nitrogen, available phosphorus and potassium are also modified by the soil texture. Although manures and fertilizers are liberally applied to this area, the organic matter and phosphorus are at the low level of concentration. The nitrogen and potassium are just at the medium level. It is likely that these soils with moderately coarse texture fail to retain the applied manures and fertilizers to any great extent. The part of the applied nutrients not used by the current crops are probably lost by leaching, oxidation and other processes.

The average level of cation exchange capacity is just medium in spite of poor contents of clay and organic matter. There are probably some 2:1 clays in these soils. But the base saturation is only 60% so that the soil reaction is very strongly acidic. There is, however, no aluminium toxicity nor is there any salinity problem.

4.6.5 SUMMARY OF THE FOUR FLOOD PLAINS

The soils of the flood plains are obviously characterized by the nature of the stream deposition. The Darakeswar and Kasai flood plains are regularly but mildly flooded where silt is the major deposit. These two flood plains have 'medium fine' soil texture. But the Silai is notorious for severe floods when considerable thick:nesses of sand are deposited. The soils of this flood plain are coarse in texture. The Subarnarekha flood plain is also dominated by sand deposits, though in a lesser degree. This river is not prone to severe floods like the Silai. Its normal deposition is sandy because it passes through 'Tertiary gravels and sand' formations before entering the region. The soil texture in the Subarnarekha plain is 'moderately coarse to medium'. The clay content is low in all the flood plains, particularly in the Silai and Subarnarekha. The form:ation of clay is probably punctuated by successive depositions. There are only a few gravels. Most of them are ironstone concretions. They are probably deposited by the streams.

A spatial distribution pattern of soil texture is apparent in the Darakeswar, Silai and Subarnarekha flood plains. The texture becomes finer away from the streams. This is because the sands are mainly deposited nearer the streams while the deposition of clay is greater away from them. The silt is rather uniformly deposited. This pattern is not found in the Kasai flood plain where the alluvial creeks obscure it by superimposing their deposits.

The composition and spatial distribution of texture greatly control the quantity and distribution pattern of other soil properties, particularly the physical properties and the exchange complex. The moderately fine textured soils of the Darakeswar and Kasai flood plains have developed a strong crumb structure. They are hard, firm, sticky and plastic in consistence. In both the plains, the water porosity and field capacity are well developed on account of a crumb structure. But the wilting point is also high because of the presence of fine particles. As a result, the available water capacity is moderate (21% on average). The bulk density is naturally low in these structurally developed soils. The total porosity, on the other hand, is 57% on the average. It is dominated by water porosity. The cation exchange capacity is at the high level although the average clay content is only 24%. There are probably some 2:1 clays. The exchangeable bases are the predominant component of exchange capacity. Consequently, the base saturation is at the high level and the soil reaction is medium acidic.

In comparison to the soils of the above areas, the relatively coarser soils of the Silai and Subarnarekha flood plains have poorly developed physical properties and lower status of the exchangeable bases. The soils of the Silai plain are structureless (single grain). They are soft, very friable, non-sticky and non-plastic in consistence. Owing to the undeveloped structure and coarse texture, these soils are low in both field capacity and wilting point. Consequently, the available water capacity is only 17% on average. For the same reasons, the bulk density is high and the total porosity is only 48%, predominated by air pores. The soils of the Subarnarekha plain contain lesser proportion of sand than the soils of the Silai plain. The former have developed a weak crumb structure by virtue of the relatively finer texture. Consequently, the water porosity and field capacity are better developed in the Subarnarekha plain than in the Silai area. But the wilting point is low on account of poor content of clay. As a result, the available water capacity is as high as 24%. The cation exchange capacity of the coarse soils of the Silai plain is expectedly low. The soils of the Subarnarekha plain have a cation exchange capacity at the medium level because of a slightly greater clay content and probably also 2:1 clays. However, the base saturation and hence the soil reaction are comparable between these two flood plains. Their base saturation is at the medium level and the soil reaction is very strongly acidic.

The spatial distribution pattern of the physical properties and exchange complex is closely related to that of soil texture. As texture becomes finer away from the streams in the Silai and Subarnarekha flood plains, the structure improves and the values of water porosity, field capacity and exchangeable bases increase in the same direction. On the other hand, there is no such pattern in the Kasai flood plain on account of a uniform texture. The Darakeswar flood plain has a tex-:tural pattern like the Silai and Subarnarekha plains, but the physical properties and exchange complex do not behave correspondingly. This is probably due to the influence of organic matter which is at a higher level in the Darakeswar plain and irregularly distributed.

In contrast to the properties described above, the concentrat-:ions of organic matter, nitrogen, available phosphorus and potassium are greatly influenced by application of manures and fertilizers in all flood plains. The quantities of these properties vary consider-:ably from one sample to another within each flood plain according to the input of manures and fertilizers. For example, the CV of avail-:able phosphorus is 199% in the Kasai flood plain. The amount of manures and fertilizers applied to a plot of land depends on the peasant's capital and the number of cropping in a year. The triple-cropped plots receive greater amount of manures and fertilizers than the single-cropped plots. But no relationship is found between the number of cropping and level of organic matter, phosphorus or the others. This is because the land use pattern shown in FIGS. 4.27 - 4.30 is not permanent. The single-cropped plot of one year may be multiple-cropped next year and vice versa. The average quantities of organic matter, nitrogen, phosphorus and potassium are, however, influenced by soil texture at each flood plain. Although the intensity of manuring and fertilization is comparable between the four flood plains, the retention of the nutrients increases with the greater fineness of the soil texture. The soils of the Darakeswar and Kasai flood plains have these nutrients at the medium level of concentration whilst the soils of the Silai and Subarnarekha plains are low in organic matter and nitrogen and just at the medium level in potassium content. The phosphorus content is also at the medium level in the Silai plain but its level is low in the Subarnarekha flood plain. The relatively better status of phosphorus and potassium than the organic matter and nitrogen in the Silai and Subarnarekha plains is due to their applica-:tion in greater quantities.

The saturation levels of aluminium and sodium are well below toxic levels in all flood plains. The electrical conductivity is also low. Therefore, these soils can sustain heavier irrigation without imminent salinity problems.

All flood plain areas are intensively cultivated. About 50 - 80% of the areas are multiple-cropped with the help of irrigation from streams and wells. The soils of the Darakeswar and Kasai plains support a wide range of crops by virtue of their favourable texture, structure, available water capacity, nutrient status, reaction and cation exchange capacity. The important produces of these two areas are rice, wheat, potato, sugarcane, oilseeds, cabbage and other veget-:ables. The loose and very strongly acidic soils of the Silai plain are ideal for potato. But few other crops do well here. The Subarnarekha plain is favourable to potato for the same reasons, but sugarcane is more important since irrigation is available round the year. Owing to relatively better soil conditions, rice, wheat, oilseeds and vegetables are more successfully grown in the Subarnarekha plain than in the Silai plain. In all flood plains more land may be brought under multiple cultivation if irrigation is available in greater quantities.

4.7 NOTES ON VERY SEVERE GULLY EROSION: A CASE STUDY

It has been mentioned in SECTION 2.1 that gully erosion is significant only in limited areas in the 'cliffs' bordering the flood plains of the fourth order streams and in some of the headstream areas (FIG. 2.4). The 'cliffs' are not steep everywhere. The angle of slope varies from 1 to 70 degrees. But they are readily recognizable in the field by a break of slope, red colour of well drained soils and often a forest vegetation. A study has been made in a very severely eroded cliff of R. Kasai to investigate the nature and causes of erosion.

The cliffs resemble the shoulder facets of land systems A - E in their position in the landform. But soil erosion is only slight to moderate in the shoulder facets of the systems A - E. Gullies are few. Much of the erosion is in the form of sheet wash. This investigation is based on a comparison of the soils and land charact-:eristics between the cliff and shoulder facets. For this purpose, the nature of the slope, land use pattern and one soil profile have been studies in the eroded cliff in the same manner as in the case of the shoulder facets (Appendix A). These are described below, followed by a comparison and conclusions.

The area of study is situated near Midnapore on the left bank of R. Kasai (latitude 22 degrees, 26 minutes north and longitude 87 degrees, 13 minutes east). Its location is shown in FIG. 2.4 in SECTION 2.1. The area consists of parts of three villages.

The rise of the cliff is very gentle. The average slope is only 1 degree and the length of slope is 1100 m. The amplitude between the flood plain and the top of the cliff is 19 m. The whole length of the slope is severely gully eroded. The area of study consists of the lower 500 m of the slope where the gullies are most vigorous (FIG. 4.31). There is a small non-perennial stream which originates 2 km to the north and flows across the area to join the Kasai. There are three major gullies and innumerable small gullies and rills within the area. The gullies eventually open out into the flood plain. The major gullies are about 3 m deep and 30 - 60 m wide

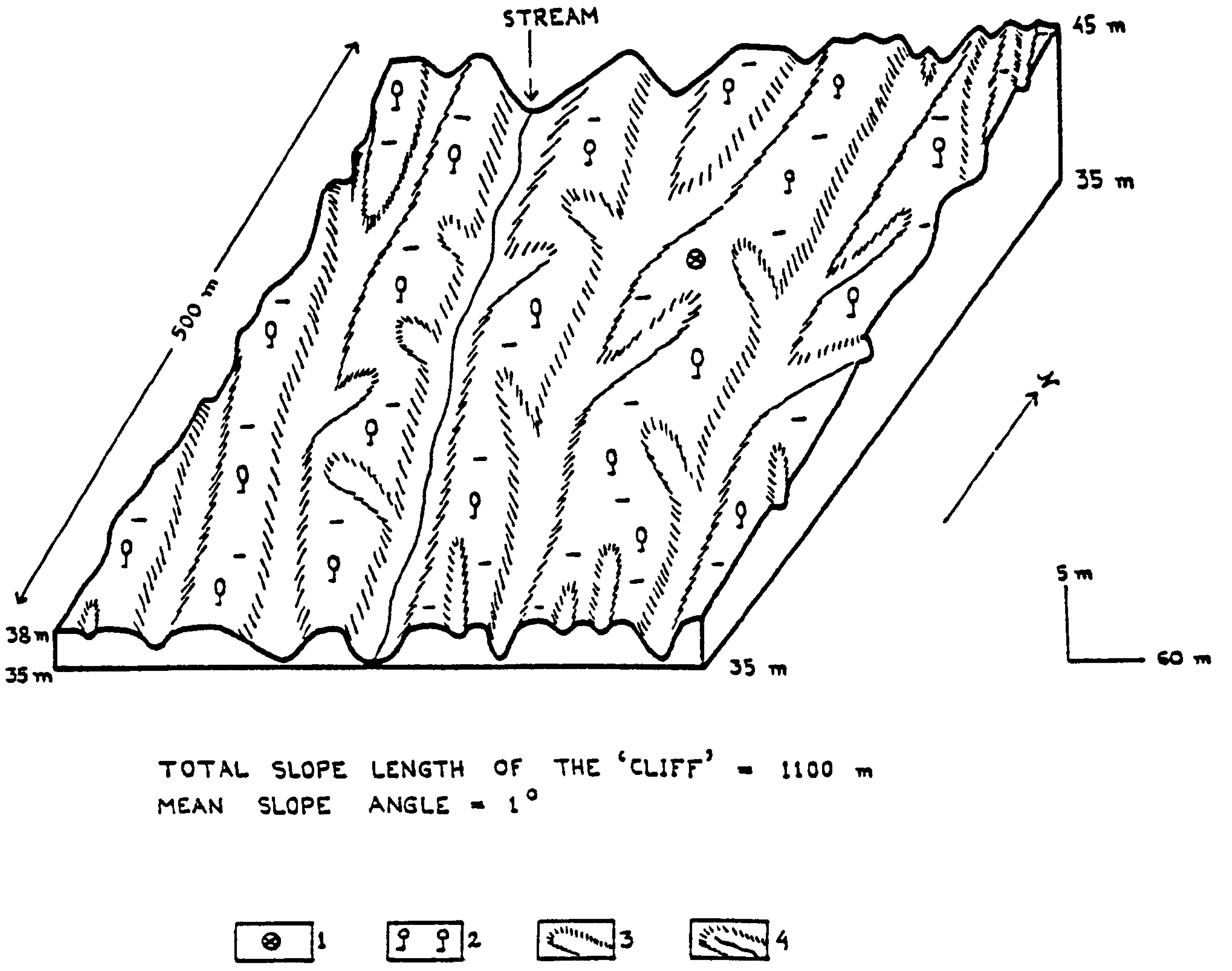

Figure 4.31 Block diagram of the gully-eroded area (drawn according to survey data presented in Appendix E).

1. Site of the soil profile; 2. Coppice wood; 3. Gullies; 4. Stream.

at the top. They are V-shaped. Most of the area is covered by an open coppice of Shorea robusta and its associates (type C; TABLE 2.10). Grass is scarce. The vegetation is heavily browsed by cattle and continuously cut by man for fuel-wood and leaves.

The soil profile is limited to medium depth by weakly cemented pisolitic ironstone (Appendix A). There are, however, few ironstone concretions on the surface. The soil is well drained. It is reddish yellow in colour in all horizons, without any mottles. Texturally it is sandy loam throughout the profile depth. There is no argillation. As a result of the uniform texture, there is little variation in other physical properties between the horizons. The total porosity is 48% on the average while bulk density is 1.4. The air porosity is slightly greater than the water porosity on account of the moderately coarse texture. Accordingly field capacity is low. The wilting point is also low because of a poor clay content. As a result, the available water capacity is 14% only. The soil is structurally massive. The consistence is slightly hard, friable and slightly sticky.

The organic matter content, nutrient status and exchange capacity are at a low value, but they tend to increase with depth. The base saturation increases to 80% in the deepest horizon. Correspondingly, the reaction changes from extremely acidic in the surface to slightly acidic at depth. There is no calcium carbonate. Free iron is present in low quantity only.

The soil profile is classified as Udic Ustochrept in the absence of an argillic horizon and calcium carbonate and by the presence of an ustic moisture regime and an ochric epipedon.

The shoulder facets of the land systems A - E are comparable to this eroded cliff area in their soil conditions (Appendix A). The morphological, physical and chemical properties of the soils are similar, with the only exception that the cliff area lacks an argillic horizon. However, the clay content of the surface horizons are comparable. The soils of the shoulder facets of the systems B, C and E are deeper than the soils of the cliff area, but the shoulder facets of systems A and D have shallower soils. For the purpose of soil erosion investigation, it is necessary to determine 'infiltration capacity' and 'aggregate stability' of soils. These experiments could not be conducted for unavailability of necessary equipment in the field and the difficulty of transporting bulk samples to the labor-:atory. Nevertheless an approximate idea of the infiltration capacity can be made from porosity while organic matter content plus texture may be taken as indicator of aggregate stability. The porosity, organic matter content and texture of the surface soils are, however, comparable between the cliff area and the shoulder facets.

Among other characteristics of the land, the state of the natural vegetation is no worse in the cliff area. In fact, the shoulder facets of systems B, D and E have neither a forest nor a close grass cover. The angle of slope in the cliff area is comparable to that of the gentlest shoulder facet. But the length of slope is very great in the cliff area (1100 m) compared to the longest shoulder facets (400 m).

Other characters being comparable, the greater slope length seems to be the main cause of very severe gully erosion in the cliff area. This hypothesis is supported by the fact that gully erosion is negligible in the cliff areas where slope length is as small as in the shoulder facets. In addition to the cliffs of great slope length, the steep cliffs are also very severely eroded by gullies. In the latter case the greater angle of slope is the main cause of gully erosion. Such steep cliffs are, however, limited in occurrence.

It has been mentioned earlier in this section that some of the headstream areas are also severely eroded by gullies. The land system C is an example of the headstream areas. The footslope facet of this system is moderately to severely eroded by gullies. Except the slope length, the other land characteristics of this area are comparable to those of the remaining land systems. The length of the footslope area is about 800 m (FIG. 4.11). Similar to the cliff areas, a greater length of slope is probably the main cause of gully erosion in the headstream areas.

Although severe gully erosion is limited in area, its threat to the land directly affected and to the lower slopes and flood plains as an agent of coarse deposition cannot be overemphasized. Since a steep angle or great length of slope is the main cause of gully erosion, the most effective control measure would be to break the slope into many terraces. However, the construction of terraces is laborious and expensive. It becomes economic in conjunction with agricultural use of a land, but the soil conditions of these eroded areas are not well suited to agriculture. The direct control of the gullies by constructing dams across each of them is also laborious and expensive. Since these areas are under forest, the most economic method of erosion control would be (a) to improve the tree canopy by reafforestation with the native plants, (b) to create a close cover upon the soil surface, particularly in the gullies by planting mat-forming grasses and legumes like <u>Cynodon dactylon</u>, <u>Pennisetum pedicellatum</u>, <u>Pueraria phaseoloides</u>

and Lablab niger var. lignosus and (c) to protect the plants and soils from human and animal interference. When the erosion is controlled, this form of land use would produce timber, fuelwood and fodder under regulated conditions.

4.8 COMPARATIVE DISCUSSION OF THE SIX LAND SYSTEMS

The land systems A - E consist of five facets where both surface soils and soil profiles have been studied. Land system F has only two facets: the flat flood plain and the 'cliff'. Only surface soil samples have been studied from the flood plain (see SECTION 3.3 for explanation). In the following discussion land systems A - E are compared first and then land system F is compared with the surface soils of the corresponding facets of systems A - E i.e. the toeslopes and the bases.

From the previous discussions of the soils of the systems A - E, certain features appear as common to all of them. They are described first, followed by the characteristics which distinguish one system from another.

The most important feature of the soils of land systems A - E is argillation. Excepting the facets affected by a shallow water-table for the greater part of the year, all facets have significant illuviat-:ion of clay to form argillic horizons. Apparently the wet-dry climate, rainfall of high intensity, medium to high air-porosity in the upper horizons and low concentration of salts favour dispersion and downward transport of the clays. The intensity of argillation probably depends on the availability of water for eluviation, for the weighted profile means of clay increase towards the lower facets where the incoming lateral flow reinforces the rainfall. At the same time, the shallow water-table in the lower facets arrests downward migration of clays so that the lowest facet (base area) often shows less argillation than the other facets. Thus the degree of argill-:ation depends upon a balance between the amount of water available at the surface and the depth and duration of the water-table.

In contrast to its illuviation, the downslope increase of clay on the surface horizons is very slight. The silt fraction is the main particle which increases significantly towards the lower facets. It is possible that the clay is also migrating but is eventually getting lost into the stream. This view is supported by the fact that the downslope increase of clay is minimum in system A (third order stream basin) and maximum in the E (streamless basin).

Secondly, the soils of the systems A - E are characterized by an immature weathering status (cf. CHAPTER 1). This is indicated by medium to high level of base saturation, greater than 16 me C.E.C./100 g of clay, medium to high silt content and low concentration of free iron oxides. There are no Oxisols nor even Ultisols in this region. Most of the soils are Alfisols. There are a few Inceptisols where argillation is impeded by shallow water-table. Plinthite and iron-:stone are present, but they do not necessarily indicate extreme weathering nor infertility of the soils. They occupy specific position in the topography. The ironstones are best developed in the freely drained summit and shoulder areas. The plinthites are formed in the footslope areas where fluctuation of water-table is most pronounced within profile depth. Apparently, the segregation and induration of iron compounds are influenced by drainage conditions or oxidation-reduction regime rather than by the length and intensity of weathering. There is evidence of transformation of plinthite into ironstone with greater oxidation.

Thirdly, the soil moisture regime has developed a pattern across the slope under the influence of topography. The summit, shoulder and footslope facets have 'ustic' moisture regimes, whilst the toeslope and base areas have 'aquic' moisture regimes. The ustic moisture regime is extended to the toeslope facet in systems D and E because of their nature of topography (see SECTIONS 4.4 and 4.5).

Fourthly, most of the surface soil properties change in a fairly predictable fashion across the slope of the land systems A - E. This is the result of transport and deposition of silt, clay, organic matter, exchangeable cations and soluble salts by lateral flow of water. The texture becomes finer and the levels of organic matter, nitrogen, exchangeable bases, exchange acidity, cation exchange capacity, electrical conductivity and calcium carbonate increase down the slope. Consequently the structure improves and water porosity, field capacity, wilting point and available water capacity increase towards the lower facets whilst the consistence becomes less friable and air porosity and bulk density decrease in the same direction. Most of these properties have developed a statistical relationship with distance downslope at significant levels. The colour of the surface soils and the activit:ies of soil animals also change down the slope. The colour passes from red into grey whilst termites are replaced by earthworms in the lower facets. These effects are due to soil drainage conditions. The downslope increase of organic matter content may also be partly influenced by soil drainage. There are a few soil properties, the distributions of which are irregular over the slope in all land systems. Available phosphorus and potassium are notable among them. Apparently, their concentrations are influenced more by the chemical environment at each facet than by lateral transport.

Lastly, the nutrient status of the soils of land systems A - E is 'low' to 'medium' (see TABLE 3.3 for classification of concentration levels of nutrients). The summit area is usually low in the concent-:rations of organic matter, nitrogen, exchangeable bases and cation exchange capacity. The properties improve down the slope and tend to reach medium levels in the toeslope and base areas. The levels of available phosphorus and potassium also range between low and medium, but their distribution over the facets is irregular. The pH of the surface soils is extremely - to strongly acidic except in system E where it is slightly acidic in the lower facets. There are no problems of salinity, alkalinity nor aluminium toxicity in these land systems.

In addition to these features held in common, each of the land systems A - E has developed distinct individuality in soil properties according to its nature of topography and valley drainage. It is apparent from SECTION 3.1 and TABLE 3.1 that these land systems have little difference between them in terms of the topographic and drainage characteristics of the summit, shoulder and footslope facets. Accord-:ingly, the nature of the soils for each of these facets is comparable between systems A - E. There are a few irregularities such as the occurrence of a clay bed in the summit area of system D, the massive ironstones in the shoulder of system D and in the summit and shoulder of system A, the absence of plinthite from the footslope of system B and the transformation of plinthite into ironstone in the footslope areas of systems C and E. But these features are not necessarily related to the soil forming processes of that particular land system.

In other words, such features can occur in any of the systems and are, therefore, not unique to where they are found.

In general terms, the soils of the summit areas of land systems A - E are well drained, deep, strong brown to red in colour and free from mottles. Texturally they are 'moderately coarse' at the surface, turning to a 'medium' texture with depth on account of argillation. The organic matter content is low and the structure is massive. Consequently, these soils are only medium in total porosity. As the air pores are dominating, the available water capacity is low. These soils are poor in nitrogen and available phosphorus. The content of available potassium is relatively higher, but still at a low level. The exchangeable bases and cation exchange capacity are also low in concentration. The base saturation is just medium so that the reaction is extremely - to very strongly acidic. There is, however, no aluminium toxicity. Since these soils are characterized by argillation, medium base saturation and ustic soil moisture regime, they are classified as Paleustalf.

The soils of the shoulder facets of land systems A - E are well - to somewhat excessively drained, deep except where massive ironstone occurs close to the surface, red in colour and devoid of mottles. These soils are comparable with the soils of the summit areas in physical and chemical properties. Only those properties which change downslope on account of lateral transport are slightly different over the shoulder facets. Thus, the texture of the surface horizon is finer and the content of exchangeable bases is greater than in the summit area. The soils of the shoulder facet are classified as Paleustalf like those of the summit area.

The footslope areas, by their situation, are under the influence of fluctuating water-tables in their lower horizons. The soil drain:age is, therefore, imperfect, resulting in a yellowish colour of the surface soils and red mottles over a grey matrix at depth. The mottles are capable of irreversible hardening upon exposure for a period of time. They often occupy the greater part of the horizons and hence are identified as 'plinthite, forming a continuous phase'. In the footslope areas of systems C and E, the plinthites have already turned into 'cemented pisolitic ironstone'. Texturally, the soils of the footslope areas are classed as 'medium'. They become 'moderately fine' to 'fine' in texture with depth as a result of argillation. The organic matter content is at the low level, but the structure is granular probably on account of the texture and presence of earthworms. The porosity and available water capacity are accordingly increased. The nutrient status and cation exchange capacity are also better than in the summit or shoulder, but still at low levels. These soils are classified as Plinthustalf or Haplustalf according to the presence or absence of plinthite in a continuous phase.

The toeslope and base facets, in contrast to the three upper facets, are distinguished by their topographic and valley drainage characteristics for each land system. It is in these two facets that the soils also achieve distinct characteristics in each land system. The land system A is drained by a third order stream which has helped to form the widest toeslope and base areas and deposited coarser particles to form a natural levee upon the base facet. Most signifi:cantly, the third order stream removes a considerable proportion of the materials brought downslope by lateral flow out of the valley. The land systems B and C are drained by second and first order streams respectively. The toeslope and base areas become narrower and the alluvial deposits of the streams decrease in quantity towards the system C. The second and first order streams remove increasingly lesser proportion of materials from the lower facets. Finally, in system E, such removal is minimum in the absence of a stream. Instead, there is a significant amount of accumulation of the materials brought down by lateral flow in the toeslope and base facets. The system D, although lacking a permanent channel, has a gentle but significant longitudinal slope along the base facet towards its open end which eventually joins a stream. A sheet flow along this longitudinal slope removes some amount of materials from the lower facets.

It is apparent from the above discussion that there is a hier-:archical relationship of the intensity of removal and accumulation between the land systems according to their hydrological character-:istics. The system A loses most from the toeslope and base and, therefore, accumulation is minimum there. The removal decreases and accumulation increases through the systems B and C to the system E where accumulation is maximum. The system D does not fit well into this pattern for the reasons indicated earlier, which were not recognized at the reconnaissance survey stage (SECTION 3.1). Never-:theless, system D illustrates that all streamless basins of this region are not the areas of maximum accumulation.

Obviously, only those materials, which can be removed relatively easily by stream flow and are not strongly controlled by other factors, show this hierarchic pattern. Thus, no such pattern is apparent with sand and silt because their quantities at base facets are modified by alluvial deposition. The organic matter, nitrogen, available phosphorus and potassium also fail to develop the pattern because they are influenced by other chemical factors and agricultural inputs. It is the properties of the exchange complex - the exchangeable bases, cation exchange capacity, base saturation, pH and also clay which show the hierarchic pattern in the toeslopes and bases between land systems A to E. These properties are listed in TABLE 4.2. There is a clear increase of the properties of the surface soils from system A to system E. The system D is irregular, as already explained. The increase from system A to C is often gradual, but there is a sharp increase between systems C and E. Apparently, the decreasing stream order from A to C does not result in a substantially lesser efficiency for removal. The weighted profile means of soil properties, however, do not show any regular hierarchic pattern (TABLE 4.2), although the values for system E are greater than those for A. The various factors such as soil drainage conditions, nature of eluviation and illuviation and other variables modifying the profile behaviour of these properties prevent them from developing the hierarchic relation-:ship.

The hierarchic relationship between the land systems is reflected to a limited extent in the soil classification. As valley drainage becomes more restricted from system A towards E, the water-table becomes shallower and persists for a longer period. Consequently, argillation is increasingly impeded towards system E. Thus, the systems A and B have Alfisols in the toeslope and base facets whilst the systems C and E have Inceptisols. Only the toeslope area of system E has an Alfisol because of its relatively higher situation (see SECTION 4.5) which ensures a deeper water-table and argillation. The system D obviously

TABLE 4.2 HIERARCHICAL DISTRIBUTION OF SOIL PROPERTIES BETWEEN LAND SYSTEMS A - E

SURFACE SOIL PROPERTIES

LAND SYSTEM	TOESLOPE					BASE				
	T.E.B.	C.E.C.	B.S.	pH	CLAY	T.E.B.	C.E.C.	B.S.	pH	CLAY
A	2	7	32	4.0	14	5	12	42	4.2	17
B	5	10	49	4.3	20	7	14	55	4.2	21
C	10	18	56	4.4	27	7	16	45	4.2	28
D	4	8	59	4.9	11	6	11	59	4.6	17
E	15	19	80	5.5	26	21	25	83	6.2	33

WEIGHTED MEANS FOR 120 cm PROFILES

LAND SYSTEM	TOESLOPE					BASE				
	T.E.B.	C.E.C.	B.S.	pH	CLAY	T.E.B.	C.E.C.	B.S.	pH	CLAY
A	16	21	75	5.5	41	11	16	65	4.9	25
B	6	8	70	5.2	17	15	19	77	6.0	29
C	17	21	81	5.8	33	8	10	78	6.2	16
D	14	17	82	6.2	29	8	11	75	5.1	16
E	32	35	92	6.8	40	21	25	84	6.6	39

Note:
T.E.B. = Total Exchangeable Bases (me/100g soil)
C.E.C. = Cation Exchange Capacity (me/100g soil)
B.S. = Base Saturation (%)
pH = pH in 0.01M $CaCl_2$ at 1:2.5 ratio
CLAY = clay (%)

SOURCE: Appendices A and C

does not fit into the pattern. It has Alfisols in its lower facets on account of the efficient valley drainage by the sheet flow.

To sum up this part of the discussion it may be said that the land systems A - E can be distinguished most clearly from each other by the hierarchical relationship of the exchange properties and clay content of the surface soils in the toeslope and base facets. The system A is characterized by low level of total exchangeable bases (see TABLE 3.3 for classification of concentration levels of soil properties), low to medium cation exchange capacity, low base satur-:ation, extremely acidic reaction and poorest clay content in the toeslope and base facets. The system B is distinguished by medium cation exchange capacity and medium base saturation. The other properties, although improved, are comparable to those of system A. In system C, the properties are further improved: the total exchange-:able bases are at medium level; the cation exchange capacity is moderately high; the clay content has also increased to a higher level. All these properties are at their maximum at the system E. The total exchangeable bases, cation exchange capacity and base saturation have reached high levels and the pH is only medium to slightly acidic. The system D may be placed in this hierarchy between systems A and B for the exchangeable bases and cation exchange capacity or between systems C and E for base saturation and pH.

So far the land system F has been left out of the discussion because it can only be compared with the toeslope and base facets of the systems A - E. There is, however, a significant difference between processes operating in these two types of areas. The land system F is characterized by flood deposits in contrast to the toeslopes and bases of the toposequences, where most of the material is received from the upper facets by lateral flow. Even between the flood plains, the Silai and Subarnarekha consist of coarse to medium deposits, but the Darakeswar and Kasai have a deposit of medium to moderately fine texture. These latter two flood plains are texturally comparable to the base facet of system A which receives levee deposition. The other toposequential systems have clay-dominated texture. The soils of the Darakeswar and Kasai plains are structurally comparable to all the toposequential systems for they have developed a granular to crumb structure at the presence of adequate organic matter and earthworms. But the soils of the Silai plain are structureless and the soils of the Subarnarekha have only a weak structure. Consequently, the Darakeswar and Kasai plains have porosities and water capacities comparable to those of systems A - E. But these properties are lower in the Silai and Subarnarekha plains.

The chemical properties of the soils are better in the flood plains than in the land systems A - E. Apparently, the flood plains receive some plant nutrients and higher-activity clays with flood deposits and also from the liberal inputs of manures and fertilizers. Even available phosphorus reaches medium levels in the flood plains. In the Darakeswar and Kasai plains the organic matter, nitrogen, phosphorus and potassium are at medium levels and the cation exchange capacity is at a high level. Such levels of fertility are not achieved by any other land system. The Silai and Subarnarekha plains are, expectedly, less fertile. But even there, phosphorus and potass-:ium are at medium levels. The pH is optimum (medium acidic) at the Darakeswar and Kasai plains. The Silai plain has the lowest pH among the flood plains and even then it is better than in systems A, B, C or D.

The cliff areas bordering the flood plains consist of soils comparable to those of the shoulder areas of the toposequential land systems. The slopes of the cliffs are often gentle (as low as 1 degree). But when the slope is long (about 1 km), severe to very severe gully erosion can occur upon such gentle slopes. The shoulder and footslope facets of the land system C areas (i.e. the headstream areas) may also be long slopes and hence subjected to severe gully erosion. There are also very steep cliffs where soil erosion is obviously very severe. However, such areas with serious erosion problem are limited in this region. Erosion may be checked by improving plant cover and protecting the plants from man and animal.

This comparative discussion may be summed up by saying that the distinction between the land systems of the Southern Rarh Plain is hierarchical according to the order of the stream draining a system. The summit, shoulder and footslope facets are similar in soil charact-:eristics between systems A to E. It is the soils of the toeslope and base facets which distinguish each system. From system A to E, the soils become progressively richer in exchangeable bases, cation exchange capacity, base saturation and clay content. But at the same time, the width of the flat toeslope and base facets decreases, soil drainage becomes poorer and stream-irrigation is less available towards the system E. The system F has the most fertile soils of this region. It also has the greatest extent of flat area and most plentiful river water for irrigation. The distribution of each of these systems and their effect on the availability of fertile soils and irrigation in the Southern Rarh Plain are discussed in the next section.

4.9 A CATENARY SOIL MAP OF THE SOUTHERN RARH PLAIN

In this region the soil properties change continuously from the summit to the base across the sides of a valley so that any soil boundary is essentially transitional. However, each type of valley has a characteristic sequence of soils which regularly repeats itself wherever the same valley form is met with. The best way to map such pattern of soil sequences is the catenary method, initially suggested by Milne (1935). The types of valley forms are identified as land systems in this project. There are six land systems. Excepting system F which is a flat plain, each system can be called a catena for the purpose of soil mapping. The same alphabetical and descriptive names of the land systems are also employed to designate the catenas, such as catena A or Godapiasal catena. The soil sequences of each catena or system are already described in SECTION 4.8.

A catenary soil map of the Southern Rarh Plain has been prepared on a 1:1 000 000 scale (FIG. 4.32). The catena boundaries were plotted by field work and by map interpretation on the 1:50 000 topographical maps. The area occupied by each catena is presented in TABLE 4.3. The land system F is included in the map and the table to complete the picture, but it is not a catena in the true sense.

The map and the table show that the streamless basins, catenas D and E, occupy a very small proportion of the region. Therefore, the most fertile (among A - E) lower facet areas of catena E are also limited in occurrence. Moreover, the relatively better drained toeslopes (imperfectly drained, in contrast to the poorly drained toeslopes of the other catenas) of catenas D and E are also limited in

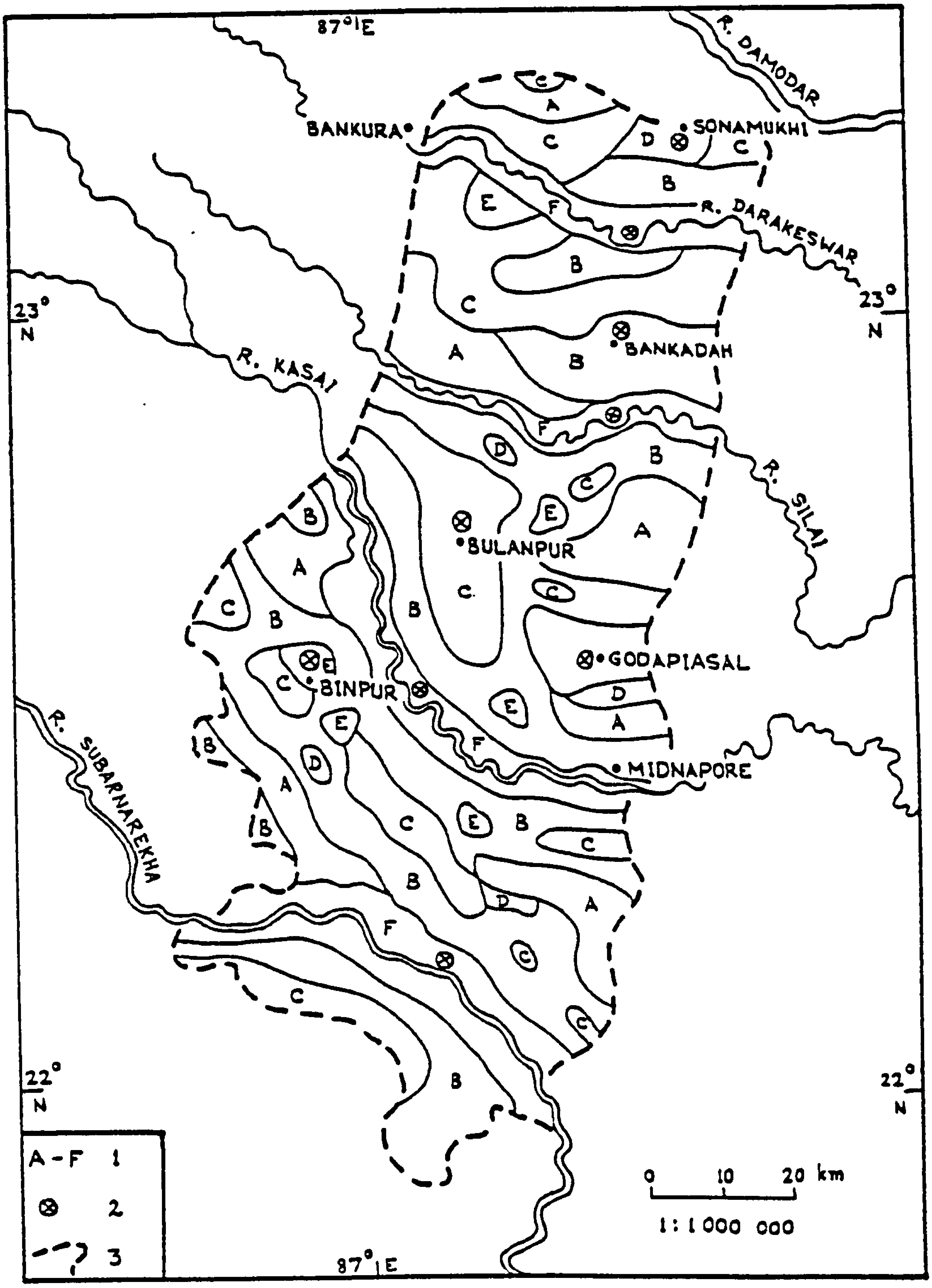

Figure 4.32 Catenary soil map of the Southern Rarh Plain (source: field work and interpretation of Survey of India maps).

1. Catenas; 2. Site of soil and land use studies; 3. Approximate boundary of the Southern Rarh Plain.
See SECTION 4.9 for further explanations.

TABLE 4.3 AREA UNDER THE CATENAS

NAME OF CATENA		AREA	AREA
ALPHA-:BETICAL	DESCRIPTIVE	sq. km	%
A	Godapiasal	870	18
B	Bankadah	1760	35
C	Bulanpur	940	19
D	Sonamukhi	150	3
E	Binpur	120	2
F	Flood plain	1160	23
	Darakeswar	(110)	
	Silai	(150)	
	Kasai	(400)	
	Subarnarekha	(500)	
	Total	5000	100

Note: The F or Flood plain is not a catena in the true sense. It is included here to have a complete picture of the region.

SOURCE: calculated from FIG. 4.32.

occurrence.

The third, second and first order stream basins, catenas A, B and C respectively, cover the greater part of the region. Among them, the width of the lower facets decreases and the fertility increases from A to C. But neither the wider lower facets of catena A nor the more fertile lower facets of catena C occur as frequently as the lower facets of catena B. The latter catena occupies the greatest proportion of the region, but is the last but one in fertility status.

The flood plains occupy a significant proportion of the region. They are flat, imperfectly drained, fertile and endowed with most abundant stream-irrigation. The most fertile Darakeswar and Kasai plains constitute almost half of the total area of the flood plains. The Silai plain, which is susceptible to damaging floods and consists of coarse soils, occupies relatively smaller proportion of the flood plains.

To conclude it may be said that wide or better drained or fertile lower facets of the catenas A - E are limited in occurrence. But the flood plains have great extent of flat, better drained and fertile areas.

CHAPTER 5

LAND SUITABILITY EVALUATION

The soil survey results, as detailed in the previous chapter, can be interpreted further to assess the fitness of a unit of land for a type of use. This process is known as land evaluation. Such an exercise is necessary to relate the soil data to their practical utilization and also to make the data more accessible to the users such as farmers, foresters and land use planners. The evaluation requires other information in addition to that of soils because the performance of a land use type is also influenced by climate, distri-:bution of water, surface form and other attributes of land.

There are various systems of land evaluation. The 'land suitability' method of evaluation is employed in this study, for it takes into account all the attributes of land responsible for the perform-:ance of a land use type and makes an evaluation for a specific type of land use under specific management practices (F.A.O., 1976; Beek, 1978; Young, 1976; Dent and Young, 1981). Its advantages over other systems have been discussed in SECTION 3.5.

The essence of land suitability evaluation rests on the compari-:son between 'land qualities' of 'land units' and 'land requirements' of 'land use types'. According to the degree of matching, the land units are classified as 'highly suitable', 'moderately suitable', 'marginally suitable' or 'not suitable' for each type of land use. The definitions of these concepts, the processes of evaluation and the structure of the classification are presented in SECTION 3.5.

In this study, the land facets are the units of suitability evaluation. The qualities of the 29 land facets are listed in

Appendix F. Both the current and some potential land use types are evaluated. The requirements of the 87 current and 67 potential crops are tabulated in Appendix G. The sources of these two sets of data have been identified in SECTION 3.6. The suitability class of each land unit for each land use type is determined by the 'limiting conditions' method (SECTION 3.5). This classification is presented in Appendix H. In this chapter, the suitability evaluations for current and potential land use types are discussed in turn and then conclusions are drawn concerning a recommended pattern of land use for the Southern Rarh Plain.

5.1 EVALUATION OF LAND FOR THE CURRENT LAND USE TYPES

The current land use pattern is characterized by three major kinds of land use: (a) rainfed and irrigated food and cash crops, (b) natural pasture and planted grass and bamboo and (c) natural forests and forest plantations. The food and cash crops are cultivated mainly in the base, toeslope and footslope facets. Rice is the main crop during the wet season. Wheat, potato, oilseeds, pulses, beans, cabbage and other vegetables are grown in winter or in summer with irrigation. Sugarcane and betel vine are important irrigated perennial crops. The summit and shoulder facets are usually occupied by the forests. Their composition has been described in SECTION 2.4. Natural pastures may occur at any of the facets, for they are, in fact, either uncultivated areas or areas where forests have been destroyed. A species of grass (babui) is also planted for the making of ropes. Groves of bamboo and small orchards are very common around the homesteads. In the flood plains there is no forest and little pasture. Most of the land is cultivated all the year round for food and cash crops.

The food crops and the fruits are obviously grown for subsis-:tence. But the surplus, if any, enters into local and regional trade. The cash crops, on the other hand, are grown for markets, but some of the produce is retained by the peasant for domestic consumption. Various parts of the crop plants, such as rice straw, are used as fodder. Cattle and goats are the main domestic animals. The surplus milk and (goat-) meat are sold regionally.

The farm work is done by traditional methods with the help of bullocks. Farmyard manure and oilseed cakes are the chief manures for the wet season crops. But chemical fertilizers, pesticides and improved seeds are increasingly used for the high-value irrigated crops. The methods and sources of irrigation are also improving from indigenous lifting of stream-, well- and pond-water to diesel- and electric-pumps and both shallow- and deep-tubewells. This region will also be served by the canals of the Kangsabati Project (the R. Kasai irrigation scheme) in near future. Since the canals run following the regional slope along the summit areas of each undulation (see SECTION 2.1), all the facets of the region can be supplied with irrigation. Thus, not only the upper facets may be brought under cultivation but the area and period of irrigated cropping can be increased in the lower facets as well. The dams and reservoirs of the project have been completed. The canals are also dug; but since they run along the porous soils of the summit areas (coarse texture and high air porosity; Appendix A), they, at least the main ones, require some kind of lining to prevent excessive loss of water by percolation. This last phase is under operation at present.

In spite of the improvements in the supply of irrigation, fertil-

:izers and seeds, the broad land use pattern and any variation in detail continue to be dominated by the system of land tenure. The small size of the farms, averaging 0.7 ha only and their further division into tiny scattered plots not only increase the cost of inputs but make the set-up for a comprehensive development plan difficult to implement. These problems are more acute when the land is cultivated by a 'share-cropper'. The share-cropper can grow only those crops approved by the land owner; he cultivates at his own cost and returns half of the produce to the land owner. He, therefore, finds little incentive in improving anything. About 40% of the cultivators of this region are share-croppers.

The pastures are 'common' lands, but there is no organization to manage them. They are excessively overgrazed. The forests, on the other hand, are owned by the State. They are managed by the Forest Department who extracts and sells the timber and fuelwood. The local people have only limited access for grazing animals and collection of forest litter and minor products (TABLE 2.11). Lacking any respons-:ibility, the local people are often careless about the forest. Destruction of forests is not uncommon in this area. As a result, 50% of the present forests are type C open coppice (TABLE 2.10). The policy of the State is to convert these areas into types A and B plantations, mainly with two exotic plants - eucalypt and akasmoni.

The writer argues that, for optimum production, a unit of land should be given to its most suitable use. At the same time, the ecological balance of the area, the interests of the local people and the economic development of the region ought to be considered. With these ends in view, the suitability of the 87 current land use types is analysed in the following five subsections. Following this, some new land use types are examined in SECTION 5.2 with the purpose of supplementing the current land use pattern and approaching closer to an optimum use of the land and to an improved economic future for the people of this region.

5.1.1 RAINFED CROPS

At present 22 rainfed crops are grown in this region. Two of them are annual cash crops. Another two are perennial food crops. The rest are annual food crops. Most of the rainfed annual crops are grown during the wet season.

Lowland rice is the most important crop of this region. It is grown during the wet season in the imperfectly- and poorly-drained facets i.e. in the footslope, toeslope and base areas of the land systems A - E and in the flood plains. But it is 'highly suitable' for only the toeslope and base facets of systems A - C, the base areas of D and E and the Darakeswar, Kasai and Subarnarekha flood plains. The remaining areas under rice are only 'moderately suitable' for it on account of inadequate moisture and nutrients, and in the case of the Silai plain, because of texturally coarse soils. Nevertheless, rice is grown in these facets because there are no other crops of a higher suitability class than rice in the wet season.

No other wet season crops (indicated below) have achieved the status of 'high degree' of suitability at any of the facets. They are entirely unsuitable for the poorly drained areas whilst over the better drained facets soil and nutrient conditions limit them to a 'moderate' suitability class. Yet they are grown in small quantities to meet the domestic requirements. Among them pigeon pea, horse gram and mat bean can be grown only in the summit and shoulder areas and on the coarse soils of the Silai and Subarnarekha flood plains. The imperfectly drained footslope areas are only 'marginally suitable' for them. The yam can also be grown over the summit and shoulder areas, but it is further limited by inadequate water. Turmeric and ginger may be grown over the same areas, but they are more sensitive to soil conditions than the others. Therefore, they are no more than 'marginally suitable' to this region. Yam, turmeric and ginger are only 'marginally' suited to the flood plains on account of the injurious effects of floods.

There is a special crop - rice straw mushroom which is occasion-:ally grown upon beds of rice straw during the wet season. Since these beds have to be placed on well drained sites, the shoulder facets of systems A - E are 'highly suitable' for this purpose.

Four food crops and two cash crops, which require lower temper-:atures and are drought-resistant, are grown in winter. They use the conserved moisture in the soil and hence, are not suitable for the coarse and massive soils of the summit and shoulder areas. The gram, lentil, green gram and safflower are grown in the lower facets of systems A - E and in the flood plains after harvesting rice. By this time, the drainage conditions of these areas improve to a favourable level for these crops through the seasonal lowering of water-table. Gram and lentil are well suited to these areas so far as drainage, soils and nutrients are concerned. But they require a lower temperature than available in the winter of this region. Therefore, the above areas are only 'moderately suitable' for gram and lentil. Green gram and safflower have no problem with temperature, but they require a 'medium' nutrient status. Thus, their suitability rises from 'moderate' at system A to 'high' levels at F.

The grass pea and castor require to be sown before the rice harvest. Since grass pea tolerates poor drainage, it is sown in the rice fields when the crop is still standing. It is a 'highly suitable' crop for the same area as rice. But castor cannot tolerate poor drainage nor is it well suited to freely drained summit and shoulder areas on account of inadequate water or soil conditions (see TABLE 3.3 for definition of the land quality 'soil conditions'). It is 'moderately suitable' only in the imperfectly drained footslope of A, toeslopes of D and E and flood plains. Its cultivation is very limited in area, for it requires the same lands as rice before the harvest of the latter.

Only one rainfed crop, upland rice, is grown in the summer, more specifically during the late summer and early monsoon period. It is obviously not suited to the poorly drained facets nor to the flood plains. The well drained summit and shoulder areas, on the other hand, are only marginally suitable due to inadequate water. This crop, at its best, is moderately suitable to the footslopes of systems A - C and footslopes and toeslopes of systems D - E. But it cannot compete with lowland rice for area in these facets because the latter gives a higher yield. Therefore, it is grown in the years of higher rainfall only over those parts of the summit and shoulder facets not covered by forest.

Although there is a reasonable variety in the rainfed annual crops, rainfed perennial crops are few in this region. Poor drainage in the lower facets on the one hand and inadequate water in the upper facets on the other are responsible for the limited number and area of perennial crops. Only two crops - papaya and banana are grown, mainly for their green fruits, on a very small scale around the home-:steads. Their requirements for free drainage, high level of nutrients and favourable soil conditions mean that they cannot be considered as 'highly suitable' for any of the facets. Moreover, banana is also limited by higher water requirements. However, they can be grown with more success under irrigation (see SECTION 5.2.4).

Of the 22 rainfed crops evaluated here, only 4 - lowland rice, grass pea, green gram and safflower achieve the 'highly suitable' class at some of the facets. The other crops suffer from either poor drainage in the lower facets or inadequate water, low nutrient level and adverse soil conditions in the areas of the upper facets. It is over the lower facets and flood plains that the 4 crops reach high suitability level. These areas are adequate in water for rice in the wet season and favourably drained for the remaining three crops in winter. However, as the nutrient status improves from system A towards F, the suitability of these areas increases in the same direction, particularly for those crops limited mainly by nutrients (as for green gram and safflower). Thus, the flood plains, on the whole, offer a better situation for majority of the crops.

The summit and shoulder facets of all systems are, at best, only moderately suitable for any of these crops. These areas are inadequate in water, poor in nutrient level and unfavourable in soil conditions for these crops. The shoulder facets of systems A and D are 'not suitable' for any of the commonly grown crops because of rockiness (massive iron-:stone at and near the surface). However, the mushroom beds may be ideal over these areas.

In this region rice will continue to occupy most of the areas of the lower facets and flood plains during wet season because it is the staple food of the local people. The other wet season crops, despite their moderate or marginal suitability, may be grown for subsistence over small areas. Safflower is a highly suitable winter crop for the lower facets of systems C, D, E and the flood plains. At present it is cultivated upon a small area. Its cultivation could be extended to all the highly suitable facets. Grass pea used to be a popular succession crop with rice. But its area declined, for it was the cause of 'stiff joints' disease, particularly among the animals. With the recent development of a harmless variety by the I.C.A.R., its former area could be profitably restored.

5.1.2 RAINFED ORCHARD

Eleven fruit trees are identified as currently grown in this region. Of them, cashewnut is raised by the Forest Department as a single crop or in mixture with forest trees. There are two kinds of palms in this region. Some of them are cultivated, but other palms utilized are probably wild. The palms are usually grown or found on the banks of roads, ponds, dykes and scattered over pastures. They are more valuable for the sap than their fruits. The remaining trees are grown for their fruits in small orchards, often around homesteads.

The cashewnut cannot tolerate waterlogging at all, but grows well even under poor nutrient conditions provided the site is well drained. Therefore, the summit and shoulder areas are 'highly suitable' for this plant. But the footslope, toeslope and base facets and the flood plains are 'not suitable' for cashewnut. Its restriction to the areas of upper facets explains why it is raised by the Forest Department, for these areas, being wooded, belong to the State. However, the upper facets may be lower in level of suitability for this plant if soil depth is limited by massive ironstones (as in system A) or if drainage is impeded by clay beds (as in system D).

The jack fruit, guava, lime, custard apple, jujube and sapodilla can tolerate imperfect drainage. So they may be grown both in the summit and shoulder areas and in the footslope areas of systems A - C, the footslope and toeslope areas of D - E and the flood plains. The imperfectly drained facets are 'moderately suitable' for these plants except jack fruit and custard apple. The latter two plants are marginally suited to these areas, for they are more sensitive to drainage conditions. The well drained summit and shoulder areas are 'moderately suitable' for all plants of this group. The custard apple is limited only by nutrient availability in these facets. Therefore, its yield may be increased by fertilization. But the other plants of this group are limited by soil conditions in the well drained facets. So their suitability level is unlikely to be further improved.

The remaining fruit trees - mango, bael, palmyra palm and Indian date palm can be grown anywhere in this region, for they tolerate a wide range of drainage and soil conditions. However, the poorly drained areas are only 'marginally suitable' for mango and bael. The remaining areas are 'moderately suited' to mango whilst the footslope and toeslope areas of system D and the Darakeswar and Kasai flood plains are 'highly suitable' for bael on account of favourable soil and nutrient conditions. Mango fails to achieve the 'high' suitability level in the same locations because of its sensitiveness to imperfect drainage.

The palmyra palm and Indian date palm can be grown with moderate success anywhere in this region. They are 'highly suitable' to the same areas as bael and also to the summit area of system D and toeslope of E. Their yield in the moderate suitability areas is unlikely to be further increased because of soil or drainage limitations.

In summary, the summit and shoulder areas are most suitable for cashewnut. A way needs to be found to allow the local people to cultivate this plant valuable for its nuts and fruits. This may involve changes in the nature of the land tenure, a topic which lies outside the scope of this thesis. But such a change is clearly essential to the improvement of the economic conditions of small-holders. The summit and shoulder areas are also suitable for jack fruit and custard apple. The latter plant can give a higher yield with fertilization. Both the well drained summit and shoulder areas and the imperfectly drained footslopes of systems A - E, toeslopes of D - E and flood plains can support the rest of the current fruit trees. Bael and the palms achieve high level of suitability towards system F. The other plants are nowhere more than moderately suitable. Nevertheless, they are valuable for their nutritious fruits. The poorly drained areas of the lower facets can only support the palms with moderate success.

5.1.3 IRRIGATED CROPS

The current irrigated crops are obviously cultivated during the dry seasons - either summer or winter. Some of them require the lower temperature of winter (e.g. wheat, potato, etc.) whilst others prefer the summer heat (e.g. cucurbits, sesame, etc.). Some of these summer crops can be cultivated in the wet season also, without irrigat-:ion. There are still other crops like rice, chilli and brinjal, the different cultivars of which may be grown in all three crop seasons. Few perennial crops are grown with irrigation on account of high cost. Only two high-value crops - sugarcane and betel vine, which can well repay the cost of irrigation, are grown in this region.

In all, 22 irrigated crops are identified in this region. There are 16 annual food crops, 4 annual cash crops and 2 perennial cash crops. Their suitability evaluation for the 29 land facets is discussed as follows.

Rice is one of the most important winter crops of this region. Although rice is better known as a crop of the hot-wet season, there have been varieties since ancient times which can be grown during dry and mild winter with a small amount of irrigation. These varieties used to be grown on a small scale, for their yield was much lower than that of lowland rice of the wet season. Since the last decade (1970) 'high-yielding varieties' of rice have been introduced to this region. These can be grown in winter giving yields three times higher than the lowland rice. Consequently, the old varieties of winter rice have been abandoned and the area under winter rice has increased enormously with the high-yielding varieties. The new varieties have soil requirements and drainage tolerance comparable to the lowland rice. So they are grown in the lower facets and flood plains after the harvest of lowland rice. But the new varieties require 'high' level of nutrients, freedom from pests and diseases and adequate irrigation to flood the fields. Therefore, only Darakeswar and Kasai plains are 'highly suitable' for this crop. The remaining areas are 'moderately suitable' for it. The yield may be increased in the lower facets of systems A - E by heavy fertilization and ensured irrigation. But the Silai and Subarnarekha plains are unlikely to be improved from 'marginal level' because of limiting soil conditions.

The remaining crops of the winter season require well drained soil. The summit and shoulder areas, although well drained, are only 'marginally suitable' for them. This results from their massive soil structure to which these plants are sensitive. The lower facets and the flood plains are more suitable for them as the soil drainage improves during dry season by seasonal fall of the water-table. Only the toe-:slope facet of system A and the base facets of systems B - E, being lowest in elevation in their respective land systems, remain within the capillary front of the winter water-table (FIGS. 4.2, 4.7, 4.12, 4.17 and 4.22). Therefore, these areas are 'marginally suitable' for the winter crops. The remaining areas i.e. the footslope and base facets of system A, the footslopes and toeslopes of systems B - E and the flood plains are at or above the level of 'moderate suitability'. The areas of moderate and high suitability only are referred to in the following discussion of the winter crops.

The cole crops (cauliflower, cabbage and kohlrabi), pea, tomato, bulb crops (onion and garlic), wheat and spinach require a loamy soil, medium to high level of nutrients and slightly acidic soil reaction. Most of the areas are only 'moderately suitable' for these crops because of limited development of the above qualities. But, as these qualities improve towards system F, the yields of these crops should also increase in that direction. A 'high suitability' level for these crops is finally achieved at the Darakeswar and Kasai plains. It is possible to increase their yield in systems A - E by fertilizat-:ion. Liming is not recommended, for different crops with different pH requirements are grown in the same plot of land. For example, potato or tobacco may suffer, if the pH is raised by liming.

The root crops (radish, carrot, beet and turnip) require a soil sandy loam in texture and medium to high in nutrient status. Since these two qualities do not coincide at any of the facets, the root crops, unlike the previous 'cole group', have nowhere achieved a high level of suitability. The footslope area of system B and the Silai and Subarnarekha plains are texturally favourable for the root crops. In these areas, their yield may be increased to a high level by fertil-:ization. Elsewhere, fertilization may increase the yield but not to a high level.

Tobacco is similar to the root crops in soil requirements, but it does well with relatively lower levels of nutrients and pH. Thus, the Silai and Subarnarekha plains are 'highly suitable' for tobacco. Two other cash crops - mustard (and rape) and linseed are similar to the 'cole group' in their soil requirements, but grow well on less nutrients. Thus, the toeslope area of system D, in addition to the Darakeswar and Kasai plains, is 'highly suitable' for them. The improvement of their yield by fertilization in the moderately suitable facets is also relatively easier than that of the 'cole group'.

The broad bean is like the 'cole group' in soil and nutrient requirements, but it needs a lower temperature than the winter temperature of this region. Therefore, none of the facets is more than 'moderately suitable' for this crop. Its yield may not be significantly increased because of temperature limitations.

The requirements of potato are also like those of the 'cole group' in some respects. But it distinguishes itself by a demand for sandy loam, silt loam or fine sandy textures and a pH between 5.0 and 5.5. None of the facets meet such requirements together with high level of nutrients. Therefore, potato does not attain the 'high suitability' level at any of the facets. Its yield may be raised to a high level by fertilization in the flood plains and footslope and toeslope areas of system B where nutrients are the main limitations.

Among the remaining seven irrigated annual crops, sesame is grown during summer. It is drought-resistant and requires less nutrients than the winter crops. Like the latter, it does not grow well upon the massive soils of the summit and shoulder areas. But it can be grown in the toeslope facet of system A and base areas of systems B - E on the further lowering of water-table during summer. Therefore, it is not only possible for sesame to be grown over a wider area than the winter crops but at 'high level' of suitability in more facets. In the other facets, its yield can be relatively easily improved by fertilization.

The notey, pui and hyacinth bean are also grown in summer. Since they require only low to medium level of nutrients, most of the lower facets and flood plain areas are 'highly suitable' for them. They are also grown during wet season, without irrigation. But in that season, they are restricted to the upper facets by drainage conditions. These areas of massive soils are only 'marginally suitable' for them.

The cucurbits (gourds, melons, cucumber and pumpkin) are also summer crops. But their nutrient requirement is relatively higher than the other crops of summer. Moreover, they require a well drained, sandy loam soil. Therefore, the lower facets are no more than 'moderately suitable' for them. Since the cucurbits tolerate soils massive in structure, they can be grown over the summit and shoulder areas during both summer and wet season. These areas are also 'moderately suitable' for them on account of nutrient limitations, but the yield may be increased significantly by fertilization.

The remaining two annual crops - chilli and brinjal - are grown all the year round. They can be grown over all facets in summer. Their winter cultivation is excluded from the toeslope of system A and the base areas of systems B - E on account of drainage limitations. Their area becomes further restricted in the wet season when they can be grown over the summit and shoulder areas only. But the upper facets are 'marginally suited' to them because of soil conditions. The lower facets are more suitable for them during winter and summer. In these areas their main limitations are nutrients and soil reaction. As these properties improve towards system F, a 'high level' of suitability is achieved by the lower facets of systems D - E and the Darakeswar and Kasai plains. Their yields can be increased in other lower facets by fertilization.

In contrast to the variety of annual crops, only two perennial crops are grown with irrigation at high cost. Both sugarcane and betel vine are cash crops. They do not tolerate poor drainage of the toeslope and base areas nor the structurally massive soils of the summit and shoulder areas. They can be grown only in the imperfectly drained areas such as footslopes of systems A - C, footslopes and toeslopes of D - E and flood plains. But betel vine is not even tolerant of imperfect drainage. Nevertheless, it has been possible to grow it over such areas by making raised beds, often by about 1 m from the ground level. Moreover, it requires a lower temperature than the hot summer of this region. This is provided by growing it under partial shade in a 'house' made of sticks. It also requires regular watering and heavy application of fertilizers. Only the Darakeswar and Kasai plains are 'highly suitable' for betel vine. In other areas its yield may be improved by fertilization. Sugarcane does well under imperfect drainage. It is mainly limited by nutrients. The same areas as for betel vine are 'highly suitable' for sugarcane. The other imperfectly drained areas can give higher yield of sugarcane with fertilization.

The evaluation of the irrigated crops has been made assuming that the supply of water is sufficient for every facet in both summer and winter. In fact, little irrigation is available for the upper facets at present. The flood plains and the lower facets of systems A - C are supplied with irrigation from the streams during winter, but there remains little water in these non-perennial streams in summer. Even in winter, availability of water decreases according to stream order from system F to C, together with a decline of the area under irrigated crops. The streamless systems - D and E - depend on groundwater only. There is a deep tubewell at system D. Consequent-:ly, a considerable area is under irrigated crops. But there is no tubewell at system E and very little cultivation is carried on during dry seasons. The situation may be improved by sinking tubewells everywhere in the region. But this may lead to regional lowering of the water-table and consequent scarcity of drinking water. The problem may be more satisfactorily solved when the canals of Kangsabati Project come into operation (SECTION 5.1).

If the irrigation problems are waived, most of the crops still suffer from nutrient limitations. As the nutrients reach higher levels over the lower facets towards system F, the crop potential also rises to a high level of suitability in this direction. The crops grown in winter are more sensitive to nutrients than the summer crops. The former reach high suitability level only in the flood plains. But some of the summer crops are highly suitable over most of the lower facets and flood plains. The yield of both summer and winter crops may be increased to a high level by fertilization in areas of moderate suitability if nutrients are the main limitations. The summit and shoulder areas are only marginally suitable for most of these crops on account of their structurally massive soils. Only cucurbits can be grown there with moderate success.

5.1.4 NATURAL PASTURE AND PLANTED GRASS AND BAMBOO

The natural pastures of this region are the areas which are not cultivated nor under forest and hence occupied by grasses and herbs. Such areas are mainly found over the upper facets where cultivation is less frequent, but they may occur anywhere in the landscape. Moreover, the arable lands, if left fallow for even one season, are rapidly colonized by herbs and grasses.

At present, the specific composition is known for the upland pastures only (Dabadghao and Shankarnarayan, 1973). No survey has so far been made for the grasses of the lower facets, although they offer better grazing in the dry season. Among the many species of the upland pastures, 9 grasses and 5 legumes are more common. These are selected for the suitability evaluation. The writer has identified one species - durba (Cynodon dactylon) - in the lowland pastures. It is also included in the evaluation.

The 14 grasses and legumes of the upper facets can be consider:ed to have identical land requirements. They cannot grow in the poorly drained areas of lower facets nor in the flood plains. Even the imperfectly drained areas are 'marginally' suitable for them. It is the well drained summit and shoulder areas which are 'highly suitable' for them, in spite of low nutrient status of the soils. The shallow soils of the shoulder area of system D are also 'moderately suitable' for them.

The durba suffers from soil and water limitations in the summit and shoulder areas. The poorly drained areas of the lower facets are also limited in suitability. The imperfectly drained areas - the footslopes of systems A - C, footslopes and toeslopes of systems D - E and the flood plains - are 'highly suitable' for this grass. The other facets are 'moderately suitable' on account of its great tolerance of adverse conditions.

The appearance of the natural pastures of any of the facets is very poor. This is obviously due to continuous overgrazing. According to the writer's estimate, 15 cattle and 10 goats are raised on every hectare of pasture. It has been observed that the grasses and legumes make relatively better growth under limited grazing. Nevertheless, the upland pastures are essentially poor in quantity, nutritive value and palatability of feed. The only lowland grass considered here is high in palatability and nutritive value and can offer moderate amount of feed under controlled grazing. The lowland pastures are significant only during the dry season and according to the proportion of fallow lands. Still, it would be worthwhile to make a survey in order to identify any promising grasses or legumes such as durba.

A species of tufted perennial grass - the babui and two species of bamboos - Dendrocalamus strictus and Bambusa arundinacea are planted in this region. The babui leaves are made into ropes. The bamboo stems are used in constructional work and for many other purposes. All three plants may be grown at any of the facets, but an imperfectly drained site with loamy soil and moderate amount of nutrients is best for them. Thus, the footslope and toeslope areas of system D and the Darakeswar and Kasai plains are 'highly suitable' for them. Their yields may be raised to high levels by fertilization in the other imperfectly drained areas. The poorly drained areas are only 'marginally suitable' for babui, but the bamboos can be grown there with moderate success. The summit areas are 'moderately suitable' for babui and D. strictus, but the shoulder areas suffer from water limitation. The B. arundinacea has greater water requirement than the other two plants. It is excluded from both summit and shoulder areas.

5.1.5 NATURAL FOREST AND FOREST PLANTATION

The natural forest of the Southern Rarh Plain is dominated by the sal (SECTION 2.4). There are many other species in association with it. Among them ten species, which are more common as well as economically important (TABLE 2.11), are selected for the suitability evaluation.

The sal may grow at any of the facets of this region. But the level of suitability varies according to drainage conditions. The poorly drained areas are 'marginally suitable' and the imperfectly drained areas, including the flood plains, are 'moderately suitable' for sal. The summit and shoulder areas offer the best sites for this plant. A free drainage, sandy loam soil, low base status and richness of iron make the upper facets 'highly suitable' for sal. It even grows on the rocky shoulder area of system A with moderate success.

The kend, silk-cotton, nim and piasal grow best, like sal, in the summit and shoulder areas. The imperfectly drained areas are also 'moderately suitable' for them. But they are not tolerant of poor drainage. They do not grow in the base areas.

The arjun, asan, bohera, mahua, palas and sidha grow best in the imperfectly drained areas, including the flood plains. They tolerate poor drainage and can also grow in the base areas with moderate success. In contrast to the other trees, they are 'moderately suitable' over the summit and shoulder areas on account of soil limitations. Yet their present distribution is mainly confined to the latter sites. This is the result of clearing them from the imperfectly- and poorly drained areas in order to create the agricult-:ural fields. Only a few of them are found scattered over the lower facet areas.

At present, relatively undisturbed natural forest occupies only 10% of the total forest area of this region (TABLE 2.10). The remaining forests have been disturbed to various degrees by the cutting of trees for timber and fuelwood, the picking of leaves, twigs and barks and the browsing of domestic animals without control. Since 1952, all forest areas have been brought under the control of State Forest Department by legislation. The Department's policy is to reafforest all disturbed areas, either by single or multiple stands of commercial timber or by coppice plantations. About 40% of the forest areas have been reafforested up to the present time.

The Forest Department is not using the plant species of the natural forest for the reafforestation programme. Apparently, the slower growth rate of the native species makes them less attractive for profit-making. Two quick-growing exotic species - the eucalypt akasmoni - are chosen as the main plants of the new forests. The cashewnut is also grown in some areas (SECTION 5.1.2). Among the native plants, only sal has been given a small proportion of the area under reafforestation.

This transformation of 90% of the forest areas into plantations of four species is certain to have considerable effect on the soil conditions, the economic situation and the social and religious functions, not to speak of the birds and animals. The writer fully realizes the need for the reafforestation of the disturbed areas and the commercial gain from the quick-growing species (which does not benefit the local population). But he does not support the idea of destroying the community of native species from 90% of the forest area nor that of completely preventing the local people from the use of minor products of the natural forests. The writer strongly advocates the use of native species for at least 50% of the reafforestation programme. He is also in favour of a compromise between the Forest

Department and the local people in the management and use of the forests. This may by achieved by the following means. The Forest Department would plan the plantation projects for each area and instruct the people in the methods of planting, fertilizing and protecting the plants. The Department would also supply the saplings and fertilizers. The local people, organized by village councils, would grow and protect the plants. The Department would supervise a regulated harvest of timber, fuelwood and minor products. The fuelwood and minor products would be shared by the local people. The Department would take the timber for sale. The co-operation of the local people would ensure the protection of plants, minimise the expenses of the Forest Department and benefit both parties.

So far as the suitability evaluation is concerned, the same areas as for sal (summit and shoulder facets) are 'highly suitable' for eucalypt and akasmoni. The imperfectly drained footslope and flood plain areas are also 'moderately suitable' for them. But they do not tolerate poor drainage. The base areas are unsuitable for them.

5.2 EVALUATION OF LAND FOR THE POTENTIAL LAND USE TYPES

All the major kinds of land use currently practised in this region (SECTION 5.1) are represented in the evaluation of potential land use types. In all, 67 food-, cash- and fruit-crops, pasture grasses and legumes and forest trees are proposed in the suitability evaluation as potential land use types. These crops are selected primarily on the basis of their adaptability to the climate of the region. For example, plants like rye, tea, bread fruit, perennial rye-grass or spruce are not considered. The sources of information on the requirements of the crops have been identified in SECTION 3.6.

The potential crops are not necessarily better crops than those currently grown. Some of the food crops and fruits will only add to the variety of diet of the people. Others, such as millets and bambara groundnut, may be useful in years of drought when rice fails. Crops like soya bean and citrus fruits will improve the nutritive value of the diet. The cash crops are obviously intended to increase the peasants' income. A special care is taken in choosing the pasture grasses and legumes. They will have to support the huge, undernourished cattle and goat population, increase milk and meat production and improve the soil conditions as well (e.g. goa bean, fixing the greatest quantity of nitrogen). The forest trees are meant mainly for the peasants. Some of them can be grown scattered over the pastures whilst others may be planted upon the dykes of cultivated fields.

The introduction of a new crop depends not only on its suit-:ability to a facet but also on the acceptability of the peasants, the presence of necessary infrastructure (seeds, processing facilities, market, etc.), the flexibility of land tenure (SECTION 5.1) and the competition with the crops currently grown. Moreover, a new crop should be tested by field trials before introduction. The investi-:gations for the social acceptability, the infrastructure required to promote a successful crop adoption and the problems inherent in the land tenure system are beyond the scope of the present study. The purpose of this project is to classify the land facets according to their degree of suitability for the potential crops and then to compare this with the suitability for the current crops. This will permit an identification of the most suitable use or set of uses for a land facet. It is not claimed that the introduction of new crops by themselves can improve the productivity of the region. The reorganization of the present land use pattern will equally contribute to this end.

In the following six subsections, the degree of suitability of 29 land facets for 67 crops is discussed. The comparison with the current crops and recommendations for any change in the land use practice are presented in SECTION 5.3.

5.2.1 RAINFED CROPS

Twenty six rainfed food- and cash crops are proposed for potential use. There are 22 annual crops and only 4 perennial crops among them.

All the annual crops require abundant water and heat. There-:fore, they are to be grown in the wet season. Only three of them can tolerate the poor drainage conditions of the lower facets where the soils and nutrients are most favourable. Barnyard millet and Job's tears are particularly suited to the poorly drained sites. Barnyard millet grows well in 'low-medium' level of nutrients. Therefore, all the lower facet areas and the flood plains are 'highly suitable' for it. It may be a good substitute for lowland rice so far as land suitability is concerned. But it cannot compete with rice in yield, quality, price or socio-religious status. Its average yield is only 500 kg/ha and protein content of the grains is 6%. Job's tears requires a medium level of nutrients and texturally medium soils. Only Darakeswar and Kasai plains are 'highly suitable' for this crop. Between the lower facets of systems A - E, it should be more successful towards system E as the concentration of nutrients increase in that direction. This crop has a higher protein content (14%) than rice. 'Little millet' can tolerate poor drainage, but grows best in the imperfectly drained areas. Its suitability progressively increases from 'moderate' level at system A to 'high level' at systems D, E and F with finer texture and greater fertility of the soils. Its yield and quality are comparable to those of barnyard millet. These three crops tolerate a wide range of drainage, nutrient and soil conditions. Barnyard millet and little millet are also resistant to drought. These qualities may favour their introduction at least on small proportions.

Soya bean tolerates poor drainage, but its yield becomes very low. The poorly drained areas of the lower facets are 'marginally suitable' for it. In the well drained summit and shoulder areas, the soil and nutrient conditions are below its requirement level. These areas are also 'marginally suited' to this crop. The imper-:fectly drained areas offer more favourable situation for this crop. But they are no more than 'moderately suitable' because soya bean suffers from the very high temperature of this region. Within the limitations of temperature, its yield should increase towards system F with more favourable soil and nutrient conditions. In spite of moderate suitability, soya bean is worth cultivating for its nutritive value as a human food (30 - 50% protein and abundant vitamin B) and an animal feed (45% protein in the meal), for the possibility of making various food products and for its nitrogen-fixing capacity (initial inoculation may be necessary).

The remaining 18 annual crops and 4 perennial crops cannot grow in the poorly drained areas. Since the better drained facets are poorer in soil and nutrient conditions, these crops have reached 'high suitability' level nowhere in this region. Bambara groundnut is the only exception. This crop grows well on poor soil with low level of nutrients provided the site is well drained. Therefore, the summit and shoulder areas are 'highly suitable' for it. The tastefulness of the nuts or the nitrogen-fixing capacity of the plant is not known to the writer. Nevertheless, it is one of the few crops that can be grown successfully over the summit and shoulder areas. The plant may serve as a good cover crop and the nuts, containing 19% protein, may improve the nutritive value of a diet.

Finger millet, common millet, kodo millet, bulrush millet, foxtail millet, maize and lima bean among the food crops and tosa jute and groundnut among the cash crops are most sensitive to drainage conditions. They are excluded from both imperfectly- and poorly drained areas including the flood plains. They can be grown only in the well drained summit and shoulder facets. But these areas are no more than 'moderately suitable' on account of massive soil structure and low level of nutrients. Tosa jute particularly requires a strong crumb structure and high nutrient level. Therefore, the suitability for this high-value textile fibre crop is only at the 'marginal level'. This region is also 'marginally suitable' for bulrush millet because of the heavy rain at flowering. The other millets also suffer from heavy rain, but to a lesser degree. These millets are resistant to drought. Their grains contain greater quantity of protein (8 - 12%) than rice, although the taste is inferior. Their straw may also be used as fodder. These qualities and their ability to grow over the summit and shoulder areas may justify their introduction at least for the years of drought. Maize also yields a nutritious food (9%

protein and rich in vitamin A), animal feed and various industrial products, but is is vulnerable to drought and hail. Moreover, it requires a 'high' level of nutrients. Careful field trials are necessary in order to determine its profitableness and impact on soil conditions. Protein-rich lima bean may be introduced if the field trials indicate its adaptability to hot weather and acid soils. Groundnut is vulnerable to termite activities. Since the termites are ubiquitous over the well drained facets of this region, their eradication may be too expensive and perhaps ecologically undesirable. A termite-resistant variety would be the ideal solution. At present, the degree of termite-damage can be checked by field trials. If the damage is not severe, it would be worthwhile to introduce this crop for the protein- and vitamin-rich nuts, edible oil, nutritious fodder (oil-cakes and green haulmes) and nitrogen-fixing capacity.

The remaining annual food and cash crops - sweet potato, sorghum, cluster bean, cotton, niger seed, sunn hemp, kenaf (mesta) and roselle (mesta) - are less sensitive to waterlogging than the previous group. They can be grown in the imperfectly drained areas, in addition to the well drained facets. But they are limited by drainage in the imperfectly drained areas and by soil and nutrients in the well drained facets. Therefore, these areas are only 'moderately suitable' for these crops except sweet potato. Sweet potato is more sensitive to waterlogging and requires a soil moderately coarse in texture. The imperfectly drained areas are 'marginally suitable' for it. It may be introduced to the summit and shoulder areas and probably also to the Silai and Subarnarekha plains. The tubers of sweet potato are rich in vitamin A and give 50% more calories than potato. The leaves are also protein-rich (13%) fodder. Among the other crops of this group, cluster bean, cotton and sunn hemp may be particularly recommended for the summit and shoulder areas. These areas are only limited by low nutrient level which may be improved by fertilization for these valuable crops. Cluster bean yields a protein-rich (33%) food, fodder and also an edible gum. Cotton provides textile fibre whilst sunn hemp gives a non-textile fibre, fodder and green manure. Sorghum (12% protein in grain and straw), niger seed (edible oil and protein-rich oil cake fodder) and mestas (textile fibre like jute) may be introduced to both well- and imperfectly drained areas.

The perennial crops, like the annual crops are greatly limited in the area of cultivation by drainage conditions. Cassava and sisal can be grown only in the summit and shoulder areas. Even these areas are 'marginally suitable' for cassava. It is a crop of warm, equable climate. It may withstand the summer heat of this region, but the yield of tubers (rich in calcium and vitamin C) will decrease significantly. It is not recommended for this region. The suit:ability for the fibre crop sisal is only 'moderate' on account of the long dry season of this region. If the crop is irrigated and fert:ilized, higher yields may be expected. But the cost of irrigation and fertilizers and the low market price may restrict its commercial cultivation at present. Nevertheless, it can be introduced for soil protection, hedging and fibre for domestic use. Cantala and henequen also produce fibres like sisal, but the quality is inferior. They tolerate imperfect drainage with reduced yield. Such areas are 'moderately suitable' for cantala and 'marginally suitable' for henequen. In the well drained summit and shoulder areas, cantala suffers from inadequate water whilst henequen is impeded by high humidity and heavy rains. These areas are 'moderately suitable' for both of them.

They may be introduced to the upper facets for the same purpose as sisal. The yield of cantala may be increased by irrigation, but that of henequen cannot be improved.

In summary, a high degree of suitability is reached for only 4 crops among the proposed 26 rainfed crops. The lower facets and flood plains are highly suitable for barnyard millet, Job's tears and little millet and the upper facets for bambara groundnut. All four are food crops, but whether they will be able to compete with the current foods in taste or social acceptability is doubtful. Never-:theless, these crops are recommended for introduction on small proportions because of their tolerance for adverse conditions. There are 3 crops - tosa jute, bulrush millet and cassava - the suitabilities of which are marginal. They are not recommended for introduction. The remaining crops are moderately suitable. The millets, sweet potato, cluster bean, cotton, sunn hemp, sisal and henequen are recomm-:ended for the summit and shoulder areas for their nutritious food, fodder or valuable fibre crops. Maize, groundnut and lima bean may also be grown in these areas if the field trials indicate their adaptability to the local conditions. The variously useful soya bean may be introduced to the imperfectly drained areas. Both the well- and imperfectly drained areas may support sorghum, niger seed, mestas and cantala for grain, fodder, oil or fibre. The yields of cluster bean, cotton, sunn hemp, sisal and cantala may be increased by irrigation and fertilization, but there is little possibility of improving the yields of sweet potato, sorghum, niger seed, mestas and henequen.

5.2.2 RAINFED ORCHARD

Thirteen plants are proposed for evaluation as rainfed perennial orchard. Eleven of them are trees and two are climbers.

Avocado, passion fruit, granadilla and tangerine are included in the evaluation for their nutritious fruits. But these four plants have never been known to be grown in this region. It is found through the evaluation process that they are hardly suitable for this region on account of high temperature. The imperfectly- and poorly drained areas are beyond any consideration, for they cannot tolerate waterlogging. The summit and shoulder areas are only 'marginally suitable'. It may not be possible to introduce these four plants to this region.

Pineapple may also be seriously affected by the high temperature and low humidity of the summer. But it is more hardy than the plants of the previous group. In spite of 'marginal suitability', the summit and shoulder areas may be made more favourable with the help of shade trees, hand watering, mulching and fertilization. It would be worthwhile to introduce this nutritious fruit, rich in vitamin A and B, at least for domestic consumption. It can also be a small-holder's cash crop if the market price exceeds the cost of inputs.

Orange and grapefruit also suffer from the high summer temperat-:ure, but to a lesser degree than pineapple. They may not be grown in the areas of imperfect or poor drainage, but the summit and shoulder areas are 'moderately suitable' for them. These areas are, however, limited by unfavourable soils and nutrients. Grapefruit may also be affected by the heavy monsoon rains. Nevertheless, they may be grown in the summit and shoulder areas with the help of shade trees and fertilization for the nutritious fruits. These facets are also 'moderately suitable' for citron which is only limited by soils and nutrients. It may also be introduced to these areas.

Bullock's heart and phalsa are tolerant of imperfect drainage. Both the well drained and imperfectly drained areas are 'moderately suitable' for them. The limitations are unfavourable soil conditions in the well drained areas and drainage in the imperfectly drained facets. They may be grown in small numbers to add to the variety of diet, but the fruits are not as valuable nor nutritious as the others.

Pummelo, jam and tamarind are the only plants among the proposed 13, which can be grown in any of the facets. But this region is only 'moderately suitable' for pummelo on account of the high summer temperature. Since the upper facets are further limited by inadequate water and the poorly drained areas by waterlogging, its cultivation may be relatively favourable in the imperfectly drained areas including the flood plains. The fruit has little market value. But it is nutritious and has medicinal value in jaundice. Therefore, its cultivation may be encouraged at least for domestic consumption. Jam and tamarind may also be more favourably grown in the imperfectly drained areas. They are mainly limited by nutrients. As the level of nutrients rises towards system F, the systems D, E and F have achieved 'high' degree of suitability for them. The yields may be increased in the other systems by fertilization. Jam provides a nutritious fruit whilst the fruits and seeds of tamarind are made into chutney, sauce and flour. Both of them are recommended for growing in the imperfectly drained areas.

Among the 13 fruits proposed for evaluation, only jam and tamarind may be highly successful in the imperfectly drained areas. Pummelo may be grown on a limited scale over the same areas. Orange, grapefruit and citron may be moderately successful over the well drained areas. Pineapple is also worthy of trials in the upper facets. Bullock's heart and phalsa may be grown in both well drained and imperfectly drained areas on a limited scale. Avocado, passion fruit, granadilla and tangerine may not be successfully grown in this region.

5.2.3 IRRIGATED CROPS

Only 5 crops are proposed for evaluation as potential irrigated crops. There is, however, a great potential in extending the area under current irrigated crops with the supply of canal irrigation (SECTIONS 5.1 and 5.1.3). Some of the rainfed crops, such as edible arum, yam and banana among the current crops and sisal, cantala and pineapple among the potential crops, can also do better with supple-:mentary irrigation. The 5 potential crops are evaluated, like the current irrigated crops, with the assumption that there is sufficient supply of water for every facet.

Barley is the only annual food crop in proposal. Its require-:ments are similar to those of wheat. Therefore, the suitability classification for barley is identical to that for the latter (SECTION 5.1.3). It may be grown with high degree of success in the Darakes-:war and Kasai plains. Comparable yields may be obtained from the footslope and toeslope areas of other systems with the aid of fertili-:zers. But barley is not a popular food. Beer-making from malt-barley is not practised in this region nor in much of India. It is unlikely that barley, although a suitable crop, will be cultivated in a significant proportion.

Among the two annual cash crops, sunflower has similar require-:ments and consequently, an identical suitability classification to that of wheat or barley. Its cultivation is strongly recommended for the lower facets and the flood plains because of the high market value and good quality of the oil and the protein-rich oil-cake. The other cash crop - white jute - is a 'summer-early wet season' crop. It may be adversely affected by the hot and dry summer of this region. This is why, the suitability for this crop is not above 'moderate level'. It also suffers from unfavourable soil conditions and nutrient levels. Still, it may be introduced for the high market value of the textile fibre to the following facets where, save temperature, nutrient availability is the only limitation: footslope area of system A, toeslope of B, footslope and toeslope of D and Darakeswar and Kasai plains.

Two perennial cash crops are proposed for evaluation. Black pepper yields a spice of high market value. Ramie provides a high-value fibre and protein-rich leaves as fodder. The requirements of black pepper are comparable to those of betel vine (SECTION 5.1.3). It may be grown in the imperfectly drained areas on a raised bed under partial shade of a 'stick-house'. Since such techniques are already in practice for betel vine, the introduction of black pepper may not be difficult. Ramie represents a marginal crop introduction. Firstly, it cannot be grown in other facets than summit and shoulder on account of drainage conditions. Secondly, even these facets are only 'marginally suitable' because of hot-dry summer, heavy monsoon rains and unfavourable soil and nutrient conditions. Field trials may be given with partial shade and liberal fertilization, but the soil and rainfall limitations and the cost of input may not make it worth growing in this region.

In summary, this region is most suitable for sunflower among the proposed 5 irrigated crops. Sunflower may be most successfully grown in the Darakeswar and Kasai plains. Comparable yields may be obtained with fertilization from the footslope and base areas of system A and the footslopes and toeslopes of systems B - E. These areas are equally suitable for barley, but its cultivation may be limited for the reluctance and difficulty of its use. White jute is recommended for some selected facets only (see previous paragraphs). Black pepper should be as successful as betel vine. But ramie does not show much promise in this region.

5.2.4 IRRIGATED ORCHARD

Papaya and banana are currently grown in this region as rainfed perennial food crops (SECTION 5.1.1). They are, at the best, moderately suitable to the imperfectly drained areas. It may appear from comparing their annual water requirement with annual amount of water of these facets that they have sufficient water for growth. In fact, they suffer significantly during the six-month long dry period. Supplementary irrigation during this period will undoubtedly increase the yields. It will be also possible to grow them in perennial orchard, partly for domestic consumption and partly for marketing them. Moreover, their areas may be extended to the upper facets with irrigation.

With these ends in view, these two valuable and nutritious fruit plants are recommended to be grown with irrigation and fertiliza-:tion. At present, it is difficult to supply the irrigation water. But, when the canal irrigation comes into operation, such orchard will help to improve the diet and economy of the region.

5.2.5 IMPROVED PASTURE

It has been stated in SECTIONS 5.1 and 5.1.4 that the natural pastures of this region are poor in the quantity, nutritive value and palatability of feed. Yet there are 10 cattle and 15 goats for every hectare of pasture. It is true that the animals are also fed on various parts of the cultivated plants e.g. rice straw, bran, rice starch, oil-cake, molasses, herbage of beans, cucurbits and other plants. But the supply of these feeds depends on the peasants' capacity to grow, buy or generate a surplus of them. More often than not, the animals are raised on pasture grass, rice straw and starch only. Consequently, milk production is only 1.0 - 1.5 litre per cow per day. Goat milk is negligible in quantity; they are kept mainly for meat.

With the intention of improving this situation, 8 grasses and 7 legumes are proposed for evaluation. They will not only yield high quantities of nutritious and palatable feed under suitable conditions but improve the structure and fertility of the soils as well. It may, however, be difficult to introduce them within the present situation of land tenure (SECTION 5.1). The pastures are either open, uncultivated lands or current fallows. The perennial species can only be grown over the former type of land. Such areas are owned by the villagers in common. At present, there is no organization to attend to the common pastures. Co-operatives, village councils or similar organizations are necessary for introduction, management and use of the new pasture crops. The annual species, particularly those of the dry season, may be grown over the fallow lands by the peasants individually.

Among the proposed pasture crops, para grass is distinguished by its very high water requirement and tolerance of very poor drainage. Most of the facets are unsuitable for it because of water limitations. Only the poorly drained areas of the lower facets and the Darakeswar and Kasai plains are 'marginally suitable' for it. Its introduction may be possible with the commencement of the canal irrigation. At present, it may be grown on stream-bank, pond-bank and beside wells. It is advocated for this region on account of its very high yield (up to 250 t/ha/yr) of nutritious and palatable fodder.

Marvel grass and dinanath grass tolerate both poor and free drainage. They may be grown at any of the facets. The imperfectly drained areas with a medium level of nutrients and loamy soils are most favourable to them. The suitability of the imperfectly drained areas reaches 'high level' at systems D, E and F where these conditions are fulfilled. The yield at systems A - C may also be increased by fertilization. The well drained and poorly drained facets are 'moderately suitable' for them. The yield and nutritive value of marvel grass are only moderate, but those of dinanath grass are high. Both of them are recommended for this region.

The remaining grasses and legumes are not tolerant of poor drainage. Blue panic grass, golden timothy grass, lucerne, kudzu and cluster bean can only be grown in the well drained and imperfectly drained areas. The imperfectly drained areas are only 'moderately suitable' for these plants. Since the limitation is drainage, the yields may not significantly improve in these facets. Over the summit and shoulder areas, kudzu and cluster bean are only limited by nutrients. Blue panic grass suffers from inadequate water and nutrients. The yields of these three plants may be increased by fertilization and irrigation. But lucerne is limited by unfavourable soil conditions in addition to nutrients. Golden timothy grass is affected by inadequate water, unfavourable soil and nutrient conditions and termites. It is unlikely that the yields of lucerne and golden timothy grass can be much increased. Still, lucerne may be intro:duced to this region for its highly nutritive and palatable fodder and nitrogen-fixing capacity. Kudzu and cluster bean are also recommended for the same reasons and for their role in soil protection. Blue panic grass may be introduced with the opening of the canal irrigation. But golden timothy grass may not be successful in this region because of the termites if not other limitations.

Rhodes grass, guinea grass, hyacinth bean, sudan grass and goa bean are less tolerant of waterlogging than the previous group. They can only be grown over the well drained summit and shoulder areas. But as these areas are limited by low level of nutrients and unfavour:able soil conditions, they are no more than 'moderately suitable' for these plants. In case of rhodes grass and hyacinth bean, nutrient availability is the main limitation. So their yields may be increased by fertilization. But guinea grass and sudan grass are limited by unfavourable soil conditions also, whilst goa bean is further limited by inadequate water. Rhodes grass and hyacinth bean will be obviously successful in this region. Guinea grass and sudan grass, although less promising, are recommended for their nutritious and palatable yield. Goa bean is more strongly advocated for this region because of its very high nitrogen-fixing capacity (23 g of nodules per plant). It is an annual crop and requires irrigation only for November and December. This will be easily supplied when the canal irrigation begins.

In contrast to the grasses and legumes discussed above, Egyptian clover and rice bean can be grown in winter with irrigation. Like other irrigated winter crops, they are best suited to the foot-:slopes and base areas of system A, footslopes and toeslopes of B - E and flood plains. Therefore, they can be grown by individual peasants in their fallow lands. This advantage alone may justify their introduction. In addition, they have nitrogen-fixing ability and yield moderate quantity of highly nutritious and palatable fodder.

In summary, rhodes grass, guinea grass, sudan grass, lucerne, kudzu, cluster bean and hyacinth bean may be introduced to the summit and shoulder areas. These facets are 'moderately suitable' for them, but the yields may be increased by fertilization. Blue panic grass and goa bean may also do well in the same areas if provided with irrigation. But golden timothy grass may not be successful on account of termite activities. Marvel grass and dinanath grass may be most successful in the imperfectly drained facets including the flood plains. If the land is unavailable, they may be grown in the upper facets. Para grass can only be grown in the base areas near sources of irrigation. All these plants may require to be grown by co-operative or village council on common land. In contrast, Egyptian clover and rice bean may be grown by individual peasants upon the lower facets during winter with irrigation.

5.2.6 FORREST PLANTATION

It has been advocated by the writer in SECTION 5.1.5 that natural forest species should not be replaced without careful planning and then only for a proportion of the area. The six trees proposed for evaluation here are not intended for the creation of extensive plantations at the expense of natural forest. They are meant to be grown on a small scale such as scattered over pastures, on the banks of ponds, streams and roads and along the earth dykes dividing the cultivated plots. In this sense, they can be grown by the local people. The Forest Department may also grow them on a small scale in the afforestation programme.

These plants will serve a multiple purpose for the benefit of the local people. Subabul, babul and siris will supply fuelwood, fodder (leaves) and manure (leaves and pods) when grown as pollard. Casuarina will also yield fuelwood. Kapok and silk-cotton will provide valuable floss. All of them will eventually yield timber.

Among these six trees, subabul and kapok are exotic to this region. Silk-cotton is a member of the natural forest (SECTION 5.1.5). The remaining three plants are known to be grown in this region as a curiosity.

Kapok and casuarina are intolerant of waterlogging. They can be grown in the summit and shoulder areas only. But the high summer temperature of this region is unfavourable for them. Therefore, these areas are no more than 'moderately suitable' for them. The low level of nutrients and, in case of casuarina, inadequate water are also limiting. It may be too expensive to fertilize them or to irrigate casuarina during summer. Still, they should be given field trials in order to find if they can be successfully grown with minimum input.

Subabul and silk-cotton can tolerate imperfect drainage. So they can be grown in the summit, shoulder and footslope areas and in the flood plains. The well drained summit and shoulder areas are 'highly suitable' for them because they can grow well with low quantities of nutrients.

Babul and siris are tolerant of wide range of drainage conditions. They can be grown in any of the facets. The imperfectly drained areas with loamy soil are 'highly suitable' for them. The other facets - well drained or poorly drained - are 'moderately suitable' for them.

It would be ideal to grow babul and siris along the dykes of the cultivated fields. Then, the litter of leaves, flowers and pods will be directly received by the soil. Subabul and silk-cotton may also be grown along the dykes in the imperfectly drained areas, but they will do better over the upper facets. They may be grown scattered around the pastures. Kapok and casuarina will be no more than moderately successful. Still, it would be worthwhile to give a trial to them.

5.3 CONCLUSIONS AND RECOMMENDATIONS

From the evaluation of currently grown crops in SECTION 5.1 and of potential crops in SECTION 5.2, the following features regarding their degree of suitability to this region and relevance to the socio-economic conditions have become apparent:

(1) some of the currently grown crops such as cowpea, ginger, castor, banana and mango are not highly suitable to any of the facets; yet they are grown on a small scale for domestic consumption;

(2) other current crops like lowland rice are highly suitable to some facets, but are also grown over less suitable areas in order to ensure a sufficient supply of the staple food; upland rice, albeit nowhere well suited, is grown for the same reason;

(3) still other current crops such as safflower, grass pea and rice straw mushroom are highly suitable to many facets and yet they are currently grown on a limited area because the markets of safflower and mushroom have not been promoted whilst the harmless variety of grass pea has not been introduced;

(4) among the crops proposed for potential cultivation bulrush millet, tosa jute, cassava, avocado, passion fruit, granadilla, tangerine and ramie are only marginally suitable to this region on account of adverse temperature, soil and other climatic limitations;

(5) the success of some proposed crops like groundnut and golden timothy grass is also doubtful because of termite activities;

(6) other potential crops like soya bean, cotton, sisal, cantala, pummelo, pineapple, grapefruit, para grass, goa bean, kapok and casuarina will achieve no more than moderate success on account of temperature, water, soil and other climatic limitations, but they have high nutritive or market value and some of them are beneficial to the soil;

(7) barnyard millet, little millet and Job's tears are highly suitable to some of the facets whilst the other millets, sorghum and maize are moderately suitable to this region; these crops will face strong competition with rice for a place in the diet and some of them

also for area of cultivation, but they will be useful in years of drought and some of them have higher nutritive value than rice;

(8) the remaining current and potential crops are either well suited to this region or their yield may be increased to high level with fertilization and irrigation;

(9) at present food and cash crops are mainly cultivated in the footslope, toeslope and base facets and in the flood plains. The summit and shoulder facets are under natural or planted forest or they are deforested areas carrying poor pasture. The native forest species as well as the exotic eucalypt and akasmoni are highly suitable to the upper facets. But some other crops like cashewnut, bambara groundnut and subabul are also highly suitable to them. Moreover, some pasture crops (rhodes, blue panic, guinea and sudan grasses and kudzu, hyacinth bean, goa bean and cluster bean legumes), fruits (orange, grapefruit and pineapple), food crops (some millets, beans and pulses) and cash crops (cotton, sunn hemp and sisal) find relatively better environment in these facets as well. On the other hand, some members of the natural forest community (arjun, mahua and others) are highly suitable to the lower facets.

Based upon the above analyses, the following sets of principles are adopted to formulate a recommended pattern of land use for this region. Firstly, it is not suggested that any of the currently grown crops are abandoned altogether, for each crop has a significant place in the diet, economy and religion of the strongly traditional society of this region. If the local cultivation of any of them is discontinued totally, many poor peasants may not be able to obtain supplies. It is only recommended at present that the less suitable crops should be cultivated in limited areas just to satisfy the domestic need with the production of a little surplus for the market. Turmeric and ginger, which are only marginally suitable, may be given the least area of all. Castor is also marginally suitable. Its cultivation may not be encouraged because it requires the same lands as rice before the harvest of the latter. Upland rice is occasionally grown over the shoulder facets in years of heavier rainfall. But its yield is too low whilst the same areas may be given to nutritious and higher-yielding leguminous vegetables, millets and valuable fibre crops like cotton and mesta. For these reasons turmeric, ginger, castor and upland rice are not included in the recommended land use pattern.

Secondly, it is proposed that instead of giving the entire foot-:slope areas to lowland rice where it is only moderately suitable, a small proportion may be reserved for other wet season crops like black gram, soya bean, white jute, etc. which are also moderately suitable to these facets. A small portion of these facets and also of the poorly drained areas, where rice is highly suitable, may be given to barnyard millet and little millet as precaution against drought and to Job's tears for protein-rich grain and fodder.

Thirdly, it is strongly recommended to extend the cultivation of safflower, grass pea and rice straw mushroom over all the highly suit-:able facets of the respective crops. In this regard, the State must take the responsibility of developing the necessary infrastructure.

Fourthly, among the proposed crops, the marginally suitable ones are not advocated for this region. Groundnut and golden timothy grass are also not recommended at present, but their suitability should be checked by field trials.

Fifthly, bambara groundnut, millets, sorghum, maize and other moderately suitable potential crops are recommended for at least limited cultivation in the first instance. Their areas may be increased if they become more acceptable to the local people or find a market.

Sixthly, all the highly suitable current and potential crops and those the yield of which can be improved by fertilization and irrigation are obviously recommended for adoption in the relevant facets. In this regard, the capacity of a peasant to supply manures and fertilizers and the availability of irrigation are not assumed to be limited. In fact, irrigation is limited at present to areas near the streams and around ponds, wells, shallow-tubewells and deep-tube-:wells. Canal irrigation will improve the situation to a great extent, but it remains to be seen whether all the cultivated areas can be irrigated during winter and summer. The application of manures and fertilizers is also limited but increasing rapidly with greater supplies and peasants' income.

Seventhly, it is strongly recommended to conserve the relatively undisturbed natural forests wherever they occur. The disturbed forest areas and the deforested areas over the summit and shoulder facets should be reafforested partly with native species and partly with the commercial, quick-growing eucalypt and akasmoni. But the entire area of these two facets need not be reafforested, particularly where the soils are deep. It is proposed to reserve small parts for suitable annual crops, perennial fruits and pastures of recommended grasses and legumes. It is also urged to sow the pastures of other facets, if any, with improved species. Trees like arjun, mahua, silk-cotton, kapok, subabul, casuarina, babul, siris and palms are recommended for growing in scatter over the pastures, beside streams, ponds and roads and along dykes. Hedging with sisal and cantala is also prescribed wherever protection is required from domestic animals. In other words, this recommendation affirms the principle of multiple land use and conservation of large areas of self-sustaining native plants.

Lastly, it may be pointed out that more than one use is recommended for each facet. The agricultural practice in this region, as everywhere in India, is to cultivate a variety of crops in small plots. Therefore, it is possible and also necessary first of all to grow the suitable crops of a facet in small plots to satisfy the domestic requirements. It is suggested to give a greater area to the crops with higher degrees of suitability. The current areas of forest and pasture belong to different systems of land tenure. The pastures are 'common lands'. It is relatively easier to develop them by forming village councils or co-operatives. But the forests belong to the State. It is suggested by the writer that this system which excludes local people from the use of the forest resource should be changed. Instead, a system of joint responsibility of the State and village councils for the development of the forests along the lines indicated would benefit everyone.

According to the sets of principles outlined above, a recommended pattern of land use is drawn for each of the six land systems of this region. They are presented in TABLES 5.1 - 5.6. The current land use pattern may be consulted from descriptions and maps in SECTIONS 4.1 - 4.6. The crops are classified according to their growing

TABLE 5.1 RECOMMENDED LAND USE PATTERN FOR SYSTEM A

FACETS	WET SEASON	WINTER	SUMMER	PERENNIAL
Summit	cluster bean (sn) and goa bean (sn) intersown with pasture.	Egyptian clover (sn) and rice bean (sn) inter-:sown with pasture.	-	reafforestation with native sal and other species on 95% of the area; pasture of dinanath (sn) grass and kudzu (sn) legume with scatterings of subabul (sn) and babul (sn) and hedge of cantala (s) on 5% of the area.
Shoul-:der	rice straw mushrooms on 10% of the area.	-	-	reafforestation with native sal (s) on 90% of the area.
Foot-:slope	cultivation of annual crops on 60% of the area; lowland rice (mn) over the greater part; black gram (o), common bean (to), cowpea (o), okra (o), arum (o), soya bean (tn), little millet (n), sorghum (o) and white jute (tn) on small proportions; cluster bean (o) intersown with pasture.	grass pea (s), green gram (n), safflower (n), cole crops (n), pea (n), chilli (n), brinjal (n), tomato (n), bulb crops (n), wheat (n), barley (n), spin-:ach (n), mustard (n), linseed (n), tobacco (sn) and sunflow-:er (n); Egyptian clo-:ver (n) and rice bean (n) as pasture crops.	chilli (n) brinjal (n) notey (n) hyacinth bean (n), sesame (n) and cucurbits (sn).	sugarcane (n), betel (n), and black pepper (n) on 10% of the area; orchard of papaya (on), banana (on), mango(on), guava (on), lime (on), jujube (on), sapodilla (on), bael (sn), pummelo (tn), jam (n) and tamarind (n) on 5% of the area; pasture of durba, marvel (n) and dinanath (n) grasses and lucerne (on) and kudzu (n) legumes with scatterings of babul, siris and subabul (o) and hedge of cantala (o) on 10% of the area; bamboos (n) and babui grass (n) on 5% of the area; arjun, asan, bohera, mahua, sidha, babul, siris and palms (n) along roads, dykes and ponds.

TABLE 5.1 (continued)

FACETS	WET SEASON	WINTER	SUMMER	PERENNIAL
Toe-:slope	cultivation of annual crops over the entire area; lowland rice mainly; barnyard millet and Job's tears (n) on small pro-:portions.	rice (n), grass pea, green gram, lentil (t) and gram (t).	sesame (n), chilli (n), brinjal (n), notey (n), pui (n) and hyacinth bean (n).	arjun (o), mahua (o), babul (o), siris (o) and palms (o) along dykes, roads and ponds.
Base	cultivation of annual crops over the entire area; lowland rice mainly; barnyard millet, Job's tears (n) and white jute (ton) on small pro-:portions.	grass pea, green gram, gram (t), lentil (t), cole crops (n), pea (n), chilli (n), brinjal (n), tomato (n), potato (sn), bulb crops (n), wheat (n), barley (n), spinach (n), mustard (n), linseed (n) and sunflower (n); Egyptian clover (n) and rice bean (n) as past-:ure crops.	sesame (n), chilli (n), brinjal (n), notey (n), pui (n), hyacinth bean (n) and cucur-:bits (sn).	para grass, bamboos and arjun along stream bank; arjun (o), mahua (o), babul (o), siris (o) and palms (o) along dykes.

Note: see SECTION 5.3 for explanations.

TABLE 5.2 RECOMMENDED LAND USE PATTERN FOR SYSTEM B

FACETS	WET SEASON	WINTER	SUMMER	PERENNIAL
Summit	cultivation of annual crops on 5% of the area; bambara, groundnut, kodo millet, cucurbits (n), yam (sn), sweet potato (sn), pigeon pea (sn), horse gram (sn) and mat bean (sn); cluster bean (sn) and goa bean (sn) intersown with pasture.	Egyptian clover (sn) and rice bean (sn) as pasture crops.	cucurbits (n).	reafforestation with native sal and other species on 50% of the area; reafforestation with eucalypt and akasmoni on 30% of the area; pasture of rhodes (n), marvel (sn), blue panic (mn), guinea (sn) and dinanath (sn) grasses and lucerne (sn), kndzu (sn) and hyacinth bean (sn) legumes with scatter-:ings of subabul and silk-cotton and hedg-:ing of sisal (cn) and cantala (m) on 10% of the area; orchard of cashewnut mainly and custard apple (sn) on 5% of the area.
Shoul-:der	cultivation of annual crops on 25% of the area; pigeon pea (n), horse gram (n), mat bean (n), cucurbits (n), cotton (n) and rice straw mushrooms mainly; cowpea (sn), okra (sn), yam (mn), sweet potato (sn), lima bean (sn), niger seed (sn), mesta (sn), bambara ground-:nut, millets (sn),	Egyptian clover (sn) and rice bean (n) as pasture crops.	cucurbits (n).	reafforestation with native sal and other species on 25% of the area; reafforestation with eucalypt and akasmoni on 15% of the area; pasture of rhodes (n), marvel (sn), blue panic (mn), dinanath (n), guinea (sn) and sudan (sn) grasses and kudzu (n), hyacinth bean (n) and lucerne (sn) legumes with scatterings of subabul and silk-cotton and hedge of sisal (cn) and cantala (m) on 10% of the area; small areas of bamboos (mn) and babui grass

TABLE 5.2 (continued)

FACETS	WET SEASON	WINTER	SUMMER	PERENNIAL
	sorghum (sn) and maize (sn) on small pro-:portions; cluster bean (n) and goa bean (msn) intersown with pasture.			(mn); orchard of cashewnut and custard apple mainly with some palms (sn), mango (sn), jack fruit (sn), guava (sn), lime (sn), jujube (sn), tamarind (n), citron (sn), orange (tn), grapefruit (tcn) and pineapple (tcn) on 10% of the area.
Foot-:slope	cultivation of annual crops on 80% of the area; lowland rice (mn) mainly; arum (os), soya bean (tn), Job's tears (n), little millet (sn) and sorghum (on) on small proport-:ions; cluster bean (o) intersown with pasture.	grass pea (s), gram (t), lentil (t), green gram (sn), root crops (n), cucurbits (n), potato (n), bulb crops (n) and tobacco (n) mainly; Egyptian clover (sn) and rice bean (n) as pasture crops.	cucurbits (n) and sesame (n) over the greater part; chilli (sn), brinjal (sn), notey (sn), pui (sn) and hyacinth bean (sn) on small proport-:ions.	small areas (5%) of sugarcane (sn), betel (n) and black pepper (n); small areas (5%) of babui grass (n) and bamboo (mn); pasture (5%) of durba, dinanath (n), marvel (sn) and blue panic (on) grasses and lucerne (on) and kudzu (n) legumes with scatterings of arjun, subabul (o), babul (s) and siris (s) and hedge of cantala (o); arjun, mahua, babul (o), siris (s) subabul (o) and palms (sn) along dykes roads and ponds.
Toe-:slope	cultivation of annual crops over the entire area; lowland rice mainly; barnyard millet, Job's tears (n), little millet (o) and white jute (ton) on small pro-:portions.	grass pea, gram (t), lentil (t), green gram (n), safflower (n), cole crops (n), pea (n), broad bean (tn), chilli (n), brinjal (n), tomato (n), potato (n), bulb crops (n), wheat (n), barley	sesame (n), notey (n), pui (n) and hyacinth bean (n).	palms (o), arjun (o), mahua (o), babul (o) and siris (o) along roads, dykes and ponds.

TABLE 5.2 (continued)

FACETS	WET SEASON	WINTER	SUMMER	PERENNIAL
		(n) spinach (n), mustard (n), linseed (n) and sun-:flower (n); Egyptian clover (n) and rice bean (n) as pasture crops.		
Base	cultivation of annual crops over the entire area; lowland rice mainly; barnyard millet, little millet, Job's tears (n) and white jute (ton) on small proport-:ions.	rice (n), grass pea, green gram (n), gram (t) and lentil (t).	chilli, brinjal, notey, pui, hyacinth bean and sesame.	para grass and bamboos (o) on the stream bank; palms (o), arjun (o), mahua (o), babul (o) and siris (o) along roads and dykes.

Note: see SECTION 5.3 for explanations.

TABLE 5.3 RECOMMENDED LAND USE PATTERN FOR SYSTEM C

FACETS	WET SEASON	WINTER	SUMMER	PERENNIAL
Summit	-	-	-	strict maintenance of the natural forest.
Shoul-:der	-	-	-	strict maintenance of the natural forest.
Foot-:slope	cultivation of annual crops over the lower slopes of the facet; lowland rice (mn) mainly; common bean (ton) and cowpea (so) over small areas; cluster bean intersown with pasture.	Egyptian clover (sn) and rice bean (n) as pasture crops.	cucurbits (n).	strictly maintained natural forest over the upper slopes; small areas of bamb-:oos (n) and babui grass (n); small pasture of durba, marvel (sn), blue panic (on) and dinanath (n) grasses and lucerne (on) and kudzu (o) legumes with scattered subabul (o), arjun and mahua and hedge of cantala (o).
Toe-:slope	cultivation of annual crops over most of the area; lowland rice mainly; barnyard millet, Job's tears (n), little millet (o) and white jute (ton) on small proportions.	grass pea, safflower, chilli, brin-:jal, mustard, linseed, sun-:flower, green gram (n), cole crops (n), pea (n), tomato (n), wheat (n), barley (n) and spinach (n) over the greater part; small areas of gram (t), lentil (t), potato (s),	chilli, brinjal, notey, pui, hyacinth bean and sesame.	small pasture of durba (o), marvel (o) and dinanath (o) grasses with a few bamboo (o), babul (o) and siris (o); small orchard of jam (o), tamarind (o) and pummelo (to); mahua (o), arjun (o), babul (o), siris (o) and palms (o) along dykes.

TABLE 5.3 (continued)

FACETS	WET SEASON	WINTER	SUMMER	PERENNIAL
		bulb crops (sn) and tobacco (s); Egyptian clover and rice bean as pasture crops.		
Base	cultivation of annual crops over the entire area; lowland rice mainly; barnyard millet, Job's tears (n), little millet (o) and white jute (ton) over small areas.	rice (n), grass pea and green gram (n) mainly; gram (t) and lentil (t) over small areas.	chilli, brinjal, notey, pui, hyacinth bean and sesame.	para grass and bamboos on the stream bank; palms (o), arjun (o), babul (o) and siris (o) along dykes.

Note: see SECTION 5.3 for explanations.

TABLE 5.4 RECOMMENDED LAND USE PATTERN FOR SYSTEM D

FACETS	WET SEASON	WINTER	SUMMER	PERENNIAL
Summit	cultivation of annual crops on 20% of the area; horse gram (n), mat bean (n), pigeon pea (sn), yam (m) bambara ground-:nut, little millet, kodo millet (n), sorghum (n), maize (n), finger millet (cn), common millet (cn), foxtail millet (cn), lima bean (sn), cotton (n), niger seed (s), sunnhemp (n) and mesta (n); cluster bean (n) and goa bean (mn) intersown with pasture.	Egyptian clover (n) and rice bean (n) as pasture crops.	cucurbits (sn).	reafforestation of 30% of the area with native sal and other species; reafforestation of 20% of the area with eucalypt and akasmoni; pasture of durba, rhodes (n), marvel (n), guinea (n), sudan (n) and blue panic (mn) grasses and lucerne (n) and kudzu (n) legumes with scatter-:ings of subabul and babul and hedge of sisal (oc) and cantala (m) on 20% of the area; orchard of papaya (n), banana (n), mango (n), guava (n), lime (n), sapodilla (n) and pineapple (tc) on 10% of the area.
Shoul-:der	rice straw mushrooms on 10% of the area.	-	-	reafforestation with native sal (ms), kend (s) and palas (s) in greater part and natural pasture in smaller part, on 80% of the area.
Foot-:slope and Toe-:slope	cultivation of annual crops on 65% of the area; lowland rice over the greater part; black gram	grass pea, safflower, chilli, brin-:jal, mustard, linseed, suflower, green gram (n), cole crops (n),	chilli, brinjal, notey, pui, hyacinth bean and sesame over	sugarcane (n), betel (n) and black pepper (n) on 15% of the area; small orchards of papaya (on), banana (on), tamarind, jam, bael, jujube (o) and

TABLE 5.4 (continued)

FACETS	WET SEASON	WINTER	SUMMER	PERENNIAL
	(o), cowpea (o), okra (o), arum (o), barnyard millet, little millet, Job's tears (o), sorghum (o), cotton (o), niger seed (o), sunn hemp (o), mesta (o), common bean (to), soya bean (tn) and white jute (tn) on small pro-:portions; cluster bean (o) inter-:sown with pasture.	pea (n), tomato (n), bulb crops (n), wheat (n), barley (n) over the greater part; gram (t), lentil (t), potato (sn), root crops (sn) and tobacco (s) on small proportions; Egyptian clover and rice bean as pasture crops.	most of the area; cucurbits (sn) on a small proportion.	pummelo (t); bamboos and babui grass on 5% of the area; small pastures of durba, marvel and dinanath grasses and lucerne (o) and kudzu (o) legumes with scattered babul and siris and cantala (o) hedge; palms, babul, siris, arjun, palas, mahua and bohera along roads dykes and ponds.
Base	cultivation of annual crops over most of the area; lowland rice mainly; Job's tears (n), barn-:yard millet (n) and little millet (o) over very small areas.	rice (n) mainly; grass pea (s), green gram (sn), gram (t) and lentil (t) over small areas.	sesame (n) mainly; notey (sn), pui (sn), hyacinth bean (sn), chilli (sn) and brinjal (sn) over small areas.	para grass in a very small area; palms (o), babul (o), siris (o) and arjun (o) along dykes.

Note: see SECTION 5.3 for explanations.

TABLE 5.5 RECOMMENDED LAND USE PATTERN FOR SYSTEM E

FACETS	WET SEASON	WINTER	SUMMER	PERENNIAL
Summit and Shoul-:der	cultivation of annual crops on 10% of the area; pigeon pea (n), horse gram (n), mat bean (n), cucurbits (n), cotton (n), sunn hemp (n), bambara groundnut and rice straw mushrooms mainly; cowpea (sn), okra (sn), yam (ms), arum (sn), sweet potato (sn), finger millet (cn), common millet (cn), kodo millet (n), foxtail millet (cn), sorghum (sn), maize (sn), lima bean (sn) and mesta (sn) on small proport-:ions; cluster bean (n) and goa bean (msn) intersown with pasture.	Egyptian clover (sn) and rice bean (n) as pasture crops.	cucurbits (n).	reafforestation with native sal and other species on 40% of the area; reafforestation with eucalypt and akasmoni on 25% of the area; pasture of rhodes (n), dinanath (n) and blue panic (mn) grasses and kudzu (n) and hyacinth bean (n) legumes with scatterings of subabul, silk-cotton, kapok(tn) and casuarina (tn) trees and hedge of sisal (cn) and cantala (m) on 10% of the area; orchard on 5% of the area with cashewnut and custard apple mainly and also papaya (sn), banana (sn), mango (sn), jack fruit (sn), guava (sn), lime (sn), jujube (sn), palms (sn), citron (sn), orange (tn), grapefruit (tcn) and pineapple (tcn).
Foot-:slope	cultivation of annual crops on 75% of the area; lowland rice (mn) mainly; arum (on),	grass pea (s) and bulb crops (n) mainly; chilli (sn), brinjal (sn), potato (sn) tomato (sn),	cucurbits (n) and sesame (n) mainly; chilli (sn),	pasture of durba and dinanath (n) grasses and kudzu (so) legume with scatterings of subabul (o) and babul (s) and hedge of cantala (o) on 15% of

TABLE 5.5 (continued)

FACETS	WET SEASON	WINTER	SUMMER	PERENNIAL
	barnyard millet (sn), little millet (sn) and niger seed (son) on small proportions; cluster bean (o) inter-:sown with pasture.	spinach (sn) and sunflow-:er (sn) on small pro-:portions; rice bean (sn) as a pasture crop.	brinjal (sn), notey (sn), pui (sn) and hyacinth bean (sn) on small proport-:ions.	the area; orchard of mango (os), guava (on), jujube (os) and bael (sn) on 5% of the area; subabul (o) and babul (s) along dykes.
Toe-:slope	cultivation of annual crops on 90% of the area; lowland rice (m) mainly; barnyard millet, little millet, black gram (o), cow-:pea (on), okra (on) and arum (on) on small proportions.	grass pea, safflower, cole crops (n), pea (n), chilli (n), brinjal (n), tomato (n), bulb crops (n), wheat (n), barley (n), spinach (n), mustard (n), linseed (n), sunflower (n), green gram (n), gram (t) and lentil (t); Egyptian clover (n) and rice bean (n) as pasture crops.	sesame (n), notey (n), pui (n), hyacinth bean (n), chilli (n) and brinjal (n).	sugar cane (n), betel (n) and black pepper (n) on 10% of the area; palms, arjun, mahua, babul and siris along dykes.
Base	cultivation of annual crops over the entire area; lowland rice mainly; barnyard millet and Job's tears (n) on small proportions.	rice (n) mainly; grass pea, green gram (n), gram (t) and lentil (t) on small proportions.	sesame, chilli, brinjal, notey, pui and hyacinth bean.	palms, arjun (o), mahua (o), babul (o) and siris (o) along dykes and ponds.

Note: see SECTION 5.3 for explanations.

TABLE 5.6 RECOMMENDED LAND USE PATTERN FOR SYSTEM F

FACETS	WET SEASON	WINTER	SUMMER	PERENNIAL
Dara-:keswar and Kasai plains	cultivation of annual crops on 70% of the area; lowland rice mainly; soya bean (t), white jute (t), sunn hemp (o), mesta (o), black gram (o), common bean (to), cowpea (o), okra (o), arum (o), sorghum (o), Job's tears, barnyard millet and little millet on small proportions; cluster bean (o) inter-:sown with pasture.	rice (n) on 20% of the cultivated area; over the rest mainly cole crops, pea, chilli, brinjal, tomato, potato (r), bulb crops, wheat, barley, spinach, mustard, linseed, sunflower, green gram, safflower and grass pea; gram (t) and lentil (t) on small proportions; Egyptian clover and rice bean as pasture crops.	sesame, notey, pui, hyacinth bean, chilli and brinjal mainly; cucurbits (s) on a small proport-:ion.	sugarcane, betel and black pepper on 20% of the area; pastures of durba, marvel, dinanath and para grasses and kudzu (o) legume with scatterings of arjun, babul, siris and subabul (o) and hedge of cantala (o) on banks of streams and ponds; small orchards of papaya (o), banana (o), mango (o), guava (o), lime (o), jujube (o), sapodilla (o), pummelo (t), bael, jam and tamar-:ind; small areas of bamboos and babui grass; palms, babul, siris, arjun, subabul (o) and silk-cotton (o) along dykes and roads.
Silai plain	cultivation of annual crops on 85% of the area; lowland rice (s) mainly; barnyard millet, little millet (s), sweet potato (o), pigeon pea (o), horse gram (o) and mat bean (o) on small	potato (n), root crops (n), tobacco, safflower (s), grass pea (s) and green gram over the greater part; wheat (sn), barley (sn), mustard (sn), linseed (sn), cole crops (sn), pea (sn), chilli	cucurbits (n) mainly; sesame (sn), notey (sn), pui (sn), hyacinth bean (sn), chilli (sn) and brinjal (sn) on small	sugarcane (sn), betel (sn) and black pepper (sn) over small areas; pastures of durba (s), marvel (sn) and dinanath (s) grasses and kudzu (os) legumes with scatterings of babul (s), siris (s) and arjun (s) and hedge of cantala (o) along banks of streams and ponds; bamboos (sn) and babui (n) along stream banks;

TABLE 5.6 (continued)

FACETS	WET SEASON	WINTER	SUMMER	PERENNIAL
	proportions; cluster bean (os) inter-:sown with pasture.	(sn), brinjal (sn), tomato (sn), bulb crops (sn) and sunflow-:er (sn) on small proportions; Egyptian clover (sn) and rice bean (sn) as pasture crops.	proport-:ions.	small orchards of mango (os), jujube (os), jam (s) and tamarind; palms (s), babul (s), siris (s) and arjun (s) along dykes and roads.
Subar-:nar-:ekha plain	cultivation of annual crops on 70% of the area; lowland rice mainly; barnyard millet, little millet (s), soya bean (ts), sweet potato (o), pigeon pea (o), horse gram (o) mat bean (o) arum (os), cowpea (os), okra (os), sunn hemp (o) and mesta (o) on small pro-:portions; cluster bean (o) inter-:sown with pasture.	potato (n), root crops (n), bulb crops (n), tobacco, grass pea (s) and safflower (s) over the greater part; cole crops (sn), pea (sn), chilli (sn), brinjal (sn), tomato (sn), wheat (sn), barley (sn), spinach (sn), mustard (sn), linseed (sn) and sun-:flower (sn) on small pro-:portions; Egyptian clover (sn) and rice bean (sn) as pasture crops.	cucurbits (n) mainly; sesame (sn), notey (sn), pui (sn), hyacinth bean (sn), chilli (sn) and brinjal (sn) on small proport-:ions.	sugarcane (sn) on 20% of the area; betel (sn) and black pepper (sn) over small areas; pastures of durba, dinanath and marvel (sn) grasses and kudzu (o) legume with scatterings of babul, siris, arjun, silk-cotton (o) and subabul (o) and hedge of cantala (o) along banks of streams and ponds; bamboos (sn) and babui (n) along stream banks; small orchards of papaya (os), banana (os), mango (os), sapodilla (o), jam(s) and tamarind; palms (s), babul, siris and arjun along roads and dykes.

Note: see SECTION 5.3 for explanations.

season. The wet season crops are obviously rainfed. Most of the winter crops and all summer crops are irrigated. There are both rainfed and irrigated crops among the perennials. The limitations to the suitability of a crop, if any, are indicated by the subclass symbols. The suitability of the potential crops should be checked by field trials before introduction. The infrastructure necessary for their production should also be ensured. The recommended land use pattern for each system is discussed briefly in the following paragraphs.

In land system A, the heavily disturbed natural forests of summit and shoulder areas require to be replanted with the same species. Eucalypt and akasmoni are not recommended because they are less suitable to the shallow soils of these facets than the native species. Arable use is not suggested for the same reason. But a small pasture can be created over the summit area where the soil is relatively deeper. A part of the shoulder facet may also be kept open for growing mushrooms.

Since pasture, bamboo and orchard find little room in the upper facets and are unsuitable to the poorly drained areas, it is recommended that 20% of the footslope area is devoted to them. The perennial cash crops are also better grown in this facet. A 10% of the area is proposed for them. This means a slight reduction of the present area under annual crops but more cash income for the peasant and better feed for the cattle.

Numerous annual crops are recommended for the footslope and base areas which may be successively grown round the year. But it is strongly advocated to grow at least one nitrogen-fixing crop once a year at each plot. The annual pasture crops may serve this purpose well. There are relatively fewer crops suitable for the toeslope area, particularly during winter, on account of its poorer drainage conditions. Rice can be an important winter crop here, but care must be taken for rotation with other crops and nitrogen-fixing legumes.

The forests of the upper facets of system B have been totally destroyed. It is considered advisable to reafforest these areas. But they are also suitable for other uses by virtue of their deep soils. Pasture, orchard, bamboo and some annual crops may be more successful here than in the lower facets. Therefore, parts of the upper facets are proposed for these uses. The greater part of the area is given to forests. Both the native forest species and eucalypt are equally suitable, but the growing of native trees is emphasized on ecological and social grounds.

Very small areas are recommended for pasture, orchard or bamboo in the footslope areas. This facet, along with the toeslope and base areas, may be mainly devoted to annual cultivation. More winter crops are suggested for the toeslope area on account of its finer soil and greater fertility. The footslope area is better suited to root crops and cucurbits on account of its coarser soil. Winter rice may be important in the base area with poorer drainage.

Land system C carries relatively undisturbed natural forest over the summit, shoulder and part of the footslope facets. It is urged that these forests should be conserved with strict controls. The remaining part of the footslope is divided between pasture, orchard, bamboo groves and annual crops. The greater proportion of the area is recommended for the annual crops. Since the pastures are limited in area, it is advocated that annual pasture species are grown over the entire cultivated area in winter. These species are also better suited to this area than other food or cash crops on account of massive soils.

Winter food and cash crops can be grown more successfully over the toeslope area. Some annual pasture crops may also be grown there. It is also suggested that small areas of pasture and orchard could be created in this facet. The poorly drained base area is best suited to rice in both wet season and winter. Some legumes should also be grown to restore soil fertility.

The summit area of system D has unique land qualities. In contrast to other summit areas, it is moderately well drained, loamy in soil texture and 'medium' in potassium content and cation exchange capacity. Therefore, this facet is well suited to many pasture species, fruit trees, food crops and cash crops, in addition to the forest trees. The shoulder facet, on the other hand, carries shallow soil where nothing but native forest species and possibly mushrooms are suitable. Both the summit and shoulder facets previously carried forests, but they have been destroyed. Recently, the State Forest Department reafforested the summit area entirely with eucalypt and akasmoni. It is suggested that the long term plan should be to reafforest 30% of the summit area with native forest species and 20% with eucalypt and akasmoni and to create pasture, orchard and arable land over the remainder. This reorganization can be done within a few years' time when the eucalypt will be felled for sale. The presently bare shoulder area should be reafforested with native forest species, leaving perhaps 10% of the area as clearings for growing mushrooms.

The footslope and toeslope facets may be mainly devoted to the cultivation of annual crops as they are now. It is recommended that small parts of the area are reserved for perennial crops, bamboo, pasture and fruit trees, which are well suited here. The base facet may be given entirely to food crops. In the cultivated areas, care needs to be taken to grow nitrogen-fixing crops in each plot once a year. This would help to restore a part of the soil fertility.

Land system E has deep soils over the summit and shoulder areas like those of system B. There is still a poor forest over a part of the area, but the rest has been destroyed. It is recommended that the greater part of the area should be reafforested and the remainder should be given to suitable pasture species, fruit trees, bamboos and annual crops. It is suggested that native forest species are planted over a greater area than eucalypt and akasmoni.

The footslope facet of this system carries some pasture. It seems sensible to maintain this area under the same land use and to sow with improved species. The remainder of the facet is proposed for annual crops. But the choice and success of crops are reduced by limited depth of the soil. The toeslope and base facets are given entirely to annual and perennial crops to which these areas are better suited.

The present land use pattern of the flood plains is characterized by intensive cultivation of annual and perennial crops. There are small orchards but no forest and little pasture. Therefore, it is recommended that trees are grown along dykes and roads. It is unlikely that the peasants will turn cultivated lands into pasture, but annual pasture crops can be grown. Moreover, the banks of streams and ponds can be developed for pastures with scattered trees. Thus, the present area of annual and perennial crops may be retained and at the same time, the supply of fodder, fuelwood and timber may be increased to a modest level.

Among the four flood plains, the Darakeswar and Kasai have comparable land qualities. Therefore, the same pattern of land use is recommended for them. Most of the annual and perennial crops are highly suitable to these two plains on account of medium texture, strong structure and moderate fertility of the soils. The coarse, structureless soils of the Silai plain limit the suitability of most crops to a moderate or marginal level, but potato, tobacco, root crops and cucurbits can be more successful in this plain. The Subarnarekha plain carries moderate coarse soils of weak structure and thus, offers conditions between the Silai and Darakeswar-Kasai plains.

By analysing the recommended land use patterns, it becomes apparent that the summit and shoulder facets between systems A - E are different in their land use potential in spite of having comparable soil types (SECTION 4.8). This is due to the influence of occurrences of massive ironstone determining the effective depth of soils. It is interesting that the massive ironstone is only significant to this region in this way. It does not indicate the fertility of the soils. The occurrences of clay beds also exert significant influence upon the land use potential, as evident from the summit area of land system D. These two features (massive ironstone and clay bed) can occur within other systems and hence are not characteristic to any of them. Cemented ironstone can also limit the effective depth of soils in other facets, such as in the footslope area of system E.

The lower facets clearly reflect the hierarchical pattern of soil texture and nutrients between the land systems (SECTION 4.8). This is not apparent in the number of crops that can be grown but in their relative success over an area. In the lower facets of system A, most of the crops are limited by inadequate nutrients. This situation improves progressively towards system E and then to the Darakeswar and Kasai plains of system F where few crops have nutrient or soil limitations.

The flood plains are most significant in this region for the production of food and cash crops. This is not only because of their high degree of suitability but also because of their cover of a great proportion of the cultivable area of the region (SECTION 4.9). Land systems D and E are next only to the flood plains in suitability to the food and cash crops. But they are least significant in this region on account of their small area. Nevertheless, these two systems along with systems A, B and C contribute towards the economy of the region by their forest and animal products.

The recommended land use pattern developed through the suitability evaluation approaches closer to an optimum use of land. It also promotes a greater diversity of crops with a chance of creating both a greater cash return and an improved diet. At the same time, it champions the ecological balance of the region and interest of the local people. In other words, it directs to an economic development of the region which may be sustained with modest input and minimum adverse effects. The implementation of the recommended pattern requires prior solution of complex social and legal problems. Then, plans have to be sketched out for every farm selecting the types of uses and the crops for seasonal succession. This farm planning depends on the size and situation of a farm and capital and interest of a peasant. A consideration of these aspects is beyond the scope of the present thesis, but it is appreciated that without them a development plan is not complete.

CHAPTER 6

SUMMARY OF THE MAIN CONCLUSIONS AND RECOMMENDATIONS

This study has examined the characteristics of the soils of the Southern Rarh Plain and on the basis of soil, climate and other characteristics, has evaluated the suitability of land for various land use types, both current and potential. For these purposes the region is classified into six land systems according to detailed changes in slope form, slope material, soil drainage, stream order and other characteristics. The constituent facets of the land systems form the units of both soil study and suitability evaluation.

The soils are studied according to the current concepts of soil taxonomy (Soil Survey Staff, 1975). Previously, the pedological concept of these soils was dominated by an association with ironstone or hard 'laterite'. In reality, ironstones are found over only 10% of the area. Nevertheless, it was believed that the soils, like the ironstones, were products of extreme weathering and hence poor in fertility (Raychaudhuri et al., 1963). A review of the relationship between ironstones and the soils in which they are found (Sivarajasingham et al., 1962 and Maignien, 1966), indicates that they may both develop independently. The plinthites and ironstones of this region are the results of local re-organization of the sesquioxidic components of alluvial parent materials and vary according to relief and drainage conditions. They do not indicate an extreme weathering status nor necessarily low soil fertility. The present study shows that the soils belong mainly to the Alfisol order, being characterized by moderate degrees of base saturation and cation exchange capacity and argillation. There are no Oxisols nor even Ultisols in this region. The significance of massive or cemented nodular ironstones lies in their influence in determining the effective depth of soils.

In each of the toposequential land systems A - E, the surface soil conditions improve from the summit towards the base facet. The texture becomes finer and organic matter content increases down the slope. Consequently, structure improves and available water capacity increases in the same direction. The nitrogen content increases with organic matter. The exchangeable bases and cation exchange capacities increase in the same way. Such improvement is the result of downslope migration of silt, clay, organic matter and exchangeable bases either as suspension or in solution, mainly with overland flow. These surface soil properties show statistically significant relationships with distance downslope.

A number of other soil properties vary less consistently. Two major nutrients, available phosphorus and potassium, are very erratic in distribution over the slope. They are probably more strongly influenced by the chemical environment than by overland flow. They are generally low in amount, except where heavily applied as fertilizers. Both calcium carbonates and free iron are present in very small quantities. The carbonates increase downslope. But the distribution of free iron over the slope is inconsistent. In some systems, it increases downslope in spite of poor drainage. The factors causing such a pattern are not fully understood at present. The total soluble salts increase downslope, but their quantity is very low. The likelihood of salination following heavier irrigation is remote. The saturation percentages of sodium and aluminium are also well below toxic levels.

In addition to improved soil conditions, an increasingly greater amount of water becomes available towards the lower slope facets by lateral flow. The water-table also becomes shallower in the same direction and consequently, the lower facets suffer from poor drainage.

Silt, clay, organic matter, exchangeable bases and water may also be lost from the lower facets by draining into a stream or sheet flow. Such loss is greatest in a third order stream basin (system A) and minimum in a streamless basin (system E). In other words, the accumulation of these materials over the lower facets increases with the decreasing stream order of a basin, from minimum at A to maximum at E. There is, therefore, a hierarchical relation-:ship between land systems A - E as determined by their hydrological characteristics. System D fails to fit into the hierarchical table (TABLE 4.2) because despite the absence of a stream, there is an efficient periodic drainage of its lower facets during wet spells.

Among the soil properties, those increase from A to E most clearly are clay, exchangeable bases, cation exchange capacity, base saturation and pH value. The silt and organic matter fail to show this increase because they are influenced by other external factors - stream deposition and application of manures respectively.

As the accumulation of water tends to increase from system A to E, the water-table becomes shallower and persists for a longer period. In these conditions, concretions of calcium carbonates and bicarbonates accumulate by precipitation at the capillary fringe of groundwater. In system C, these concretions occur below 2 m in depth. In system E, they are found within 1 m. They are associated with earth mounds in system E. The concretions and mounds may be genetically linked to each other although it has not been possible to prove this during the present field work.

The soil properties within profiles also change from summit sites to basal sites in land systems A - E, as indicated by weighted means of 120 cm profiles. But the pattern of change is not as regular as that of surface soil properties. Firstly, throughflow and groundwater flow are less efficient than overland flow in trans:porting materials in suspension. Secondly, complex local processes of vertical removal and accumulation prevent the soil profiles from developing a regular pattern across the slope. Therefore, the trend of soil conditions improving down the slope and from system A to E, is more clearly indicated by surface soil properties.

Land system F, being the flood plains of fourth order streams, experiences different processes from those in the toposequential systems. The soil conditions here are controlled by the nature of annual flood deposition of the streams. In the Darakeswar and Kasai plains, annual deposits are dominated by silt on account of regular but mild floods. The soil texture groupings are medium to medium fine. The organic matter content is also moderate. These soils are high in exchangeable bases and in their cation exchange capacities. All nutrients, including phosphorus and potassium, are at moderate levels. The Silai plain is, on the other hand, severely flooded. Its soils are coarse, structureless and, except for heavily applied phosphorus and potassium, poor in nutrients. The Subarnarekha plain has soils of moderately coarse to medium texture because of the nature of stream load. The soil conditions are better than in the Silai plain.

It is apparent from the above summary that among the twelve land qualities or requirements relevant to plant growth in this region, the soil-related qualities improve towards the lower facets in a toposequence and, over the lower facets from system A to E. The soil conditions are best on the Darakeswar and Kasai plains. More water also becomes available in the same directions, but soil drainage becomes increasingly poor. The floods, particularly at the Silai plain, are also injurious to some plants. The upper facets, in addition to having poor soil conditions, are hosts to termites which may be destructive to some plants. Soil erosion is limited to slight or moderate sheet erosion. Only where the slope of the upper facets is long, does moderate gully erosion become noticeable. The cliffs bordering the flood plains are also very severely gully eroded at localized areas on account of long or steep slopes. The climate-related qualities are virtually uniform over all facets. They determine the overall regional suitability for crops. The soil-related qualities, water availability and soil drainage are the main determinants of suitability for crops between the facets. Flood, erosion and pests influence only some crops locally.

The summit and shoulder areas of systems A - E are not suitable for many of the cultivated crops on account of poor soil conditions. They are suitable for perennial trees, permanent pasture and some hardy annual crops which require free drainage. So far, these two facets have been left to forests. They are highly suitable for native forest species, but the forests have been severely disturbed by man. The policy of the State, to whom the ownership of all forests belongs, is to reafforest these areas with quick-growing exotic species for rapid commercial return. It is obviously necessary to reafforest the disturbed areas, but a large scale replacement of the native species is destroying the wildlife and disrupting the economic and social life of the local peoplė. Therefore, it is strongly recommended that a greater proportion of the reafforestation is given over to native species. Moreover, the State ought to share the forest products with the local people. A system of joint activities between the State and local people for developing and using the forest resources would serve this end most beneficially.

All the summit and shoulder areas need not to be given over to forests. In areas of deep soils, small parcels of land may be used as permanent pastures of improved species with scattered multi-purpose trees and hedge plants. The responsibility for improving and managing the pastures, which are 'common', may be taken by village councils or co-operatives. Orchards of valuable and nutri-:tious fruits such as cashewnut and orange may also be created. Small areas may be used for growing annual crops. Pigeon pea, mat bean and cucurbits among the currently grown crops and cotton, sunn hemp and millets as potential crops are well suited to these areas. The pasture, orchard and annual crops may not be successful where the soils are limited in depth by occurrence of massive ironstone. But mushrooms can be grown in small parcles over these areas besides the forests.

In a few places these facets may be underlain by local beds of clay, resulting in moderately well drained soils with finer texture and better nutrient availability. These areas are more suitable than other summits for the annual crops, orchard and improved pasture. Therefore, it is recommended that a greater proportion of land is allocated to these uses in such cases.

The footslope areas possess better soil conditions than the summit and shoulder facets. They also have better drainage conditions than the toeslope and base areas. But nutrient deficiencies prevent them from achieving a high degree of suitability for many crops. Nevertheless, they are moderately suitable for a wide range of annual and perennial crops, pasture species, fruit trees, bamboos, planted grass and multi-purpose trees. They offer the best situation for vegetables in the wet season. They are also the best areas for valuable perennial crops such as sugarcane, betel and black pepper which are excluded from the upper facets by poor soils and from the lower facets by poor drainage. For the same reasons, the foot-:slope areas are best for some fruit trees, pasture species, bamboos and multi-purpose trees. At present, the winter and summer culti-:vation and the growing of perennial crops is very limited in the footslope facets due to scarcity of irrigation. With plentiful supplies of canal irrigation and manures and fertilizers, these facets could be utilized to their full potential in the future.

The toeslope areas of systems D and E are also imperfectly drained, like the footslope facets, on account of their topographic situation. These toeslope areas possess better soil conditions and higher nutrient status than the footslope facets. Therefore, they are suitable for more crops to a higher degree. But there remains the same problem of irrigation for the perennial and dry season crops.

The toeslope areas of systems A, B and C and the basal areas of all toposequential systems are poorly drained. During the wet season, these areas are highly suitable for rice which is grown universally. Some millets are also found suitable for these facets. They are potentially significant for their resistance to drought or protein-rich grains. During the winter, the water-table falls below the root zone of most crops in the toeslope facets of systems B and C and base facet of system A because of their relatively higher situation. Therefore, these three facets are suitable for many valuable food and cash crops and leguminous fodder during winter. At present, the area of winter cultivation is restricted by insufficient supply of irrigation. However, there are some crops such as grass pea and safflower which are highly suitable to these facets and require little irrigation. Their cultivation can be extended in area. The other crops currently grown and potential crops like sunflower and annual pasture legumes could be grown over extended areas if adequate irrigation becomes available from the canals.

The basal areas of systems B, C, D and E and the toeslope area of A remain under the influence of shallow water-table in winter. Therefore, these areas are best suited to rice. But successive cultivation of rice may exhaust the soil fertility. It is strongly recommended that nitrogen-fixing crops like grass pea and green gram are brought into rotation.

During summer, the water-table falls further so that the root zone becomes free from its influence in all poorly drained areas.

But summer cultivation is more limited than winter cultivation on account of scarcity of irrigation. If canal irrigation is available in summer, the valuable oilseeds and vegetables could be grown over extended areas.

The degree of suitability of the lower facets for annual crops increases from system A to system E. This results from increasingly greater availability of nutrients towards system E. But the availability of stream irrigation decreases in the same direction. Consequently, the area of dry season cultivation is more limited towards system E. The lower facets are not suitable for perennial crops on account of drainage limitations. Only multi-purpose trees can be grown along dykes and bamboos on stream-banks.

The flood plains, like the lower facets of toposequential systems, are better suited to the cultivation of crops. At present, virtually the entire area of flood plains is under annual and perennial crops. But pastures of improved species with scattered multi-purpose trees and hedges ought to be created in places like stream-, pond- and road-banks in order to meet the domestic requirements of fuel and fodder. It is also recommended that annual pasture crops are grown in the fallow plots and multi-purpose trees upon dykes.

All four flood plains are given to lowland rice in the wet season. These areas are well suited to rice, but the Silai and Subarnarekha plains may also support small patches of pigeon pea, mat bean and millets on account of relatively coarser soil texture. In the winter, the Darakeswar and Kasai plains are highly suitable for rice, vegetables, wheat and oilseeds. The Silai and Subarnarekha plains are better suited to potato and other root crops. The

Darakeswar and Kasai plains may do best with oilseeds and vegetables during summer whilst cucurbits would be most successful in the Silai and Subarnarekha plains. The Darakeswar, Kasai and Subarnarekha plains are also well suited for perennial crops. There are extensive areas under perennial and dry season crops in the flood plains due to availability of stream irrigation. The introduction of potential irrigated crops would also be relatively easier in the flood plains.

At present, the flood plains offer the best conditions for cultivated crops on account of favourable soil conditions, medium level of nutrients, imperfect drainage and availability of irrigation. These plains occupy 23% of the total area of the region. The lower facets of toposequential systems are also suitable for intensive cultivation, but they are limited in area and suffer from inadequate supply of irrigation. Land system E, containing most fertile lower facets, covers only 2% of the total area and lacks stream irrigation. The conditions of the toposequences could be improved with fertilization and irrigation when the canal system comes into operation, planned to be opened within the next few years. Nevertheless, the toposequential systems are suitable for various uses: forest, pasture, bamboos, orchard and cultivated crops; they would permit the development of a composite economy for the region.

The objective of the project has been the economic development of the Southern Rarh Plain through an optimum use of the productivity of land. The problem has been taken up from the basic level of land classification and the study of characteristics of each type of land. The soils have been specially studied, for they were believed to be the main drawback for the development of the region. It has been proved here that there is a significant proportion of fertile soils in this region. The data of land characteristics (classified as qualities) have been used to determine the degree of suitability of a type of land for various land use types. Many new types of land use have been found out to be suitable through this process. The current land use types have also been checked and the more suitable types sorted out. Finally, the optimum uses for each type of land have been selected from the suitable ones in view of economic, social, nutritional and ecological conditions of the region. It is recommended that the current land use pattern is re-shaped with the optimum uses. This would lead to the maximum possible yield with relatively minimum input and few adverse effects.

As a development plan, the project is far from complete. Only a step has been taken towards the solution of development problems of this region. The next step would be the implementation of the recommended land use pattern. It would depend on the acceptability of the peasants, the flexibility of land tenure, the economic viability of the suggested crops and the degree of assistance and co-operation of the State. A detailed analysis of these factors is beyond the scope of this project, but will form the object of future research. Nevertheless, a basic ground has been created through this project for future development plans. It has been shown that "laterite plains" are not without potential for development. Methods of study-:ing these regions for development purpose have been systematized in this thesis. These methods can be applied to other "lateritic plains". The methods are flexible; they can be improved. More new crops or other types of land use (e.g. construction) can be included for evaluation within the frame. Furthermore, a consider-:able amount of data on the land characteristics of the region have been collected, forming the basis of other development programmes. At the same time, a quantity of information has been compiled concern-:ing the requirements of 154 land use types. This may be used in other suitability evaluations.

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APPENDIX A

MORPHOLOGICAL, PHYSICAL AND CHEMICAL PROPERTIES OF SOILS IN LAND SYSTEMS A-E AND IN GULLY ERODED AREA

source: field and laboratory work; see SECTIONS 3.3 and 3.4 for methods of studies.

ABBREVIATIONS USED IN APPENDIX A

ORG. MTR. or O.M. = Organtic matter
Av. = Available
Ex. = Exchangeable
L.R. = Lime requirement
T.E.B. = Total exchangeable bases
C.E.C. = Cation exchange capacity
B.S. = Base saturation
E.C. = Electrical conductivity
F.C. = Field capacity
W.P. = Wilting point
A.W.C. = Available water capacity
B.D. = Bulk density

LAND SYSTEM A, SUMMIT FACET

Location: 1480 m south of R. Parang and 800 m west of railway track, Bhabrigere village, Salbani police station, Midnapore district, West Bengal.
Elevation: 50 m above m.s.l.
Slope angle: 0.1 degree.
Depth to water-table: 6 m in the wet season and 13 m in the summer.
Soil drainage: well.
Vegetation and land use: open coppice of Shorea robusta and associates.
Soil erosion: slight sheet erosion.
Stoniness: class 1.
Rockiness: class 0.
Flooding: nil.
Soil classification: Rhodic Paleustalf.

Horizon	Depth (cm)	Description
A1	0-29	Red (2.5YR 4/6), dry to dark red (2.5YR 3/6), moist; sandy loam; structureless, massive; slightly sticky and slightly plastic (wet), friable (moist), slightly hard (dry) in consistence; common very fine, a few fine roots; many termites and ants; common small ironstone concretions; diffuse boundary.
B21t	29-60	Dark red (2.5YR 3/6), dry to dark reddish brown (2.5YR 2/4), moist; sandy clay loam; slightly sticky and slightly plastic (wet), friable (moist), slightly hard (dry) in consistence; common very fine, a few fine, common medium and coarse roots; many ants; common small ironstone concretions; diffuse boundary.
B22cn	60-87	A few very fine and fine, common medium and coarse roots; many (80%) small and medium ironstone concretions; diffuse boundary.
B23m	87-100	Weakly cemented pisolitic ironstone passing into strongly cemented massive ironstone.

LAND SYSTEM A, SHOULDER FACET

Slope angle: 3.6 degrees.
Depth to water-table: 4m in the wet season and 10m in the summer.
Soil drainage: excessive.
Vegetation and land use: open coppice of Shorea robusta and associates.
Soil erosion: moderate sheet erosion.
Stoniness: class 3.
Rockiness: class 4.
Flooding: nil.

A pit could not be dug on account of outcrops of strongly cemented pisolitic and massive ironstones occupying 85% of the area.

LAND SYSTEM A, FOOTSLOPE FACET

Location: 1110 m south of R. Parang and 800 m west of railway track, Bhabrigere village, Salbani police station, Midnapore district, West Bengal.
Elevation: 38 m above m.s.l.
Slope angle: 0.95 degree.
Depth to water-table: 1 m in the wet season and 6 m in the summer.
Soil drainage: imperfect.
Vegetation and land use: cultivated; single crop of rice.
Soil erosion: nil.
Stoniness: class 0.
Rockiness: class 0.
Flooding: nil.
Soil classification: Plinthustalf.

Horizon	Depth (cm)	Description
Ap	0-20	Pale yellow (2.5Y 8/4), dry to light olive brown (2.5Y 5/4), moist; a few fine faint yellowish red mottles along rice roots; loam; moderate medium crumb in structure; slightly sticky and slightly plastic (wet), friable (moist), slightly hard (dry) in consistence; common very fine roots; a few earthworms, common ants; a few small and medium ironstone concretions; clear boundary.
B21t	20-48	Pale yellow (2.5Y 8/4), dry to pale yellow (2.5Y 7/4), moist; common medium faint reddish yellow (7.5YR 7/6, dry and 6/6, moist) mottles; loam; slightly sticky and slightly plastic (wet), friable (moist), slightly hard (dry) in consistence; common very fine roots; a few small ironstone concretions; gradual boundary.
B22t	48-75	Yellow (10YR 8/6), dry to brownish yellow (10YR 6/6), moist; common medium distinct red (2.5YR 5/8, dry and 4/8, moist) mottles; sandy clay loam; slightly sticky and slightly plastic (wet), friable (moist), slightly hard (dry) in consistence; a few very fine roots; ant hole; common medium and big ironstone concretions; diffuse boundary.
B23t	75-97	White (2.5Y 8/2), dry to pale yellow (2.5Y 7/3), moist; many (over 50%) medium prominent red (10R 5/8, dry and 4/8, moist) mottles; sandy clay loam; slightly sticky and plastic (wet), friable (moist), slightly hard (dry) in consistence; common small and medium ironstone concretions; diffuse boundary.
B24tg	97-128	White (7.5Y 8/1), dry to light grey (7.5Y 7/1), moist; many (over 50%) coarse prominent red (2.5YR 5/8, dry and 4/8, moist) mottles; sandy clay loam; sticky and plastic (wet), firm (moist),

slightly hard (dry) in consistence; a few small and medium ironstone concretions.

LAND SYSTEM A, TOESLOPE FACET

Location: 825 m south of R. Parang and 800 m west of railway track, Bhabrigere village, Salbani police station, Midnapore district, West Bengal.
Elevation: 35 m above m.s.l.
Slope angle: +/- 0.15 degree.
Depth to water-table: near surface in the wet season and 3.5 m in the summer.
Soil drainage: poor.
Vegetation and land use: cultivated; single crop of rice.
Soil erosion: nil.
Stoniness: class 0.
Rockiness: nil.
Flooding: nil.
Soil classification: Typic Ochraqualf.

Horizon	Depth (cm)	Description
Apg	0-11	White (N 8/0), dry to light grey (N 7/0), moist; common fine faint yellow mottles along rice roots; silt loam; moderate medium crumb in structure; slightly sticky and slightly plastic (wet), friable (moist), slightly hard (dry) in consistence; common very fine and fine roots; common earthworms, a few ants; a few small ironstone concretions; clear boundary.
B21tg	11-29	White (7.5Y 8/1), dry to light grey (7.5Y 6/1), moist; many fine and medium distinct brown (10YR 6/6, dry and 4/6, moist) mottles; silt loam; slightly sticky and slightly plastic (wet), friable (moist), slightly hard (dry) in consistence; common very fine, a few fine roots; a few small ironstone and medium manganese concretions; clear boundary.
B22tg	29-72	White (N 8/0), dry to light grey (N 7/0), moist; many medium and coarse distinct brown (7.5YR 6/6, dry and 5/6, moist) mottles; silty clay; sticky and plastic (wet), firm (moist), very hard (dry) in consistence; common very fine roots; a few medium manganese, common small ironstone concretions; clay skins; gradual boundary.
B23tg	72-117	Light grey (N 7/0), dry to light grey (N 6/0), moist; clay; slightly sticky and plastic (wet), very firm (moist), very hard (dry) in consistence; a few very fine roots; a few medium manganese, common small ironstone concretions; gradual boundary.

B24tg	117-130	White (N 8/0), dry to light grey (N 7/0), moist; clay; slightly sticky and plastic (wet), extremely firm (moist), very hard (dry) in consistence; a few very fine roots; a few medium manganese, common small ironstone concretions.

LAND SYSTEM A, BASE FACET

Location: 210 m south of R. Parang and 800 m west of railway track, Bhabrigere village, Salbani police station, Midnapore district, West Bengal.
Elevation: 37 m above m.s.l.
Slope angle: +/- 0.5 degree.
Depth to water-table: near surface in the wet season and 4 m in the summer.
Soil drainage: poor.
Vegetation and land use: cultivated; single crop of rice in the year of field work (1981); multiple-cropped in some years; rice, wheat, potato, oilseeds and vegetables main crops.
Soil erosion: nil.
Stoniness: class 0.
Rockiness: nil.
Flooding: very mild and regular.
Soil classification: Typic Ochraqualf.

Horizon	Depth (cm)	Description
Ap	0-16	Pale yellow (2.5Y 7/3), dry to light brownish grey (2.5Y 6/2), moist; many fine distinct brown mottles along rice roots; loam; moderate medium crumb in structure; slightly sticky and slightly plastic (wet), friable (moist), slightly hard (dry) in consistence; common very fine roots; common earthworms and ants; a few small ironstone and manganese concretions; clear boundary.
A2	16-45	White (2.5Y 8/2), dry to light grey (2.5Y 7/2), moist; many fine distinct brown (7.5YR 6/6, dry and 4/6, moist) and medium black (2.5YR 2/1, dry and moist) mottles; loam; slightly sticky and non-plastic (wet), very friable (moist), slightly hard (dry) in consistence; common very fine roots; a few small manganese and ironstone concretions; abrupt boundary.
B21tg	45-53	White (5Y 8/1), dry to light grey (5Y 6/1), moist; common fine distinct brown (7.5YR 7/8), dry and 5/6, moist) and medium black (7.5YR 2/1, dry and moist) mottles; silt loam; slightly sticky and plastic (wet), firm (moist), very hard (dry) in consistence; a few small manganese and ironstone concretions; clay skins; clear boundary.

B22tg	53-130	White (2.5Y 8/2), dry to light grey (2.5Y 7/2), moist; common fine distinct brown (7.5YR 7/8, dry and 5/6, moist) and a few medium distinct black (7.5YR 2/1, dry and moist) mottles; silty clay loam; sticky and plastic (wet), firm (moist), very hard (dry) in consistence; a few small manganese and ironstone concretions.

LAND SYSTEM A

DEPTH IN cm	ORG. MTR. %	ORG. C. %	TOTAL N %	C:N	Av. P µg/g	Av. P kg/ha	Av. K µg/g	Av. K kg/ha
A. SUMMIT								
0–29	0.469	0.272	0.027	10.07	1.32	3.300	37.59	93.98
29–60	0.536	0.311	0.038	8.18	1.51	3.775	27.13	67.82
A. FOOTSLOPE								
0–20	0.969	0.562	0.052	10.81	0.35	0.875	31.33	78.31
20–48	0.331	0.192	0.024	8.00	2.18	5.450	26.40	66.01
48–75	0.193	0.112	0.022	5.09	0.82	2.050	36.95	92.36
75–97	0.195	0.113	0.022	5.14	2.06	5.150	43.32	108.29
97–128	0.141	0.082	0.022	3.73	2.28	5.700	55.90	139.75
A. TOESLOPE								
0–11	1,126	0,653	0.065	10.05	0.20	0.500	22.28	55.69
11–29	0.426	0.247	0.035	7.06	1.25	3.125	32.20	80.49
29–72	0.448	0.260	0.038	6.84	2.83	7.075	76.41	191.02
72–117	0.365	0.212	0.030	7.07	2.89	7.225	87.66	219.16
117–130	0.221	0.128	0.025	5.12	10.29	25.725	91.11	227.78
A. BASE								
0–16	1.314	0.762	0.076	10.03	0.77	1.925	35.84	89.60
16–45	0.262	0.152	0.023	6.61	1.17	2.925	32.69	81.72
45–53	0.759	0.440	0.039	11.28	1.03	2.575	62.91	157.28
53–130	0.390	0.226	0.037	6.11	0.72	1.800	58.88	147.21

LAND SYSTEM A

DEPTH IN cm	Ex.Ca++ me/100g	Ex. Mg++ me/100g	Ex. Na+ me/100g	Ex. K+ me/100g	Ex. Al +++ me/100g	Al saturat-:ion %	Ex. Acidity me/100g	L.R. kg/ha
A. SUMMIT								
0-29	2.53	0.77	0.03	0.10	0.40	5.06	4.47	5587.5
29-60	3.47	1.42	0.06	0.07	0.20	2.06	4.69	
A. FOOTSLOPE								
0-20	1.78	0.31	0.03	0.08	0.60	9.32	4.24	5300.0
20-48	3.80	1.02	0.03	0.06	0.00	0.00	2.74	
48-75	5.97	1.27	0.06	0.10	0.20	1.80	3.69	
75-97	6.86	1.36	0.07	0.12	0.10	0.81	3.92	
97-128	8.32	1.66	0.08	0.17	0.10	0.68	4.45	
A. TOESLOPE								
0-11	1.96	0.35	0.03	0.04	1.40	19.07	4.96	6200.0
11-29	6.77	1.94	0.12	0.08	0.00	0.00	3.12	
29-72	12.19	3.33	0.53	0.24	0.10	0.45	5.76	
72-117	16.00	4.18	1.07	0.31	0.10	0.36	6.20	
117-130	19.02	4.78	1.40	0.34	0.00	0.00	3.97	
A. BASE								
0-16	3.97	1.03	0.03	0.08	1.70	13.96	7.07	8837.5
16-45	6.37	1.68	0.05	0.07	0.00	0.00	2.25	
45-53	12.01	2.90	0.14	0.18	0.10	0.49	5.05	
53-130	9.45	2.70	0.24	0.17	1.00	5.13	6.92	

LAND SYSTEM A

DEPTH IN cm	T.E.B. me/100g	C.E.C. me/100g	B.S. %	pH 1: 2.5 H_2O	pH 1: 2.5 0.01M $CaCl_2$	E. C. mmhos/cm	$CaCO_3$ %	Free Fe %
A. SUMMIT								
0–29	3.43	7.90	43.42	5.52	4.70	0.011	0	3.14
29–60	5.02	9.71	51.70	6.00	4.92	0.002	0	3.47
A. FOOTSLOPE								
0–20	2.20	6.44	34.16	5.07	4.40	0.022	0	1.54
20–48	4.91	7.65	64.18	6.49	5.45	0.002	0	1.69
48–75	7.40	11.09	66.73	5.78	5.06	0.002	0.017	2.40
75–97	8.41	12.33	68.21	6.01	5.22	0.002	0	3.38
97–128	10.23	14.68	69.69	6.12	5.35	0.002	0.016	3.67
A. TOESLOPE								
0–11	2.38	7.34	32.42	4.88	4.00	0.016	0	0.69
11–29	8.91	12.03	74.06	6.87	5.83	0.014	0	1.87
29–72	16.29	22.05	73.88	6.84	5.70	0.020	.0	2.69
72–117	21.56	27.76	77.67	6.86	5.55	0.018	0.008	2.52
117–130	25.54	29.51	86.55	7.82	6.67	0.037	0.009	2.36
A. BASE								
0–16	5.11	12.18	41.95	4.80	4.21	0.031	0	1.09
16–45	8.17	10.42	78.41	6.70	5.87	0.012	0	1.17
45–53	15.23	20.28	75.10	6.52	5.46	0.013	0.008	1.62
53–130	12.56	19.48	64.48	5.89	4.56	0.014	0.012	1.57

LAND SYSTEM A

DEPTH IN cm	GRAVEL % > 2mm	SAND % 2-0.05mm	SILT % 0.05-0.002mm	CLAY % < 0.002mm	F.C. % VOL/VOL	W.P. % VOL/VOL	A.W.C. % VOL/VOL	A.W.C. cm/cm
A. SUMMIT								
0-29	4.8	57.20	26.34	16.46	25.80	7.52	18.28	0.18
29-60	9.2	50.47	27.16	22.37	24.85	11.78	13.07	0.13
A. FOOTSLOPE								
0-20	3.5	36.14	48.70	15.16	34.51	7.74	26.77	0.27
20-48	2.8	48.70	31.27	20.03	29.95	12.85	17.10	0.17
48-75	14.6	47.91	22.57	29.52	25.89	13.83	12.06	0.12
75-97	26.7	52.85	17.57	29.58	26.87	15.01	11.86	0.12
97-128	35.3	48.07	18.89	33.04	31.61	15.40	16.21	0.16
A. TOESLOPE								
0-11	1.6	19.68	65.94	14.38	33.08	13.79	19.29	0.19
11-29	1.8	15.90	58.55	25.55	35.46	17.74	17.72	0.18
29-72	3.5	13.49	41.96	44.55	42.21	27.97	14.24	0.14
72-117	5.8	14.60	35.88	49.52	48.43	32.86	15.57	0.16
117-130	5.2	9.75	39.10	51.15	47.83	35.85	11.98	0.12
A. BASE								
0-16	3.2	41.63	40.88	17.49	36.40	12.16	24.24	0.24
16-45	0.4	50.27	35.06	14.67	33.82	11.23	22.59	0.23
45-53	3.5	20.58	52.52	26.90	38.82	14.10	24.72	0.25
53-130	5.8	13.06	55.00	31.94	39.33	23.59	15.74	0.16

LAND SYSTEM A

DEPTH IN cm	B.D. g/cm^3	TOTAL POROSITY %	WATER-FILLED POROSITY %	AIR-FILLED POROSITY %
A. SUMMIT				
0-29	1.37	48.30	25.80	22.50
29-60	1.17	55.85	24.85	31.00
A. FOOTSLOPE				
0-20	1.28	51.70	34.51	17.19
20-48	1.25	52.83	29.95	22.88
48-75	1.12	57.74	25.89	31.85
75-97	1.16	56.23	26.87	29.36
97-128	1.20	54.72	31.61	23.11
A. TOESLOPE				
0-11	1.04	60.76	33.08	27.68
11-29	1.17	55.85	35.46	20.39
29-72	1.22	53.96	42.21	11.75
72-117	1.28	51.70	48.43	3.27
117-130	1.25	52.83	47.83	5.00
A. BASE				
0-16	1.12	57.74	36.40	21.34
16-45	1.25	52.83	33.82	19.01
45-53	1.28	51.70	38.82	12.88
53-130	1.25	52.83	39.33	13.50

LAND SYSTEM B, SUMMIT FACET

Location: 780 m west of R. Chanpa and 270 m north of Baital road, Upar Amdahara village, Bishnupur police station, Bankura district, West Bengal.
Elevation: 64 m above m.s.l.
Slope angle: 0.1 degree.
Depth to water-table: 6m in the wet season and 12 m in the summer.
Soil drainage: well.
Vegetation and land use: widely scattered Shorea robusta and associate trees over natural pasture.
Soil erosion: slight sheet erosion.
Stoniness: class 0.
Rockiness: nil.
Flooding: nil.
Soil classification: Ultic Paleustalf.

Horizon	Depth (cm)	Description
A1	0-15	Reddish yellow (7.5YR 7/6), dry to strong brown (7.5YR 5/6), moist; loamy coarse sand; structureless, single grain; non-sticky and non-plastic (wet), very friable (moist), soft (dry) in consistence; many very fine, a few medium roots; many ants; gradual boundary.
B21t	15-54	Reddish yellow (5YR 6/8), dry to yellowish red (5YR 4/8), moist; sandy clay loam; slightly sticky and non-plastic (wet), very friable (moist), slightly hard (dry) in consistence; many very fine, a few fine and medium roots; many ants and termites; a few small ironstone concretions; diffuse boundary.
B22t	54-127	Red (2.5YR 4/8), dry to dark red (2.5YR 3/6), moist; sandy clay loan; slightly sticky and slightly plastic (wet), very friable (moist), slightly hard (dry) in consistence; a few fine, medium and coarse roots; many ants; a few medium ironstone concretions.

LAND SYSTEM B, SHOULDER FACET

Location: 480 m west of R. Chanpa and 190 m north of Baital road, Upar Amdahara village, Bishnupur police station, Bankura district, West Bengal.
Elevation: 60 m above m.s.l.
Slope angle: 1.5 degrees.
Depth to water-table: 4 m in the wet season and 9 m in the summer.
Soil drainage: well.
Vegetation and land use: cucurbits grown in the summer; occupied by native grasses for rest of the year.
Soil erosion: moderate sheet erosion.
Stoniness: class 0.

Rockiness: class 0.
Flooding: nil.
Soil classification: Ultic Paleustalf.

Horizon	Depth (cm)	Description
A1	0-13	Reddish yellow (5YR 6/6), dry to yellowish red (5YR 3/6), moist; sandy loam; structureless, massive; slightly sticky and slightly plastic (wet), friable (moist), slightly hard (dry) in consistence; common very fine, a few fine roots; many ants; gradual boundary.
B21t	13-64	Red (2.5YR 5/8), dry to dark red (2.5YR 3/6), moist; sandy clay loam; slightly sticky and slightly plastic (wet), very friable (moist), slightly hard (dry) in consistence; common very fine roots; many ants and termites; a few medium ironstone concretions; diffuse boundary.
B22t	64-125	Red (2.5YR 5/8), dry to dark red (2.5YR 3/6), moist; sandy clay loam; slightly sticky and slightly plastic (wet), very friable (moist), soft (dry) in consistence; a few very fine roots; common ants and termites; common medium ironstone concretions.

LAND SYSTEM B, FOOTSLOPE FACET

Location: 240 m west of R. Chanpa and 190 m north of Baital road, Upar Amdahara village, Bishnupur police station, Bankura district, West Bengal.
Elevation: 55 m above m.s.l.
Slope angle: 1.0 degree.
Depth to water-table: 1 m in the wet season and 5 m in the summer.
Soil drainage: imperfect.
Vegetation and land use: cultivated; single crop of rice.
Soil erosion: slight sheet erosion.
Stoniness: class 0.
Rockiness: nil.
Flooding: nil.
Soil classification: Udic Haplustalf.

Horizon	Depth (cm)	Description
Ap	0-13	Brownish yellow (10YR 6/6), dry to dark yellowish brown (10YR 4/4), moist; sandy loam; moderate coarse granular in structure; sticky and plastic (wet), friable (moist), slightly hard (dry) in consistence; many very fine, a few fine roots; many ants; a few small ironstone concretions; clear boundary.

A12	13-26	Yellow (2.5Y 8/6), dry to yellow (2.5Y 7/6), moist; loam; slightly sticky and slightly plastic (wet), friable (moist), slightly hard (dry) in consistence; common very fine roots; common ants; a few small ironstone concretions; clear boundary.
A2	26-34	Pale yellow (2.5Y 8/3), dry to pale yellow (2.5Y 7/3), moist; common fine distinct brown (7.5YR 7/8, dry and 5/8, moist) mottles; sandy loam; slightly sticky and non-plastic (wet), friable (moist), slightly hard (dry) in consistence; common very fine roots; common ants and termites; common small and medium ironstone concretions; clear boundary.
B21t	34-54	Pale yellow (2.5Y 8/3), dry to pale yellow (2.5Y 7/3), moist; common fine distinct yellowish red (5YR 6/8, dry and 5/8, moist) mottles; loam; slightly sticky and plastic (wet), firm (moist), slightly hard (dry) in consistence; common very fine roots; a few medium ironstone concretions; gradual boundary.
B22t	54-78	White (5Y 8/2), dry to light grey (5Y 7/2), moist; many fine faint brown (7.5YR 6/7), dry and 5/7, moist) mottles; clay; slightly sticky and plastic (wet), firm (moist), hard (dry) in consistence; common very fine roots; a few medium ironstone concretions; diffuse boundary.
B23tg	78-123	White (7.5Y 8/1), dry to light grey (7.5Y 7/1), moist; many medium faint pale brown (10YR 8/4, dry and 7/4, moist) mottles; clay; sticky and plastic (wet), very firm (moist), very hard (dry) in consistence; a few fine roots; a few fine and medium ironstone concretions.

LAND SYSTEM 8, TOESLOPE FACET

Location: 180 m west of R. Chanpa and 190 m north of Baital road, Upar Amdahara village, Bishnupur police station, Bankura district, West Bengal.

Elevation: 54 m above m.s.l.

Slope angle: 0.8 degree.

Depth to water-table: near surface in the wet season and 3.5 m in the summer; 0.6 m during field work due partly to proximity of ponded stream water.

Soil drainage: poor.

Vegetation and land use: cultivated; single crop of rice in the year of field work (1981); multiple-cropped in some years; rice, wheat, potato and vegetables main crops.

Soil erosion: nil.

Stoniness: nil.

Rockiness: nil.

Flooding: nil.
Soil classification: Typic Ochraqualf.

Horizon	Depth (cm)	Description
Ap	0-15	White (5Y 8/2), dry to light grey (5Y 7/2), moist; mottled yellowish red along rice roots; loam; moderate coarse granular in structure; slightly sticky and slightly plastic (wet), friable (moist), hard (dry) in consistence; many very fine, common fine roots; many earth-worms, common termites and millipedes; clear boundary.
A21g	15-25	White (5Y 8/1), dry to light grey (5Y 6/1), moist; many fine and medium prominent yellow (10YR 7/8, dry and 6/8, moist) mottles; sandy loam; sticky and slightly plastic (wet), firm (moist), hard (dry) in consistence; common very fine, a few fine roots; clear boundary.
A22g	25-40	White (N 8/0), dry to light grey (N 7/0), moist; common fine and medium distinct reddish yellow (7.5YR 8/8, dry and 6/8, moist) and black (7.5YR 2/1, dry and moist) mottles; sandy loam; non-sticky and non-plastic (wet), friable (moist), hard (dry) in consistence; common very fine roots; a few small and medium manganese and ironstone concretions; clear boundary.
B2tg	40-55	White (7.5Y 8/1), dry to light grey (7.5Y 7/1), moist; common medium and coarse distinct reddish yellow (7.5YR 7/8, dry and 6/8, moist) mottles; sandy loam; slightly sticky and non-plastic (wet), firm (moist), hard (dry) in consistence; a few very fine roots; a few big ironstone concretions.

LAND SYSTEM 8, BASE FACET

Location: 50 m west of R. Chanpa and 160 m north of Baital road, Upar Amdahara village, Bishnupur police station, Bankura district, West Bengal.
Elevation: 52 m above m.s.l.
Slope angle: 0.1 degree.
Depth to water-table: near surface in the wet season and 3 m in the summer; 0.6 m during field work due partly to proximity of ponded stream water.
Soil drainage: poor.
Vegetation and land use: cultivated; single crop of rice in the year of field work (1981); multiple-cropped in some years; rice main crop.
Soil erosion: nil.
Stoniness: nil.
Rockiness: nil.
Flooding: very mild and occasional.

Soil classification: Aeric Ochraqualf.

Horizon	Depth (cm)	Description
Ap	0-12	White (5Y 8/2), dry to light grey (5Y 7/2), moist; mottled yellowish red along rice roots; sandy clay loam; moderate coarse granular in structure; slightly sticky and non-plastic (wet), friable (moist), slightly hard (dry) in consistence; many very fine, a few fine roots; common ants and earthworms, a few millipedes; clear boundary.
A2	12-20	White (2.5Y 8/2), dry to light yellowish brown (2.5Y 6/3), moist; common medium faint brown (7.5YR 7/8), dry and 5/8, moist) mottles; sandy loam; slightly sticky and slightly plastic (wet), friable (moist), slightly hard (dry) in consistence; common very fine roots; clear boundary.
B21t	20-37	Pale yellow (2.5Y 8/3), dry to pale yellow (2.5Y 7/3), moist; many fine and medium distinct brown (7.5YR 7/7, dry and 5/7, moist) mottles; sandy loam; slightly sticky and slightly plastic (wet), firm (moist), very hard (dry) in consistence; common very fine roots; common small and medium ironstone concretions; gradual boundary.
B22tg	37-58	White (N 8/0), dry to light grey (N 6/0), moist; many fine distinct yellowish red (5YR 7/8, dry and 5/8, moist) mottles; clay loam; slightly sticky and plastic (wet), firm (moist), hard (dry) in consistence; a few very fine roots; a few annelids; a few medium ironstone concretions.

LAND SYSTEM B

DEPTH IN cm	ORG. MTR. %	C %	N %	C:N	Av. P µg/g	Av. P kg/ha	Av.K µg/g	Av.K kg/ha
B. SUMMIT								
0-15	0.226	0.131	0.020	6.55	0.20	0.50	39.17	97.92
15-54	0.336	0.195	0.026	7.50	0.92	2.31	45.15	112.88
54-127	0.200	0.116	0.023	5.04	1.16	2.89	42.03	105.09
B. SHOULDER								
0-13	0.314	0.182	0.025	7.28	0.40	1.01	93.15	232.89
13-64	0.159	0.092	0.020	4.60	1.12	2.81	77.61	194.04
64-125	0,071	0.041	0.017	2.41	3.42	8.56	71.57	178.92
B. FOOTSLOPE								
0-13	0.838	0.486	0.045	10.80	0.00	0.00	54.72	136.79
13-26	0.527	0.306	0.037	8.27	0.31	0.77	32.69	81.73
26-34	0.331	0.192	0.024	8.00	0.76	1.89	21.21	53.02
34-54	0.445	0.258	0.037	6.97	0.31	0.77	47.39	118.48
54-78	0.253	0.147	0.028	5.25	2.11	5.27	84.25	210.64
78-123	0.145	0.084	0.021	4.00	2.53	6.32	88.48	221.19
B. TOESLOPE								
0-15	1.188	0.689	0.071	9.70	0.15	0.38	38.69	96.72
15-25	0.365	0.212	0.023	9.22	0.91	2.29	22.38	55.94
25-40	0.138	0.080	0.020	4.00	0.00	0.00	19.11	47.78
40-55	0.193	0.112	0.017	6.59	0.10	0.25	51.97	129.93
B. BASE								
0-12	0.946	0.549	0.063	8.71	5.82	14.56	55.17	137.94
12-20	0.262	0.152	0.024	6.33	0.00	0.00	31.52	78.79
20-37	0.281	0.163	0.026	6.27	1.28	3.19	45.95	114.88
37-58	0.533	0.309	0.038	8.13	8.81	22.03	62.21	155.54

LAND SYSTEM B

DEPTH IN cm	Ex.Ca^{++} me/100g	Ex.Mg^{++} me/100g	Ex.Na^{+} me/100g	Ex.K^{+} me/100g	Ex.Al^{+++} me/100g	Al satur- :ation %	Ex.Acidity me/100g	L. R. kg/ha
B. SUMMIT								
0–15	0.42	0.16	0.00	0.13	0.40	22.10	1.10	1375.0
15–54	2.42	0.70	0.00	0.14	0.80	12.03	3.39	
54–127	2.91	1.08	0.00	0.17	0.60	8.09	3.26	
B. SHOULDER								
0–13	2.10	0.69	0.00	0.35	0.60	10.05	2.83	3537.5
13–64	2.55	0.99	0.00	0.26	1.10	13.77	4.19	
64–125	3.59	1.32	0.01	0.22	0.40	4.85	3.11	
B. FOOTSLOPE								
0–13	5.20	1.52	0.15	0.18	0.10	1.09	2.13	2662.5
13–26	5.80	1.78	0.19	0.09	0.20	1.80	3.27	
26–34	3.08	1.12	0.10	0.06	0.10	1.57	2.02	
34–54	7.71	2.41	0.23	0.16	0.10	0.71	3.61	
54–78	14.89	5.56	0.43	0.34	0.00	0	4.63	
78–123	16.06	5.87	0.49	0.35	0.00	0	3.48	
B. TOESLOPE								
0–15	3.81	1.17	0.05	0.12	1.00	9.48	5.40	6750.0
15–25	3.66	1.23	0.02	0.08	0	0	1.93	
25–40	2.79	0.79	0.00	0.05	0	0	0.70	
40–55	4.94	1.38	0.02	0.18	0	0	2.45	
B. BASE								
0–12	5.38	1.85	0.07	0.18	1.40	10.29	6.13	7662.5
12–20	3.95	1.27	0.005	0.08	0.40	4.73	3.15	
20–37	7.64	2.35	0.03	0.14	0	0	2.96	
37–58	13.51	4.37	0.09	0.21	0	0	4.56	

LAND SYSTEM B

DEPTH IN cm	T.E.B. me/100g	C.E.C. me/100g	B.S. %	pH 1:2.5 H_2O	pH 1:2.5 0.01M $CaCl_2$	E.C. mmhos/cm	$CaCO_3$ %	Free Fe %
B. SUMMIT								
0-15	0.71	1.81	39.23	5.32	4.45	0.010	0	0.38
15-54	3.26	6.65	49.02	5.46	4.40	0.002	0	1.36
54-127	4.16	7.42	56.06	5.60	4.58	0.002	0	1.69
B. SHOULDER								
0-13	3.14	5.97	52.60	5.02	4.36	0.027	0	1.27
13-64	3.80	7.99	47.56	5.04	4.41	0.017	0	1.71
64-125	5.14	8.25	62.30	5.19	4.63	0.030	0	1.75
B. FOOTSLOPE								
0-13	7.05	9.18	76.80	5.91	4.75	0.042	0	0.81
13-26	7.86	11.13	70.60	6.08	4.81	0.013	0	1.09
26-34	4.36	6.38	68.34	6.04	4.84	0.013	0	1.16
34-54	10.51	14.12	74.43	6.32	5.22	0.017	0.008	1.57
54-78	21.22	25.85	82.09	6.87	5.60	0.018	0.007	1.93
78-123	22.77	26.25	86.74	7.02	6.07	0.021	0.008	1.60
B. TOESLOPE								
0-15	5.15	10.55	48.81	4.96	4.31	0.033	0.040	0.99
15-25	4.99	6.92	72.11	6.24	5.47	0.013	0.007	1.81
25-40	3.63	4.33	83.83	6.77	5.67	0.002	0.007	0.33
40-55	6.52	8.97	72.69	6.21	5.20	0.002	0.006	1.36

B. BASE								
0-12	7.48	13.61	54.96	4.98	4.23	0.035	0	1.20
12-20	5.305	8.455	62.74	5.42	4.39	0.011	0.008	1.27
20-37	10.16	13.12	77.44	6.54	5.56	0.015	0.015	1.39
37-58	18.18	22.74	79.95	7.22	6.49	0.022	0.008	3.27

LAND SYSTEM B

DEPTH IN cm	GRAVEL %	SAND %	SILT %	CLAY %	F.C. % VOL/VOL	W.P. % VOL/VOL	A.W.C. % VOL/VOL	A.W.C. cm/cm
B. SUMMIT								
0-15	0.5	85.02	8.51	6.47	13.27	2.93	10.34	0.10
15-54	0.4	62.73	16.71	20.56	21.00	8.23	12.77	0.13
54-127	3.5	56.69	16.95	26.36	19.38	8.76	10.62	0.11
B. SHOULDER								
0-13	2.5	66.95	15.96	17.09	19.69	7.12	12.57	0.13
13-64	4.8	56.62	17.40	25.98	25.13	11.44	13.69	0.14
64-125	15.4	60.49	15.57	23.94	17.83	8.36	9.47	0.09
B. FOOTSLOPE								
0-13	5.2	59.05	27.70	13.25	28.41	7.20	21.21	0.21
13-26	2.5	44.79	34.37	20.84	29.88	9.08	20.80	0.21
26-34	9.8	67.28	19.87	12.85	21.03	5.52	15.51	0.15
34-54	2.8	44.82	30.41	24.77	29.79	12.45	17.34	0.17
54-78	1.8	27.84	30.41	41.75	42.90	24.00	18.90	0.19
78-123	2.5	25.29	33.17	41.54	40.08	26.50	13.58	0.14
B. TOESLOPE								
0-15	1.8	41.07	38.65	20.28	34.10	11.18	22.92	0.23
15-25	2.8	56.47	29.82	13.71	29.65	7.45	22.20	0.22
25-40	3.5	68.36	23.71	7.93	23.68	4.11	19.57	0.20
40-55	3.4	54.92	26.17	18.91	30.08	10.30	19.78	0.20

B. BASE

0-12	8.3	59.78	19.38	20.84	33.27	10.81	22.46	0.22
12-20	9.8	74.75	12.28	12.97	21.19	6.54	14.65	0.15
20-37	12.7	56.62	23.69	19.69	31.46	11.16	20.30	0.20
37-58	5.2	35.08	31.53	33.39	39.23	18.44	20.79	0.21

LAND SYSTEM B

DEPTH IN cm	B.D. g/cm^3	TOTAL POROSITY %	WATER-FILLED POROSITY %	AIR-FILLED POROSITY %
A. SUMMIT				
0-15	1.50	43.40	13.27	30.13
15-54	1.27	52.07	21.00	31.07
54-127	1.20	54.72	19.38	35.34
B. SHOULDER				
0-13	1.36	48.68	19.69	28.99
13-64	1.27	52.07	25.13	26.94
64-125	1.14	56.98	17.83	39.15
B. FOOTSLOPE				
0-13	1.45	45.28	28.41	16.87
13-26	1.39	47.55	29.88	17.67
26-34	1.38	47.92	21.03	26.83
34-54	1.27	52.07	29.79	22.28
54-78	1.29	51.32	42.90	8.42
78-123	1.23	53.58	40.08	13.50
B. TOESLOPE				
0-15	1.24	53.21	34.10	19.11
15-25	1.47	44.53	29.65	14.88
25-40	1.57	40.75	23.68	17.07
40-55	1.38	47.92	30.08	17.87

B. BASE				
0-12	1.38	47.92	33.27	14.65
12-20	1.41	46.79	21.19	25.60
20-37	1.42	46.41	31.46	14.95
37-58	1.28	51.70	39.23	12.47

LAND SYSTEM C, SUMMIT FACET

Location: 1460 m west of R. Tamal and 160 m north of canal, Salbani village, Garhbeta police station, Midnapore district, West Bengal.
Elevation: 102 m above m.s.l.
Slope angle: 0.2 degree.
Depth to water-table: 4 m in the wet season and 9 m in the summer.
Soil drainage: well.
Vegetation and land use: slightly dense forest of Shorea robusta and associates.
Soil erosion: slight sheet erosion.
Stoniness: nil.
Rockiness: nil.
Flooding: nil.
Soil classification: Ultic Paleustalf.

Horizon	Depth (cm)	Description
A1	0-14	Reddish yellow (7.5YR 6/6), dry to strong brown (7.5YR 4/6), moist; sandy loam; structureless, massive; non-sticky and non-plastic (wet), friable (moist), slightly hard (dry) in consistence; common very fine and fine, a few medium and coarse roots; many ants and termites; diffuse boundary.
B21t	14-40	Light red (2.5YR 6/8), dry to red (2.5YR 5/8), moist; sandy loam; non-sticky and slightly plastic (wet), friable (moist), slightly hard (dry) in consistence; common very fine, fine, medium and coarse roots; many ants and termites; diffuse boundary.
B22t	40-125	Light red (2.5YR 6/8), dry to red (2.5YR 4/8), moist; sandy clay loam; slightly sticky and slightly plastic (wet), friable (moist), slightly hard (dry) in consistence; a few very fine, common fine, medium and coarse roots; many ants and termites; a few small and medium ironstone concretions.

LAND SYSTEM C, SHOULDER FACET

Location: 1250 m west of R. Tamal and 160 m north of canal, Salbani village, Garhbeta police station, Midnapore district, West Bengal.
Elevation: 97 m above m.s.l.
Slope angle: 1.1 degrees.
Depth to water-table: 2 m in the wet season and 6 m in the summer.
Soil drainage: moderately well.
Vegetation and land use: slightly dense forest of Shorea robusta and associates.
Soil erosion: moderate sheet and slight gully erosion.

Stoniness: nil.
Rockiness: nil.
Flooding: nil.
Soil classification: Rhodic Paleustalf.

Horizon	Depth (cm)	Description
A1	0-30	Reddish yellow (5YR 6/6), dry to yellowish red (5YR 4/6), moist; sandy clay loam; structureless, massive; sticky and slightly plastic (wet), friable (moist), slightly hard (dry) in consistence; common very fine, a few fine, medium and coarse roots; many ants and termites; diffuse boundary.
A2	30-90	Reddish yellow (5YR 6/8), dry to yellowish red (5YR 4/8), moist; sandy clay loam; slightly sticky and slightly plastic (wet), friable (moist), slightly hard (dry) in consistence; common very fine, a few fine and medium, common coarse roots; many ants and termites; common small, medium and big ironstone concret-:ions; diffuse boundary.
B2t	90-115	Red (10R 4/6), dry to dark red (10R 3/6), moist; common medium faint pale brown (10YR 8/4, dry and 7/4, moist) mottles; sandy clay; sticky and slightly plastic (wet), firm (moist), slightly hard (dry) in consistence; a few very fine and fine roots; a few small and medium ironstone concretions.

LAND SYSTEM C, FOOTSLOPE FACET, UPPER PROFILE

Location: 930 m west of R. Tamal and 160 m north of canal, Salbani village, Garhbeta police station, Midnapore district, West Bengal.
Elevation: 91 m above m.s.l.
Slope angle: 1.1 degrees.
Depth to water-table: 1 m in the wet season and 4.5 m in the summer.
Soil drainage: imperfect.
Vegetation and land use: slightly dense forest of _Shorea robusta_ and associates.
Soil erosion: moderate sheet and gully erosion.
Stoniness: nil.
Rockiness: nil.
Flooding: nil.
Soil classification: Ultic Haplustalf.

Horizon	Depth (cm)	Description
A1	0-23	Very pale brown (10YR 8/4), dry to very pale brown (10YR 7/4), moist; sandy loam; structureless, massive; non-sticky and non-plastic (wet), friable (moist), slightly hard (dry) in

		consistence; common very fine and fine, a few medium and coarse roots; many ants and termites; gradual boundary.
B21t	23-39	Very pale brown (10YR 8/4), dry to very pale brown (10YR 7/4), moist; loam; slightly sticky and slightly plastic (wet), friable (moist), slightly hard (dry) in consistence; common very fine, fine, medium and coarse roots; common ants and termites; gradual boundary.
B22tg	39-100	White (5Y 8/1), dry to light grey (5Y 7/1), moist; common small faint reddish yellow (7.5YR 7/8 , dry and 6/8, moist) mottles; loam; sticky and slightly plastic (wet), friable (moist), slightly hard (dry) in consistence; a few very fine, fine, medium and coarse roots; diffuse boundary.
B23tg	100-115	White (N 8/0), dry to light grey (N 7/0), moist; a few medium prominent red (10R 4/8, dry and 3/6, moist) mottles; sandy clay loam; sticky and non-plastic (wet), firm (moist), hard (dry) in consistence.

LAND SYSTEM C, FOOTSLOPE FACET, MIDDLE PROFILE REPRESENTING THE FACET

Location: 690 m west of R. Tamal and 110 m north of canal, Salbani village, Garhbeta police station, Midnapore district, West Bengal.
Elevation: 87 m above m.s.l.
Slope angle: 1.0 degree.
Depth to water-table: 1 m in the wet season and 4 m in the summer.
Soil drainage: imperfect.
Vegetation and land use: open forest of Shorea robusta and associates.
Soil erosion: severe gully erosion.
Stoniness: class 0.
Rockiness: nil.
Flooding: nil.
Soil classification: Ultic Haplustalf.

Horizon	Depth (cm)	Description
A1	0-21	Yellow (10YR 8/6), dry to brownish yellow (10YR 6/6), moist; sandy clay loam; structure-:less, massive; slightly sticky and slightly plastic (wet), friable (moist), slightly hard (dry) in consistence; common very fine, a few fine, medium and coarse roots; many ants and termites; diffuse boundary.
B21t	21-52	Yellow (10YR 7/6), dry to brownish yellow (10YR 6/6), moist; clay loam; slightly sticky and plastic (wet), firm (moist), hard (dry) in

		consistence; a few very fine and fine, common medium and coarse roots; many ants and termites; a few small ironstone concretions; gradual boundary.
B22gcn	52-107	White (10Y 8/1), dry to light grey (10Y 7/1), moist; sandy clay loam; sticky and plastic (wet), firm (moist), very hard (dry) in consistence; a few very fine and fine roots; many small and medium ironstone concretions; gradual boundary.
B23cn	107-115	Many (85%) small, medium and big ironstone concretions.
B24m	115+	Cemented pisolitic ironstone.

LAND SYSTEM C, FOOTSLOPE FACET, LOWER PROFILE

Location: 240 m west of R. Tamal and 190 m north of canal, Salbani village, Garhbeta police station, Midnapore district, West Bengal.
Elevation: 80 m above m.s.l.
Slope angle: 0.9 degree.
Depth to water-table: 1 m in the wet season and 3.5 m in the summer.
Soil drainage: well.
Vegetation and land use: open forest of *Shorea robusta* and associates.
Soil erosion: moderate gully erosion
Stoniness: Class 0.
Rockiness: nil.
Flooding: nil.
Soil classification: Typic Ustifluvent.

Horizon	Depth (cm)	Description
A1	0-16	Reddish yellow (7.5YR 7/6), dry to strong brown (7.5YR 5/6), moist; sandy loam; structureless, massive; non-sticky and non-plastic (wet), friable (moist), slightly hard (dry) in consistence; many very fine, a few fine roots; many ants and termites; a few small and medium ironstone concretions; clear boundary.
C1	16-39	Reddish yellow (7.5YR 6/6), dry to strong brown (7.5YR 4/6), moist; loamy coarse sand; non-sticky and non-plastic (wet), loose (moist), hard (dry) in consistence; common very fine, a few fine roots; many ants and termites; stratified sand with many small and medium iron-stone concretions; abrupt boundary.
C2	39-77	Very pale brown (10YR 7/4), dry to yellowish brown (10YR 5/4), moist; loam; slightly sticky and slightly plastic (wet), firm (moist), very hard (dry) in consistence; common very fine, a

		few fine, medium and coarse roots; common small and medium ironstone concretions; abrupt boundary.
C3	77-140	Pink (7.5YR 8/4), dry to light brown (7.5YR 6/4), moist; coarse sand; non-sticky and non-plastic (wet), loose (moist), loose (dry) in consistence; a few very fine, fine and medium roots; stratified sand, inclined towards the stream, with many small and medium and a few big ironstone concretions; abrupt boundary.
C4	140-150	White (5Y 8/2), dry to light grey (5Y 7/2), moist; common medium prominent reddish yellow (7.5YR 7/8, dry and 6/8, moist) mottles; clay loam; sticky and plastic (wet), firm (moist), slightly hard (dry) in consistence; a few very fine, fine and medium roots; stratified clay.

LAND SYSTEM C, TOESLOPE FACET

Location: 120 m west of R. Tamal and 160 m north-east of canal-end, Salbani village, Garhbeta police station, Midnapore district, West Bengal.
Elevation: 80 m above m.s.l.
Slope angle: 1.0 degree.
Depth to water-table: near surface in the wet season and 2.5 m in the summer.
Soil drainage: poor.
Vegetation and land use: cultivated; single crop of rice in the year of field work (1981); occasionally multiple-cropped; rice and wheat main crops.
Soil erosion: nil.
Stoniness: class 0.
Rockiness: nil.
Flooding: nil.
Soil classification: Typic Haplaquept.

Horizon	Depth (cm)	Description
Ap	0-17	Pale yellow (2.5Y 7/4), dry to light olive brown (2.5Y 5/3), moist; mottled brown along rice roots; clay loam; medium crumb in structure; slightly sticky and slightly plastic (wet), friable (moist), hard (dry) in consistence; many very fine and a few fine roots; common ants, termites and earthworms; a few small ironstone concret-:ions; clear boundary.
B21g	17-59	White (5Y 8/1), dry to light grey (5Y 7/1), moist; common fine and medium distinct brown (7.5YR 5/6 , dry and 4/6, moist) mottles; clay loam; sticky and plastic (wet), firm (moist), hard (dry) in consistence; many very fine and a few fine roots; many ants and termites;

		common small, a few medium and big ironstone concretions; gradual boundary.
B22g	59-78	White (N 8/0), dry to light grey (N 7/0), moist; many medium distinct yellow (10YR 7/6, dry and 6/6, moist) mottles; clay loam; slightly sticky and plastic (wet), very firm (moist), hard (dry) in consistence; a few very fine and very coarse roots; a few small ironstone concretions; diffuse boundary.
B23g	78-109	White (N 8/0), dry to light grey (N 7/0), moist; many medium and coarse distinct yellow (10YR 7/8, dry and 6/8, moist) mottles; clay loam; sticky and plastic (wet), very firm (moist), very hard (dry) in consistence; a few very fine, coarse and very coarse roots; a few small ironstone concretions; diffuse boundary.
B24g	109-140	White (N 8/0), dry to light grey (N 7/0), moist; many coarse distinct yellow (10YR 7/6, dry and 6/6, moist) mottles; clay loam; slightly sticky and plastic (wet), very firm (moist), hard (dry) in consistence; a few fine and coarse roots; a few small ironstone concretions.

LAND SYSTEM C, BASE FACET

Location: 40 m west of R. Tamal and 320 m east-north-east of canal-end, Salbani village, Garhbeta police station, Midnapore district, West Bengal.
Elevation: 78 m above m.s.l.
Slope angle: 0.1 degree.
Depth to water-table: near surface in the wet season and 2 m in the summer; 1.1 m during field work.
Soil drainage: poor.
Vegetation and land use: cultivated; single crop of rice in the year of field work (1981); occasionally multiple-cropped; rice, wheat, oilseeds and vegetables main crops.
Soil erosion: nil.
Stoniness: class 0.
Rockiness: nil.
Flooding: nil.
Soil classification: Typic Haplaquept.

Horizon	Depth (cm)	Description
Ap	0-15	Pale yellow (2.5Y 8/4), dry to pale yellow (2.5Y 7/4), moist; mottled brown along rice roots; clay loam; medium crumb in structure; slightly sticky and plastic (wet), very firm (moist), very hard (dry) in consistence; many very fine, a few fine roots; many ants and earthworms; common small ironstone concretions; clear boundary.

B21g	15-38	White (5Y 8/1), dry to light grey (5Y 6/1), moist; common fine distinct yellow (10YR 7/8, dry and 6/6, moist) mottles; loam; slightly sticky and plastic (wet), very firm (moist), very hard (dry) in consistence; many very fine roots; abrupt boundary.
IIC1	38-49	Strong brown (7.5YR 5/6), dry to brown (7.5YR 4/4), moist; coarse sand; non-sticky and non-plastic (wet), very friable (moist), soft (dry) in consistence; a few very fine roots; common small ironstone concretions; abrupt boundary.
IIC2	49-70	Variegated in colour, maily reddish coating upon particles; coarse sand; non-sticky and non-plastic (wet), loose (moist), loose (dry) in consistence; a few very fine roots; common small ironstone concretions; abrupt boundary.
IIIC3g	70-110	White (7.5Y 8/1), dry to light grey (7.5Y 7/1), moist; common medium and coarse prominent yellow (10YR 7/8, dry and 6/8, moist) and black (10YR 2/1, dry and moist) mottles; sandy loam; slightly sticky and slightly plastic (wet), very firm (moist), hard (dry) in consistence; common medium and big manganese and ironstone concretions.

LAND SYSTEM C

DEPTH IN cm	O.M. %	C %	N %	C/N	Av. P µg/g	Av. P kg/ha	Av. K µg/g	Av. K kg/ha
C. SUMMIT								
0–14	0.464	0.269	0.022	12.23	2.21	5.53	55.28	138.20
14–40	0.381	0.221	0.025	8.84	0.35	0.88	43.42	108.55
40–125	0.209	0.121	0.027	4.48	0.41	1.02	60.95	152.38
C. SHOULDER								
0–30	0.365	0.212	0.028	7.57	1.98	4.96	68.24	170.60
30–90	0.331	0.192	0.028	6.86	1.63	4.07	91.60	229.01
90–115	0.193	0.112	0.033	3.39	1.33	3.33	92.17	230.44
C. FOOTSLOPE (Upper)								
0–23	0.276	0.160	0.014	11.43	0.50	1.26	39.21	98.02
23–39	0.389	0.231	0.023	10.04	0.81	2.02	40.44	101.09
39–100	0.174	0.101	0.023	4.39	0.56	1.39	56.69	141.73
100–115	0.209	0.121	0.021	5.76	1.68	4.19	69.10	172.75
(Middle)								
0–21	0.581	0.337	0.023	14.65	0.41	1.03	55.52	138.79
21–52	0.402	0.233	0.030	7.77	1.17	2.93	51.23	128.08
52–107	0.198	0.115	0.018	6.93	0.79	1.98	51.79	129.46
(Lower)								
0–16	0.207	0.120	0.017	7.06	0.30	0.76	36.35	90.88
16–39	0.121	0.070	0.010	7.00	0.75	1.89	24.16	60.40
39–77	0.374	0.217	0.029	7.48	1.56	3.90	58.25	145.64
77–140	0.052	0.030	0.003	10.00	0.50	1.25	9.03	22.56
140–150	0.405	0.235	0.029	8.10	0.51	1.28	59.62	149.04

C. TOESLOPE								
0-17	1.443	0.837	0.083	10.08	1.15	2.88	68.01	170.03
17-59	0.590	0.342	0.039	8.77	2.13	5.32	73.64	184.11
59-78	0.179	0.104	0.025	4.16	1.25	3.13	77.34	193.35
78-109	0.198	0.115	0.021	5.48	1.57	3.94	74.66	186.65
109-140	0.198	0.115	0.019	6.05	1.42	3.55	68.36	170.89
C. BASE								
0-15	1.529	0.887	0.087	10.19	0.57	1.42	67.07	167.68
15-38	0.550	0.319	0.040	7.97	1.95	4.88	40.09	100.23
38-49	0.052	0.030	0.008	3.75	0.60	1.51	17.12	42.81
49-70	0.034	0.020	0.004	5.00	0.80	2.01	8.03	20.07
70-110	0.053	0.031	0.009	3.44	2.85	7.14	36.70	91.74

LAND SYSTEM C

DEPTH IN cm	Ex.Ca++ me/100g	Ex.Mg++ me/100g	Ex.Na+ me/100g	Ex.K+ me/100g	Ex.Al+++ me/100g	Al saturat-:ion %	Ex.Acidity me/100g	L.R. kg/ha
C. SUMMIT								
0–14	1.67	0.41	0.005	0.16	0.10	2.53	1.71	2137.5
14–40	2.24	0.64	0.008	0.12	0.50	8.56	2.83	
40–125	3.80	1.25	0.02	0.19	0.10	1.20	3.05	
C. SHOULDER								
0–30	2.68	1.00	0.04	0.22	0.70	8.22	4.58	5725.0
30–90	4.51	2.03	0.04	0.34	0.10	1.01	2.95	
90–115	6.10	2.21	0.04	0.34	0.10	0.83	3.38	
C. FOOTSLOPE (Upper)								
0–23	0.97	0.29	0.02	0.12	0.70	21.14	1.91	2387.5
23–39	1.40	0.56	0.04	0.13	1.30	21.07	4.04	
39–100	2.81	0.69	0.10	0.19	1.10	15.65	3.24	
100–115	3.94	1.34	0.09	0.22	0.80	8.95	3.35	
(Middle)								
0–21	4.70	1.99	0.07	0.20	2.10	16.65	5.65	7062.5
21–52	9.17	3.12	0.16	0.16	2.00	10.35	6.72	
52–107	11.13	3.91	0.17	0.18	0.30	1.52	4.33	
(Lower)								
0–16	2.80	0.87	0.03	0.11	0.50	8.16	2.32	2900.0
16–39	2.37	0.74	0.49	0.07	0.10	2.18	0.91	
39–77	6.63	2.31	0.11	0.19	0.40	2.96	4.26	
77–140	1.25	0.27	0.03	0.02	0	0	0.50	
140–150	7.12	2.79	0.20	0.20	0.80	5.28	4.83	

C. TOESLOPE								
0-17	7.69	2.34	0.16	0.24	1.60	8.65	8.06	10075.0
17-59	12.22	4.05	0.14	0.28	0	0	3.94	
59-78	13.62	4.58	0.35	0.29	0.10	0.44	4.08	
78-109	14.28	4.52	0.43	0.28	0.10	0.45	2.73	
109-140	14.87	4.37	0.45	0.27	0	0	2.31	
C. BASE								
0-15	5.00	1.61	0.17	0.25	2.10	13.47	8.56	10700.00
15-38	7.41	2.56	0.11	0.12	0	0	3.39	
38-49	3.07	0.74	0.03	0.04	0	0	0.60	
49-70	1.39	0.33	0.09	0.04	0	0	0.20	
70-110	7.63	2.20	0.40	0.12	0	0	0.92	

LAND SYSTEM C

DEPTH IN cm	T.E.B. me/100g	C.E.C. me/100g	B.S. %	pH 1:2.5 H_2O	pH 1:2.5 0.01M $CaCl_2$	E.C. mmhos/cm	$CaCO_3$ %	Free Fe %
C. SUMMIT								
0–14	2.245	3.955	56.76	5.80	4.95	0.013	0	0.58
14–40	3.008	5.84	51.51	5.42	4.60	0.010	0	1.31
40–125	5.26	8.31	63.30	5.90	5.26	0.002	0	1.98
C. SHOULDER								
0–30	3.94	8.52	46.24	5.34	4.51	0.012	0	2.10
30–90	6.92	9.87	70.11	6.22	5.62	0.011	0	2.06
90–115	8.69	12.07	72.00	6.40	5.56	0.010	0	2.85
C. FOOTSLOPE (Upper)								
0–23	1.40	3.31	42.30	5.21	4.21	0.011	0	0.44
23–39	2.13	6.17	34.52	5.23	4.11	0.012	0	0.77
39–100	3.79	7.03	53.91	5.44	4.12	0.013	0	0.29
100–115	5.59	8.94	62–53	5.34	4.34	0.010	0	0.53
(Middle)								
0–21	6.96	12.61	55.19	5.23	4.23	0.014	0	1.24
21–52	12.61	19.33	65.23	5.44	4.42	0.013	0	1.84
52–107	15.39	19.72	78.04	5.80	4.92	0.014	0	2.58

(Lower)								
0-16	3.81	6.13	62.15	5.52	4.50	0.016	0	1.32
16-39	3.67	4.58	80.13	6.06	5.15	0.002	0	1.03
39-77	9.24	13.50	68.44	5.70	4.51	0.016	0	1.75
77-140	1.57	2.07	75.84	6.22	5.54	0.002	0	0.72
140-150	10.31	15.14	68.10	5.63	4.51	0.016	0	1.73
C. TOESLOPE								
0-17	10.43	18.49	56.41	5.34	4.40	0.017	0.008	1.63
17-59	16.69	20.63	80.90	6.74	5.92	0.018	0.007	1.76
59-78	18.84	22.92	82.20	6.80	5.55	0.016	0.007	1.67
78-109	19.50	22.23	87.72	7.37	6.27	0.022	0.014	1.62
109-140	19.96	22.27	89.63	7.68	6.72	0.030	0.007	1.77
C. BASE								
0-15	7.03	15.59	45.09	5.15	4.16	0.025	0.009	1.40
15-38	10.20	13.59	75.05	6.33	5.33	0.015	0	1.50
38-49	3.88	4.48	86.61	7.05	6.17	0.012	0	0.79
49-70	1.85	2.05	90.24	7.50	6.81	0.013	0.006	0.52
70-110	10.35	11.27	91.84	8.24	6.94	0.025	0.017	1.19

LAND SYSTEM C

DEPTH IN cm	GRAVEL %	SAND %	SILT %	CLAY %	F.C. % VOL/VOL	W.P. % VOL/VOL	A.W.C. % VOL/VOL	A.W.C. cm/cm
C. SUMMIT								
0-14	0.7	75.07	16.21	8.72	18.92	4.98	13.98	0.14
14-40	0.4	65.38	16.48	18.14	20.79	8.13	12.66	0.13
40-125	1.1	52.88	19.61	27.51	22.91	11.23	11.68	0.12
C. SHOULDER								
0-30	0.7	51.93	19.63	28.44	22.97	10.85	12.12	0.12
30-90	2.5	52.41	19.91	27.68	23.31	11.48	11.83	0.12
90-115	1.8	46.52	17.10	36.38	25.32	13.59	11.73	0.12
C. FOOTSLOPE (Upper)								
0-23	0.7	67.55	23.64	8.81	19.92	4.21	15.71	0.16
23-39	1.8	35.58	49.58	14.84	31.20	9.02	22.18	0.22
39-100	0.7	31.12	47.09	21.79	29.70	10.35	19.35	0.19
100-115	1.8	52.93	21.42	25.65	26.55	12.04	14.51	0.14
(Middle)								
0-21	1.6	57.35	20.49	22.16	24.63	8.54	16.09	0.16
21-52	3.5	42.15	21.48	36.37	29.00	14.36	14.64	0.15
52-107	13.2	49.00	20.61	30.39	29.17	14.86	14.31	0.14

(Lower)								
0-16	1.1	66.92	20.48	12.60	21.04	5.10	15.94	0.16
16-39	6.1	85.30	8.22	6.48	12.41	3.68	8.73	0.09
39-77	3.8	35.59	39.15	25.26	33.18	11.15	22.03	0.22
77-140	9.2	97.47	0.44	2.09	3.35	1.75	1.60	0.02
140-150	6.1	36.31	34.46	29.23	37.91	16.46	21.45	0.21
C. TOESLOPE								
0-17	6.1	31.15	41.56	27.29	33.98	12.09	21.89	0.22
17-59	3.5	43.63	25.42	30.95	32.50	15.01	17.49	0.17
59-78	2.2	42.47	22.20	35.33	34.05	18.23	15.82	0.16
78-109	5.8	39.89	23.73	36.38	33.67	19.18	14.49	0.15
109-140	7.7	39.84	24.45	35.71	33.17	16.87	16.30	0.16
C. BASE								
0-15	5.8	31.90	40.16	27.94	40.46	15.62	24.84	0.25
15-38	3.5	44.98	31.75	23.27	35.70	18.80	16.90	0.17
38-49	7.4	90.85	2.62	6.53	9.03	3.29	5.74	0.06
49-70	5.2	96.19	0.92	2.89	3.78	1.77	2.01	0.02
70-110	5.2	74.15	9.79	16.06	26.50	9.55	16.95	0.17

LAND SYSTEM C

DEPTH IN cm	B.D. g/cm^3	TOTAL POROSITY %	WATER-FILLED POROSITY %	AIR-FILLED POROSITY %
C. SUMMIT				
0-14	1.50	43.40	18.92	24.48
14-40	1.30	50.94	20.79	30.15
40-125	1.25	52.83	22.91	29.92
C. SHOULDER				
0-30	1.28	51.70	22.97	28.73
30-90	1.20	54.72	23.31	31.41
90-115	1.16	56.23	25.32	30.91
C. FOOTSLOPE (Upper)				
0-23	1.45	45.28	19.92	25.36
23-39	1.31	50.57	31.20	19.37
39-100	1.25	52.83	29.70	23.13
100-115	1.38	47.92	26.55	21.37
(Middle)				
0-21	1.29	51.32	24.63	26.69
21-52	1.19	55.09	29.00	26.09
52-107	1.27	52.07	29.17	22.90

(Lower)				
0-16	1.47	44.53	21.04	23.49
16-39	1.51	43.02	12.41	30.61
39-77	1.20	54.72	33.18	21.54
77-140	1.54	41.89	3.35	38.54
140-150	1.27	52.07	37.91	14.16
C. TOESLOPE				
0-17	1.04	60.75	33.98	26.77
17-59	1.22	53.96	32.50	21.46
59-78	1.27	52.07	34.05	18.02
78-109	1.22	53.96	33.67	20.29
109-140	1.23	53.58	33.17	20.41
C. BASE				
0-15	1.17	55.85	40.46	15.39
15-38	1.45	45.28	35.70	9.58
38-49	1.38	47.92	9.03	38.89
49-70	1.38	47.92	3.78	44.14
70-110	1.36	48.68	26.50	22.18

LAND SYSTEM D, SUMMIT FACET

Location: 1050 m south-west of talweg and 650 m north-west of Sonamukhi road, Patharmara village, Sonamukhi police station, Bankura district, West Bengal.
Elevation: 86 m above m.s.l.
Slope angle: 0.2 degree.
Depth to water-table: 5 m in the wet season and 11 m in the summer.
Soil drainage: moderately well; slow permeability.
Vegetation and land use: coppice plantation of *Eucalyptus* spp. and *Acacia auriculiformis*.
Soil erosion: slight sheet erosion.
Stoniness: class 0.
Rockiness: nil.
Flooding: nil.
Soil classification: Ultic Haplustalf.

Horizon	Depth (cm)	Description
A1	0-17	Reddish yellow (7.5YR 6/6), dry to strong brown (7.5YR 4/6), moist; loam; structureless, massive; slightly sticky and slightly plastic (wet), friable (moist), slightly hard (dry) in consistence; common very fine, fine and medium roots; many ants and termites; diffuse boundary.
B21t	17-53	Yellowish red (5YR 5/8), dry to yellowish red (5YR 4/8), moist; clay loam; slightly sticky and slightly plastic (wet), friable (moist), slightly hard (dry) in consistence; common very fine, a few fine, common medium and coarse roots; many ants and termites; gradual boundary.
B22t	53-78	Yellowish red (5YR 5/6), dry to yellowish red (5YR 4/6), moist; a few fine distinct pale yellow (5Y 8/4, dry and 7/4, moist) mottles; clay; sticky and slightly plastic (wet), friable (moist), slightly hard (dry) in consistence; common very fine, a few fine, common medium roots; many ants and termites; a few small ironstone concretions; gradual boundary.
B23t	78-98	Reddish yellow (5YR 6/6), dry to yellowish red (5YR 5/6), moist; many medium distinct pale yellow (5Y 8/4, dry and 7/4, moist) mottles; clay; sticky and slightly plastic (wet), very firm (moist), very hard (dry) in consistence; a few very fine and fine roots; many ants; a few small ironstone concretions; gradual boundary.
B24tg	98-128	White (10Y 8/1), dry to light grey (10Y 7/1), moist; common fine distinct red (2.5YR 5/8, dry and 4/6, moist) mottles; clay; slightly sticky and plastic (wet), firm (moist), hard (dry) in consistence; a few very fine roots; a few small ironstone concretions.

LAND SYSTEM D, SHOULDER FACET

Location: 675 m south-west of talweg and 600 m north-west of Sonamukhi road, Patharmara village, Sonamukhi police station, Bankura district, West Bengal.
Elevation: 81 m above m.s.l.
Slope angle: 1.8 degrees.
Depth to water-table: 4 m in the wet season and 9 m in the summer.
Soil drainage: excessive.
Vegetation and land use: natural pasture in poor conditions.
Soil erosion: moderate sheet erosion.
Stoniness: class 4.
Rockiness: class 1.
Flooding: nil.
Soil classification: Petroferric Paleustalf?

Horizon	Depth (cm)	Description
A1	0-14	Yellowish red (5YR 5/6), dry to yellowish red (5YR 4/6), moist; loamy sand; structureless, massive; non-sticky and non-plastic (wet), very friable (moist), soft (dry) in consistence; common very fine roots; many ants and termites; many (30%) small and medium ironstone concretions; gradual boundary.
B21cn	14-29	Common very fine roots; many (95%) medium and big ironstone concretions; fragments (20-50cm) of massive ironstone.
B22m	29+	Massive ironstone.

LAND SYSTEM D, FOOTSLOPE FACET

Location: 360 m south-west of talweg and 540 m north-west of Sonamukhi road, Patharmara village, Sonamukhi police station, Bankura district, West Bengal.
Elevation: 72 m above m.s.l.
Slope angle: 1.2 degrees.
Depth to water-table: 1 m in the wet season and 5 m in the summer.
Soil drainage: imperfect.
Vegetation and land use: cultivated; single crop of rice in the year of field work (1981); multiple-cropped in some years; rice, sugarcane, wheat, oilseeds main crops.
Soil erosion: nil.
Stoniness: class 0.
Rockiness: class 0.
Flooding: nil.
Soil classification: Plinthustalf.

Horizon	Depth (cm)	Description
Ap	0-15	Pale yellow (2.5Y 8/3), dry to light yellowish brown (2.5Y 6/3), moist; loam; medium crumb in

		structure; slightly sticky and slightly plastic (wet), friable (moist), slightly hard (dry) in consistence; common very fine, a few fine roots; common ants and earthworms; a few small and medium ironstone concretions; clear boundary.
A2	15-26	Pale yellow (2.5Y 8/3), dry to light yellowish brown (2.5Y 6/3), moist; sandy loam; slightly sticky and slightly plastic (wet), friable (moist), hard (dry) in consistence; a few very fine roots; common small and medium ironstone concretions; gradual boundary.
B21t	26-55	White (2.5Y 8/2), dry to light brownish grey (2.5Y 6/2), moist; loam; sticky and plastic (wet), friable (moist), hard (dry) in consistence; common very fine roots; common small ironstone concretions; clear boundary.
B22tg	55-125	White (N 9/0), dry to white (5Y 8/1), moist; many (over 50%) medium and coarse distinct red (10R 5/8 , dry and 4/8, moist) mottles; clay loam; very sticky and plastic (wet), very firm (moist), hard (dry) in consistence; a few very fine roots; a few small ironstone concretions.

LAND SYSTEM D, TOESLOPE FACET

Location: 165 m south-west of talweg and 500 m north-west of Sonamukhi road, Patharmara village, Sonamukhi police station, Bankura district, West Bengal.
Elevation: 69 m above m.s.l.
Slope angle: 1.0 degree.
Depth to water-table: 1 m in the wet season and 4.5 m in the summer.
Soil drainage: imperfect.
Vegetation and land use: cultivated; multiple-cropped; rice, wheat, oilseeds and sugarcane main crops.
Soil erosion: nil.
Stoniness: class 0.
Rockiness: nil.
Flooding: nil.
Soil classification: Udic Haplustalf.

Horizon	Depth (cm)	Description
Ap	0-18	Pale yellow (2.5Y 8/4), dry to light olive brown (2.5Y 5/3), moist; mottled brown along rice roots; loam; medium crumb in structure; slightly sticky and non-plastic (wet), friable (moist), slightly hard (dry) in consistence; common very fine, a few fine roots; common ants and earthworms; a few small ironstone concret:ions; clear boundary.
B21t	18-41	Olive yellow (2.5Y 6/6), dry to olive brown (2.5Y 4/6), moist; loam; slightly sticky and

		slightly plastic (wet), friable (moist), slightly hard (dry) in consistence; common very fine roots; common ants; a few medium iron-:stone concretions; gradual boundary.
B22t	41-80	White (5Y 8/2), dry to light grey (5Y 7/2), moist; many medium distinct yellow (10YR 8/7, dry and 6/7, moist) mottles; clay loam; slightly sticky and plastic (wet), firm (moist), very hard (dry) in consistence; a few very fine roots; common medium ironstone concretions; gradual boundary.
B23tg	80-120	White (7.5Y 8/1), dry to light grey (7.5Y 7/1), moist; many small and medium prominent red (2.5YR 5/8 , dry and 4/8, moist) mottles; clay loam; slightly sticky and plastic (wet), firm (moist), very hard (dry) in consistence; a few very fine roots.

LAND SYSTEM D, BASE FACET

Location: 15 m south-west of talweg and 480 m north-west of Sonamukhi road, Patharmara village, Sonamukhi police station, Bankura district, West Bengal.
Elevation: 66 m above m.s.l.
Slope angle: 0.1 degree
Depth to water-table: near surface in the wet season and 3 m in the summer; 1 m during field work.
Soil drainage: poor.
Vegetation and land use: cultivated; single crop of rice in the year of field work (1981); multiple-cropped in some years; rice main crop.
Soil erosion: nil.
Stoniness: class 0.
Rockiness: nil.
Flooding: nil.
Soil classification: Typic Ochraqualf.

Horizon	Depth (cm)	Description
Ap	0-12	White (5Y 8/2), dry to light grey (5Y 7/2), moist; mottles brown along rice roots; sandy loam; medium crumb in structure; non-sticky and non-plastic (wet), friable (moist), slightly hard (dry) in consistence; common very fine, a few fine roots; common ants and earthworms; a few medium ironstone concretions; clear boundary.
A21	12-25	White (2.5Y 8/2), dry to light grey (2.5Y 6/2), moist; common fine distinct brown (7.5YR 7/8, dry and 5/8, moist) mottles; sandy loam; non-sticky and non-plastic (wet), friable (moist),

		slightly hard (dry) in consistence; common very fine roots; common ants; a few small ironstone concretions; gradual boundary.
A22	25-47	White (2.5Y 8/2), dry to light grey (2.5Y 7/2), moist; many fine and medium distinct reddish yellow (7.5YR 7/8, dry and 6/8, moist) mottles; sandy loam; slightly sticky and non-plastic (wet), friable (moist), hard (dry) in consist-:ence; a few very fine roots; diffuse boundary.
B21tg	47-72	White (7.5Y 8/1), dry to light grey (7.5Y 7/1), moist; many fine and medium distinct strong brown (7.5YR 6/8, dry and 4/6, moist) mottles; loam; sticky and slightly plastic (wet), firm (moist), hard (dry) in consistence; a few very fine roots; diffuse boundary.
B22tgca	72-100	White (5Y 8/1), dry to light grey (5Y 7/1), moist; common medium and big distinct reddish yellow (7.5YR 7/8, dry and 6/8, moist) mottles; loam; sticky and plastic (wet), firm (moist), hard (dry) in consistence; a few medium calcium carbonate concretions.

LAND SYSTEM D

DEPTH IN cm	ORG. MTR. %	C %	N %	C/N	Av. P µg/g	Av. P kg/ha	Av. K µg/g	Av. K kg/ha
D. SUMMIT								
0-17	0.510	0.296	0.036	8.22	0.82	2.05	123.20	308.01
17-53	0.407	0.236	0.033	7.15	1.84	4.59	89.68	224.20
53-78	0.281	0.163	0.034	4.79	1.64	4.11	66.83	167.07
78-98	0.252	0.146	0.031	4.71	1.89	4.73	95.62	239.05
98-128	0.198	0.115	0.025	4.60	0.94	2.36	100.65	251.62
D. SHOULDER								
0-14	0.396	0.230	0.029	7.93	1.71	4.27	40.15	100.38
D. FOOTSLOPE								
0-15	1.862	1.080	0.092	11.74	0.40	1.01	80.77	201.94
15-26	0.448	0.260	0.024	10.83	1.01	2.52	47.32	118.30
26-55	0.140	0.081	0.016	5.06	0.61	1.52	129.50	323.76
55-125	0.160	0.093	0.025	3.72	3.41	8.52	263.48	658.71
D. TOESLOPE								
0-18	1.240	0.719	0.067	10.73	0.00	0.00	54.68	136.69
18-41	0.212	0.123	0.023	5.35	3.07	7.67	73.66	184.14
41-80	0.162	0.094	0.022	4.27	1.46	3.66	91.97	229.93
80-120	0.162	0.094	0.020	4.70	2.77	6.92	97.15	242.87

D. BASE								
0-12	0.824	0.478	0.051	9.37	0.30	0.76	42.67	106.69
12-25	0.191	0.111	0.014	7.93	0.15	0.38	28.28	70.71
25-47	0.122	0.071	0.014	5.07	0.00	0.00	33.38	83.44
47-72	0.210	0.122	0.018	6.78	2.44	6.11	46.84	117.11
72-100	0.212	0.123	0.019	6.47	0.10	0.26	48.26	120.66

LAND SYSTEM D

DEPTH IN cm	Ex.Ca^{++} me/100g	Ex.Mg^{++} me/100g	Ex.Na^{+} me/100g	Ex.K^{+} me/100g	Ex.Al^{+++} me/100g	Al saturat-:ion %	Ex.Acidity me/100g	L.R. kg/ha
D. SUMMIT								
0-17	2.85	0.51	0.00	0.49	1.70	17.89	5.65	7062.5
17-53	7.19	2.44	0.05	0.33	2.20	11.86	8.54	
53-78	10.32	3.49	0.04	0.22	0.90	4.22	7.23	
78-98	11.07	4.28	0.05	0.36	0.60	2.66	6.83	
98-128	12.64	4.50	0.08	0.41	0.60	2.48	6.60	
D. SHOULDER								
0-14	1.11	0.14	0.00	0.11	0.30	8.64	2.11	2637.5
D. FOOTSLOPE								
0-15	3.36	0.60	0.20	0.27	0.10	1.13	4.44	5550.0
15-26	2.65	0.43	0.01	0.14	0.10	2.07	1.61	
26-55	3.93	0.89	0.02	0.49	0	0	1.31	
55-125	9.74	3.14	0.08	1.29	0	0	3.41	
D. TOESLOPE								
0-18	3.37	0.89	0.09	0.17	0.10	1.30	3.14	3925.0
18-41	8.08	2.36	0.13	0.25	0	0	1.74	
41-80	11.15	3.50	0.23	0.35	0	0	2.82	
80-120	12.45	4.90	0.40	0.37	0.10	0.45	3.97	

D. BASE								
0-12	4.65	1.29	0.17	0.12	0.40	3.77	4.37	5462.5
12-25	4.20	1.02	0.09	0.06	0	0	1.31	
25-47	4.63	1.12	0.10	0.08	0.10	1.31	1.72	
47-72	6.49	1.97	0.15	0.12	0.10	0.88	2.65	
72-100	6.83	2.28	0.16	0.16	0.10	0.80	3.08	

LAND SYSTEM D

DEPTH IN cm	T.E.B. me/100g	C.E.C. me/100g	B.S. %	pH 1:2.5 H_2O	pH 1:2.5 0.01M $CaCl_2$	E.C. mmhos/cm	$CaCO_3$ %	Free Fe %
D. SUMMIT								
0-17	3.85	9.50	40.53	5.05	4.28	0.025	0	1.54
17-53	10.01	18.55	53.96	5.34	4.37	0.010	0	2.36
53-78	14.07	21.30	66.06	5.18	4.59	0.027	0	2.35
78-98	15.76	22.59	69.76	5.27	4.67	0.025	0.016	2.39
98-128	17.63	24.23	72.76	5.51	4.86	0.022	0.008	2.44
D. SHOULDER								
0-14	1.36	3.47	39.19	5.22	4.41	0.013	0	2.01
D. FOOTSLOPE								
0-15	4.43	8.87	49.94	5.03	4.59	0.095	0.031	0.80
15-26	3.23	4.84	66.73	5.65	4.87	0.018	0.005	0.62
26-55	5.33	6.64	80.27	6.69	5.68	0.014	0	0.33
55-125	14.25	17.66	80.69	7.21	6.20	0.022	0.007	2.87
D. TOESLOPE								
0-18	4.52	7.66	59.01	5.79	4.86	0.029	0.021	0.62
18-41	10.82	12.56	86.15	7.64	6.76	0.032	0	1.02
41-80	15.23	18.05	84.38	7.24	6.50	0.036	0	1.66
80-120	18.12	22.09	82.03	6.95	6.10	0.036	0	2.28

D. BASE								
0–12	6.23	10.60	58.77	5.27	4.60	0.044	0	1.15
12–25	5.37	6.68	80.39	6.65	5.60	0.012	0	0.76
25–47	5.93	7.65	77.52	6.33	5.33	0.011	0	0.72
47–72	8.73	11.38	76.71	6.52	5.36	0.013	0.020	0.93
72–100	9.43	12.51	75.38	6.18	4.96	0.012	0.021	0.91

LAND SYSTEM D

DEPTH IN cm	GRAVEL %	SAND %	SILT %	CLAY %	F.C. % VOL/VOL	W.P. % VOL/VOL	A.W.C. % VOL/VOL	A.W.C. cm/cm
D. SUMMIT								
0-17	5.8	40.86	39.14	20.00	30.74	7.79	22.95	0.23
17-53	6.8	27.22	33.28	39.50	28.64	17.56	11.08	0.11
53-78	9.8	24.64	33.29	42.07	28.31	13.93	14.38	0.14
78-98	2.8	24.14	33.25	42.61	37.59	17.40	20.19	0.20
98-128	8.3	24.93	33.38	41.69	41.13	19.40	21.73	0.22
D. SHOULDER								
0-14	32.1	85.97	9.29	4.74	14.54	3.20	11.34	0.11
D. FOOTSLOPE								
0-15	4.8	40.37	49.09	10.54	36.18	11.00	25.18	0.25
15-26	4.0	58.05	34.34	7.61	26.81	7.61	19.20	0.19
26-55	3.5	51.45	32.65	15.90	28.09	7.89	20.20	0.20
55-125	11.3	42.63	21.83	35.54	33.32	16.91	16.41	0.16
D. TOESLOPE								
0-18	0.0	41.92	47.47	10.61	34.70	17.20	17.50	0.17
18-41	2.8	37.19	39.16	23.65	34.31	21.31	13.00	0.13
41-80	1.1	29.41	36.81	33.78	38.77	17.85	20.92	0.21
80-120	8.9	33.19	32.05	34.76	41.54	19.36	22.18	0.22

D. BASE

0-12	3.2	58.06	25.07	16.87	33.87	10.81	23.06	0.23
12-25	1.8	68.84	20.90	10.26	23.06	5.92	17.14	0.17
25-47	2.2	64.12	24.84	11.04	27.05	5.88	21.17	0.21
47-72	2.8	40.82	42.44	16.74	35.77	11.93	23.84	0.24
72-100	6.8	45.70	34.38	19.92	33.90	15.66	18.24	0.18

LAND SYSTEM D

DEPTH IN cm	B.D. g/cm^3	TOTAL POROSITY %	WATER-FILLED POROSITY %	AIR-FILLED POROSITY %
D. SUMMIT				
0-17	1.32	50.19	30.74	19.45
17-53	1.01	61.89	28.64	33.25
53-78	0.98	63.02	28.31	34.71
78-98	1.15	56.60	37.59	19.01
98-128	1.28	51.70	41.13	10.57
D. SHOULDER				
0-14	1.52	42.64	14.54	28.10
D. FOOTSLOPE				
0-15	1.19	55.09	36.18	18.91
15-26	1.41	46.79	26.81	19.98
26-55	1.46	44.91	28.09	16.82
55-125	1.27	52.07	33.32	18.75
D. TOESLOPE				
0-18	1.31	50.57	34.70	15.87
18-41	1.31	50.57	34.31	16.26
41-80	1.27	52.07	38.77	13.30
80-120	1.34	49.43	41.54	7.89

D. BASE

0-12	1.41	46.79	33.87	12.92
12-25	1.34	49.43	23.06	26.37
25-47	1.33	49.81	27.05	22.76
47-72	1.38	47.92	35.77	12.15
72-100	1.28	51.70	33.90	17.80

LAND SYSTEM E, SUMMIT AND SHOULDER FACET

Location: 105 m east of canal and 740 m north of Binpur road, Mohanpur village, Binpur police station, Midnapore district, West Bengal.
Elevation: 85 m above m.s.l.
Slope angle: 0.5 degree.
Depth to water-table: 5 m in the wet season and 10 m in the summer.
Soil drainage: well.
Vegetation and land use: natural pasture in poor conditions.
Soil erosion: slight to moderate sheet erosion.
Stoniness: class 0.
Rockiness: nil.
Flooding: nil.
Soil classification: Ultic Paleustalf.

Horizon	Depth (cm)	Description
A1	0-35	Reddish yellow (5YR 6/6), dry to yellowish red (5YR 5/6), moist; sandy loam; structureless, massive; non-sticky and non-plastic (wet), friable (moist), slightly hard (dry) in consistence; common very fine, a few coarse roots; many ants; diffuse boundary.
B21t	35-100	Reddish yellow (5YR 6/8), dry to yellowish red (5YR 4/8), moist; sandy clay loam; slightly sticky and slightly plastic (wet), friable (moist), slightly hard (dry) in consistence; a few fine, common medium and coarse roots; many ants; diffuse boundary.
B22tcn	100-132	Reddish yellow (5YR 6/8), dry to yellowish red (5YR 5/8), moist; sandy clay loam; slightly sticky and slightly plastic (wet), friable (moist), slightly hard (dry) in consistence; common medium and big ironstone concretions passing into many (60%) big ironstone concretions with depth.

LAND SYSTEM E, FOOTSLOPE FACET

Location: 465 m east of canal and 740 m north of Binpur road, Mohanpur village, Binpur police station, Midnapore district, West Bengal.
Elevation: 79 m above m.s.l.
Slope angle: 0.9 degree.
Depth to water-table: 1 m in the wet season and 5 m in the summer.
Soil drainage: imperfect.
Vegetation and land use: cultivated; single crop of rice.
Soil erosion: moderate sheet and slight gully erosion.
Stoniness: class 0.
Rockiness: class 0.
Flooding: nil.
Soil classification: Udic Haplustalf.

Horizon	Depth (cm)	Description
Ap	0-21	Yellow (2.5Y 8/6), dry to olive yellow (2.5Y 6/6), moist; sandy loam; moderate coarse granular in structure; slightly sticky and slightly plastic (wet), friable (moist), slightly hard (dry) in consistence; common very fine roots; common ants; common small and medium ironstone concretions; diffuse boundary.
A2	21-67	Yellow (10YR 7/7), dry to brownish yellow (10YR 6/7), moist; sandy loam; slightly sticky and slightly plastic (wet), friable (moist), slightly hard (dry) in consistence; common very fine roots; common termites; common medium manganese and ironstone concretions; gradual boundary.
B21tgcn	67-87	White (N 8/0), dry to light grey (10Y 8/1), moist; clay; slightly sticky and very plastic (wet), firm (moist), slightly hard (dry) in consistence; many (90%) medium and big iron-:stone concretions.
B22m	87+	Cemented pisolitic ironstone.

LAND SYSTEM E, TOESLOPE FACET

Location: 900 m east of canal and 700 m north of Binpur road, Ghoraisoli village, Binpur police station, Midnapore district, West Bengal.
Elevation: 78 m above m.s.l.
Slope angle: +/- 1.1 degrees.
Depth to water-table: 1 m in the wet season and 4 m in the summer.
Soil drainage: imperfect.
Vegetation and land use: cultivated; single crop of rice.
Soil erosion: nil.
Stoniness: class 0.
Rockiness: nil.
Flooding: nil.
Soil classification: Typic Haplustalf.

Horizon	Depth (cm)	Description
Ap	0-21	Pale yellow (5Y 7/4), dry to pale olive (5Y 6/3), moist; common medium faint brown mottles along rice roots; loam; moderate coarse granular in structure; sticky and plastic (wet), firm (moist), slightly hard (dry) in consistence; common very fine, a few fine roots; common earthworms; a few small and medium ironstone concretions; clear boundary.
B21t	21-45	Yellow (2.5Y 7/5), dry to olive yellow (2.5Y 6/5), moist; clay; slightly sticky and plastic (wet),

		firm (moist), very hard (dry) in consistence; a few very fine roots; many termites; a few small and medium ironstone concretions; diffuse boundary.
B22tca	45-82	Pale yellow (2.5Y 7/4), dry to light yellowish brown (2.5Y 6/4), moist; clay; slightly sticky and plastic (wet), very firm (moist), very hard (dry) in consistence; a few very fine roots; many termites; a few small ironstone concretions; a few small and medium calcium carbonate concretions; clear boundary.
B23tcag	82-130	Light grey (5Y 7/1), dry to grey (5Y 6/1), moist; clay; slightly sticky and very plastic (wet), very firm (moist), very hard (dry) in consistence; common small and medium ironstone concretions; many (25%) medium and big calcium carbonate concretions.

LAND SYSTEM E, BASE FACET

Location: 1230 m east of canal and 660 m north of Binpur road, Ghoraisoli village, Binpur police station, Midnapore district, West Bengal.
Elevation: 76 m above m.s.l.
Slope angle: 0.1 degree.
Depth to water-table: near surface in the wet season and 2 m in the summer; 1 m during field work.
Soil drainage: poor.
Vegetation and land use: cultivated; single crop of rice.
Soil erosion: nil.
Stoniness: class 0.
Rockiness: nil.
Flooding: nil.
Soil classification: Typic Haplaquept.

Horizon	Depth (cm)	Description
Apg	0-21	White (7.5Y 8/1), dry to light grey (7.5Y 7/1), moist; common medium faint reddish yellow mottles along rice roots; clay loam; moderate coarse granular in structure; slightly sticky and plastic (wet), firm (moist), very hard (dry) in consistence; common very fine, a few fine roots; common earthworms, a few spiders and millipedes; a few small and medium ironstone concretions; clear boundary.
B21g	21-44	Light grey (7.5Y 7/1), dry to grey (7.5Y 5/1), moist; common medium faint brown (7.5YR 7/8, dry and 5/8, moist) mottles; silty clay loam; sticky and plastic (wet), firm (moist), very hard (dry) in consistence; common very fine

		roots; many termites; a few small and medium ironstone concretions; clear boundary.
B22g	44-73	Light grey (N 7/0), dry to grey (N 5/0), moist; many medium distinct yellowish red (5YR 6/8, dry and 4/8, moist) mottles; silty clay; sticky and plastic (wet), firm (moist), very hard (dry) in consistence; common very fine roots; gradual boundary.
B23g	73-100	White (N 8/0), dry to light grey (N 6/0), moist; many medium distinct brown (7.5YR 6/8, dry and 5/8, moist) mottles; clay loam; slightly sticky and plastic (wet), firm (moist), very hard (dry) in consistence; a few very fine roots.

LAND SYSTEM E

DEPTH IN cm	ORG. MTR.%	C %	N %	C/N	Av. P µg/g	Av. P kg/ha	Av. K µg/g	Av. K kg/ha
E. SUMMIT and SHOULDER								
0-35	0.209	0.121	0.016	7.56	0.00	0.00	38.22	95.56
35-100	0.193	0.112	0.023	4.87	0.61	1.52	83.39	208.48
100-132	0.122	0.071	0.017	4.18	1.22	3.06	82.65	206.63
E. FOOTSLOPE								
0-21	0.510	0.296	0.033	8.97	0.51	1.275	42.84	107.10
21-67	0.176	0.102	0.015	6.80	1.12	2.800	42.79	106.97
67-87	0.217	0.126	0.028	4.50	0.31	0.775	96.49	241.22
E. TOESLOPE								
0-21	0.557	0.323	0.036	8.97	3.65	9.125	77.21	193.03
21-45	0.257	0.149	0.027	5.52	2.67	6.675	92.92	232.30
45-82	0.240	0.139	0.024	5.79	8.71	21.775	91.92	229.80
82-130	0.146	0.085	0.021	4.05	3.86	9.650	99.53	248.83
E. BASE								
0-21	1.283	0.744	0.070	10.63	1.25	3.125	66.60	166.49
21-44	0.590	0.342	0.041	8.34	2.87	7.175	81.55	203.87
44-73	0.591	0.343	0.040	8.57	1.47	3.675	90.15	225.37
73-100	0.341	0.198	0.032	6.19	5.78	14.450	69.33	173.32

LAND SYSTEM E

DEPTH IN cm	Ex.Ca^{++} me/100g	Ex.Mg^{++} me/100g	Ex.Na^{+} me/100g	Ex.K^{+} me/100g	Ex.Al^{+++} me/100g	Al saturat-:ion %	Ex.Acidity me/100g	L.R. KG/HA
E. SUMMIT and SHOULDER								
0-35	1.53	0.16	0.005	0.10	0.80	18.58	2.51	3137.5
35-100	4.09	1.25	0.03	0.30	0.10	1.14	3.05	
100-132	4.52	1.22	0.03	0.27	0.10	1.21	2.24	
E. FOOTSLOPE								
0-21	3.25	0.88	0.05	0.12	0.50	6.52	3.37	4212.5
21-67	5.37	1.13	0.04	0.13	0.10	1.10	2.44	
67-87	14.54	3.60	0.15	0.37	0.10	0.42	4.93	
E. TOESLOPE								
0-21	11.71	3.20	0.10	0.29	0	0	3.76	4700.0
21-45	18.95	4.76	0.31	0.35	0	0	4.59	
45-82	21.33	5.08	0.51	0.35	0	0	4.38	
82-130	45.20	5.79	0.97	0.39	0	0	0	
E. BASE								
0-21	16.44	3.64	0.63	0.24	0	0	4.27	5337.5
21-44	16.81	3.83	0.43	0.29	0	0	4.50	
44-73	17.43	3.92	0.41	0.32	0	0	4.19	
73-100	16.31	3.93	0.27	0.28	0	0	3.57	

LAND SYSTEM E

DEPTH IN cm	T.E.B. me/100g	C.E.C. me/100g	B.S. %	pH 1:2.5 H_2O	pH 1:2.5 0.01M $CaCl_2$	E.C. mmhos/cm	$CaCO_3$ %	Free Fe %
E. SUMMIT and SHOULDER								
0-35	1.795	4.305	41.70	5.11	4.33	0.012	0	0.82
35-100	5.67	8.72	65.02	5.69	4.97	0.012	0	1.77
100-132	6.04	8.28	72.95	5.91	5.40	0.010	0	1.87
E. FOOTSLOPE								
0-21	4.30	7.67	56.06	5.47	4.66	0.012	0	1.49
21-67	6.67	9.11	73.22	6.42	5.55	0.002	0	2.00
67-87	18.66	23.59	79.10	6.55	5.67	0.013	0	4.71
E. TOESLOPE								
0-21	15.30	19.06	80.27	6.41	5.49	0.019	0.008	1.28
21-45	24.37	28.96	84.15	7.35	6.30	0.024	0.015	2.00
45-82	27.27	31.65	86.16	7.06	6.23	0.023	0.016	1.85
82-130	52.35	52.35	100.00	8.61	7.90	0.102	4.241	1.07
E. BASE								
0-21	20.95	25.22	83.07	6.75	6.21	0.085	0.024	1.53
21-44	21.36	25.86	82.60	7.32	6.50	0.032	0.017	2.01
44-73	22.08	26.27	84.05	7.49	6.55	0.029	0.014	1.82
73-100	20.79	24.36	85.34	7.89	6.80	0.032	0.008	1.82

LAND SYSTEM E

DEPTH IN cm	GRAVEL %	SAND %	SILT %	CLAY %	F.C. % VOL/VOL	W.P. % VOL/VOL	A.W.C. % VOL/VOL	A.W.C. cm/cm
E. SUMMIT and SHOULDER								
0-35	1.1	73.28	15.74	10.98	17.65	6.62	11.03	0.11
35-100	1.8	58.83	16.72	24.45	23.09	12.38	10.71	0.11
100-132	25.3	60.08	17.23	22.69	23.41	11.87	11.54	0.11
E. FOOTSLOPE								
0-21	6.1	58.22	23.83	17.95	29.40	10.82	18.58	0.19
21-67	5.8	59.57	22.95	17.48	28.58	12.35	16.23	0.16
67-87	76.6	33.46	20.06	46.48	34.69	22.91	11.78	0.12
E. TOESLOPE								
0-21	8.0	43.49	30.59	25.92	36.46	18.09	18.37	0.18
21-45	5.8	27.04	29.26	43.70	47.35	29.63	17.72	0.18
45-82	5.5	23.65	32.61	43.74	45.41	21.65	23.76	0.24
82-130	31.6	25.06	32.12	42.82	43.33	22.00	21.33	0.21
E. BASE								
0-21	5.8	27.73	38.72	33.55	42.00	25.81	16.19	0.16
21-44	2.5	14.90	45.58	39.52	41.30	27.43	13.87	0.14
44-73	3.5	16.68	40.97	42.35	42.34	21.13	21.21	0.21
73-100	2.5	24.25	36.63	39.12	41.61	26.89	14.72	0.15

LAND SYSTEM E

DEPTH IN cm	B.D. g/cm^3	TOTAL POROSITY %	WATER-FILLED POROSITY %	AIR-FILLED POROSITY %
E. SUMMIT and SHOULDER				
0-35	1.43	46.04	17.65	28.39
35-100	1.28	51.70	23.09	28.61
100-132	1.27	52.07	23.41	28.66
E. FOOTSLOPE				
0-21	1.40	47.17	29.40	17.77
21-67	1.46	44.91	28.58	16.33
67-87	1.15	56.60	34.69	21.91
E. TOESLOPE				
0-21	1.34	49.43	36.46	12.97
21-45	1.33	49.81	47.35	2.46
45-82	1.26	52.45	45.41	7.04
82-130	1.35	49.06	43.33	5.73
E. BASE				
0-21	1.33	49.81	42.00	7.81
21-44	1.28	51.70	41.30	10.40
44-73	1.27	52.07	42.34	9.73
73-100	1.27	52.07	41.61	10.46

GULLY ERODED AREA

Location: 320 m north of Dherua road and 640 m east of forest road, Khas jangal trailokyapur village, Midnapore police station, Midnapore district, West Bengal.
Elevation: 45 m above m.s.l.
Slope angle: 1.0 degree.
Depth to water-table: 4 m in the wet season and 10 m in the summer.
Soil drainage: well.
Vegetation and land use: open coppice of _Shorea_ _robusta_ and associates.
Soil erosion: severe to very severe gully erosion.
Stoniness: class 0.
Rockiness: class 1.
Flooding: nil.
Soil classification: Udic Ustochrept.

Horizon	Depth (cm)	Description
A1	0-16	Reddish yellow (7.5YR 8/6), dry to reddish yellow (7.5YR 6/7), moist; sandy loam; struct-:ureless, massive; slightly sticky and non-plastic (wet), very friable (moist), slightly hard (dry) in consistence; common very fine, a few fine, common medium roots; many ants; diffuse boundary.
B21	16-32	Reddish yellow (7.5YR 7/6), dry to reddish yellow (7.5YR 6/7), moist; sandy loam; slightly sticky and slightly plastic (wet), friable (moist), slightly hard (dry) in consistence; common very fine, a few fine and medium, common coarse roots; many ants; diffuse boundary.
B22	32-50	Reddish yellow (7.5YR 8/6), dry to reddish yellow (7.5YR 6/7), moist; sandy loam; slightly sticky and slightly plastic (wet), friable (moist), slightly hard (dry) in consistence; common very fine, a few fine and medium, common coarse roots; many ants; a few small ironstone concretions; gradual boundary.
B23cn	50-67	A few very fine and fine roots; many (60%) small, medium and big ironstone concretions; gradual boundary.
B24cn	67-74	Many (95%) small, medium and big ironstone concretions.
B25m	74+	Weakly cemented pisolitic ironstone.

GULLY EROSION: A CASE STUDY

DEPTH IN cm	ORG.MTR. %	ORG. C.%	N %	C:N	Av.P µg/g	Av.P kg/ha	Av.K µg/g	Av.K kg/ha
0-16	0.174	0.101	0.015	6.73	0.70	1.76	42.33	105.82
16-32	0.245	0.142	0.020	7.10	1.01	2.52	23.22	58.05
32.50	0.228	0.132	0.020	6.60	0.81	2.02	25.22	63.05

DEPTH IN cm	$Ex.Ca^{++}$ me/100g	$Ex.Mg^{++}$ me/100g	$Ex.Na^{+}$ me/100g	$Ex.K^{+}$ me/100g	$Ex.Al^{+++}$ me/100g	Al saturat-:ion %	Ex.Acid-:ity me/100g	L.R. kg/ha
0-16	1.54	0.64	0.04	0.10	0.60	13.22	2.22	2775.0
16-32	2.52	0.87	0.04	0.05	0.30	5.66	1.82	
32-50	3.63	1.12	0.06	0.06	0	0	1.21	

DEPTH IN cm	T.E.B. me/100g	C.E.C. me/100g	B.S. %	pH 1:2.5 H_2O	pH 1:2.5 0.01M $CaCl_2$	E.C. mmhos/cm	$CaCO_3$ %	Free Fe %
0-16	2.32	4.54	51.10	5.19	4.49	0.028	0	1.06
16-32	3.48	5.30	65.66	5.64	4.87	0.012	0	1.21
32-50	4.87	6.08	80.10	7.06	6.31	0.018	0	1.20

DEPTH IN cm	GRAVEL %	SAND %	SILT %	CLAY %	F.C. % VOL/VOL	W.P. % VOL/VOL	A.W.C. % VOL/VOL	A.W.C. cm/cm
0-16	1.8	58.84	23.62	17.54	23.20	7.32	15.88	0.16
16-32	3.6	56.55	23.50	19.95	22.89	8.47	14.42	0.14
32-50	9.8	61.46	21.15	17.39	20.98	8.21	12.77	0.13

DEPTH IN cm	B.D. g/cm^3	TOTAL POROSITY %	WATER-FILLED POROSITY %	AIR-FILLED POROSITY %
0-16	1.42	46.41	23.20	23.21
16-32	1.36	48.68	22.89	25.79
32-50	1.35	49.06	20.98	28.08

APPENDIX B

DIRECTIONS AND SIGNIFICANCE LEVELS OF CORRELATION BETWEEN SURFACE SOIL PROPERTIES AND DISTANCE DOWN-:SLOPE, HEIGHT ABOVE MEAN SEA LEVEL AND SLOPE ANGLE

source: computed from data presented in Appendices A and E using SPSS.

ABBREVIATIONS USED IN APPENDIX B

O.M.	=	Organic matter
Av.	=	Available
Ex.	=	Exchangeable
T.E.B.	=	Total exchangeable bases
C.E.C.	=	Cation exchange capacity
B.S.	=	Base saturation
E.C.	=	Electrical conductivity
F.C.	=	Field capacity
W.P.	=	Wilting point
A.W.C.	=	Available water capacity
Tot.	=	Total
Por.	=	Porosity

LAND SYSTEM A

	SIGNIFICANT RELATIONSHIP					Non-significant relationship
	0.001	0.01	0.02	0.05	0.1	
DISTANCE DOWN-SLOPE		N	E.C.	O.M., Al, Ex. Acid.	C.E.C., F.C., Water Por.	C/N,Av.P,Av.K,Ca, Mg,Na,K,T.E.B.,B.S., pH,Fe,Sand,Silt, Clay,W.P.,A.W.C., B.D., TOT.POR.,AIR.POR.
HEIGHT ABOVE MEAN SEA LEVEL		Fe		O.M(-),Av.P, pH,F.C.(-), WATER POR (-).	N(-),Sand, Silt(-),B.D., TOT.POR.(-).	C/N,Av.K,Ca,Mg,Na,K, Al,Ex.Acid,T.E.B., C.E.C.,B.S.,E.C.,Clay, W.P.,A.W.C.,AIR.POR.
SLOPE ANGLE				C/N		O.M,N,Av.P,Av.K,Ca,Mg, Na,K,Al,Ex.Acid,T.E.B., C.E.C.,B.S.,pH,E.C.,Fe, Sand,Silt,Clay,F.C.,W.P., A.W.C.,B.D.,TOT.POR., WATER POR.,AIR POR.

LAND SYSTEM B

	SIGNIFICANT RELATIONSHIP					Non-significant relationship
	0.001	0.01	0.02	0.05	0.1	
DISTANCE DOWN-SLOPE	C.E.C.	Ca, Mg, T.E.B., F.C., A.W.C., WATER POR.	W.P., AIR POR(-).	O.M., N, Ex.Acid, Sand (-), Clay.	E.C., Fe, Silt.	C/N,Av.P,Av.K,Ex.Na, K,Al,B.S.,pH,$CaCO_3$; B.D., TOT.POR.
HEIGHT ABOVE MEAN SEA LEVEL	C.E.C.(-), F.C. (-), WATER POR.(-).	Ca(-),Mg (-),T.E.B. (-),A.W.C. (-), AIR POR.	O.M.(-), W.P.(-).	N(-), Ex.Acid(-), Sand, Clay(-).	C/N(-), E.C.(-), Silt(-).	Av.P,Av.K,Na,K,Al, B.S.,pH,$CaCO_3$,Fe, B.D.,TOT.POR.
SLOPE ANGLE					E.C.	All except E.C.

LAND SYSTEM C

	SIGNIFICANT RELATIONSHIP					Non-significant relationship
	0.001	0.01	0.02	0.05	0.1	
DISTANCE DOWN-SLOPE		Na, Al, Silt, A.W.C.	N, Ex.Acid, C.E.C., E.C., $CaCO_3$, F.C., WATER POR.	O.M., Ca, Mg, T.E.B., pH(-), Sand (-), B.C.(-), TOT.POR.	Av.P (-), W.P.	C/N, Av.K, K, B.S., Fe, Clay, AIR POR.
HEIGHT ABOVE MEAN SEA LEVEL		Al (-)	Na (-), Silt (-), A.W.C.(-).	O.M.(-), N(-), Av.P, Ca(-), Mg(-), Ex.Acid(-), T.E.B.(-), C.E.C.(-), pH, E.C.(-), $CaCO_3$(-), Sand, F.C.(-), WATER POR.(-).	W.P. (-), B.D., TOT.POR. (-).	C/N, Av.K, K, B.S., Fe, Clay, AIR. POR.
SLOPE ANGLE						All

LAND SYSTEM D

	SIGNIFICANT RELATIONSHIP					Non-significant relationship
	0.001	0.01	0.02	0.05	0.1	
DISTANCE DOWN-SLOPE			B.S.	pH	Av.K (-), Mg, Na, K(-), Al(-).	O.M.,N,C/N,Av.P,Ex.Ca, Ex.Acid,T.E.B.,C.E.C., EC,$CaCO_3$,Fe,Sand,Silt, Clay,FC,WP,AWC,B.D., TOT.POR., WATER POR., AIR POR.
HEIGHT ABOVE MEAN SEA LEVEL			B.S. (-)	Na (-), pH (-).	Mg (-), Al, Fe.	O.M.,N,C/N,Av.P,Av.K, Ca,K,Ex.Acid, T.E.B., C.E.C.,EC,$CaCO_3$,Sand, Silt,Clay,FC,WP,AWC, B.D.,TOT.POR.,WATER POR.,AIR POR.
SLOPE ANGLE		C.E.C.(-), Clay (-).		Ex.Acid (-), T.E.B. (-).	Ca(-), Mg(-), A.W.C.(-), AIR POR.	O.M.,N,C/N,Av.P,Av.K, Na,K,Al,B.S.,pH,EC, $CaCO_3$,Fe,Sand,Silt,F.C., W.P.,B.D.,TOT.POR., WATER POR.

LAND SYSTEM E

	SIGNIFICANT RELATIONSHIP					Non-significant relationship
	0.001	0.01	0.02	0.05	0.1	
DISTANCE DOWN-SLOPE	Sand(-), Clay.	Ex.Acid, C.E.C.,pH, Silt, F.C.,W.P., B.D.(-), TOT.POR., WATER POR., AIR POR(-).	Ca,Mg, Al(-), T.E.B., B.S.	O.M.,N,C/N, $CaCO_3$.	Av.K, Na, K, EC.	Av.P, Fe, A.W.C.
HEIGHT ABOVE MEAN SEA LEVEL		Ex.Acid(-), F.C.(-), WATER POR. (-), AIR POR.		C/N(-),Al, B.S.(-), Fe(-), Sand,Silt (-),Clay (-),B.D., TOT.POR (-).	O.M.(-), N(-), Ca(-), Mg(-), T.E.B.(-), C.E.C.(-), pH(-), W.P.(-).	Av.P, Av.K, Na, K, EC, $CaCO_3$, A.W.C.
SLOPE ANGLE						All

LAND SYSTEMS A - E

	SIGNIFICANT RELATIONSHIP					Non-significant relationship
	0.001	0.01	0.02	0.05	0.1	
DISTANCE DOWN-SLOPE	O.M.,N,Ca, Mg,Ex.Acid T.E.B., C.E.C., F.C.,W.P., WATER POR.	Na,Sand(-), Clay,A.W.C. B.D.(-), TOT.POR, AIR POR (-).	Silt	C/N, B.S., E.C.	Al, $CaCO_3$.	Av.P, Av.K, K, pH, Fe.
HEIGHT ABOVE MEAN SEA LEVEL			Av.K, Silt(-), A.W.C.(-).	K, TOT. POR.(-).	O.M.(-), N(-), pH, Sand, F.C. (-), B.D., WATER POR. (-).	C/N,Av.P,Ca,Mg,Na, Al,Ex.Acid,T.E.B., C.E.C.,B.S.,,E.C., $CaCO_3$,Fe,Clay,W.P., AIR POR.
SLOPE ANGLE					AIR POR.	All except AIR POR.

APPENDIX C

WEIGHTED MEANS OF PROPERTIES OF 120 cm SOIL PROFILES OF LAND SYSTEMS A - E

source: calculated from data presented in Appendix A using the formula

$$\bar{X}_w = \frac{\Sigma wX}{\Sigma w}$$

where $\bar{X}_w$ = weighted arithmetic mean,
X = values of observations,
w = weights applied to X values.

ABBREVIATIONS USED IN APPENDIX C

O.M.	=	Organic matter
Av.	=	Available
Ex.	=	Exchangeable
T.E.B.	=	Total exchangeable bases
C.E.C.	=	Cation exchange capacity
B.S.	=	Base saturation
E.C.	=	Electrical conductivity
F.C.	=	Field capacity
W.P.	=	Wilting point
A.W.C.	=	Available water capacity
B.D.	=	Bulk density
Tot.	=	Total

LAND SYSTEM A

PROPERTIES	SUMMIT	FOOTSLOPE	TOESLOPE	BASE
O.M. (%)	0.520	0.345	0.470	0.507
C (%)	0.300	0.200	0.273	0.294
N (%)	0.035	0.027	0.037	0.039
C/N	8.64	6.47	7.21	7.10
Av.P (μg/g)	1.46	1.57	2.56	0.86
Av.K (μg/g)	29.66	38.35	69.40	49.75
Ex.Ca^{++}(me/100)	3.24	5.38	12.04	8.15
Ex.Mg^{++}(me/100)	1.26	1.14	3.20	2.24
Ex.Na^{+}(me/100)	0.05	0.05	0.65	0.16
Ex.K^{+}(me/100)	0.08	0.10	0.23	0.13
Ex.Al^{+++}(me/100)	0.25	0.18	0.20	0.79
Ex.Acidity (,,)	4.64	3.75	5.41	5.69
T.E.B. (me/100)	4.63	6.68	16.11	10.68
C.E.C. (me/100)	9.27	10.43	21.52	16.37
B.S. (%)	49.94	64.05	74.86	65.24
pH (0.01M $CaCl_2$)	4.87	5.13	5.53	4.89
E.C. (mmhos/cm)	0.004	0.005	0.018	0.016
$CaCO_3$ (%)	0.00	0.007	0.003	0.007
Free Fe (%)	3.39	2.51	2.31	1.41
Sand (%)	52.10	47.07	14.74	26.36
Silt (%)	26.96	27.33	44.29	48.13
Clay (%)	20.94	25.60	40.96	25.50
F.C. (% vol)	25.08	29.55	42.83	37.57
W.P. (% vol)	10.75	13.10	27.17	18.45
A.W.C. (% vol)	14.33	16.45	15.67	19.13
B.D. (g/cm^3)	1.22	1.20	1.22	1.23
Tot.Porosity (%)	54.02	54.73	53.99	53.41
Water Poros. (%)	25.08	29.55	42.83	37.57
Air Porosity (%)	28.94	25.18	11.16	15.84

LAND SYSTEM B

PROPERTIES	SUMMIT	SHOULDER	FOOTSLOPE	TOESLOPE	BASE
O.M. (%)	0.247	0.135	0.345	0.325	0.520
C (%)	0.143	0.078	0.200	0.188	0.302
N (%)	0.024	0.019	0.029	0.025	0.038
C/N	6.03	3.87	6.21	6.87	7.80
Av.P (µg/g)	0.962	2.11	1.44	0.16	6.86
Av.K (µg/g)	42.69	76.47	66.60	43.74	57.16
Ex.Ca^{++}(me/100)	2.44	2.99	11.28	4.42	11.23
Ex.Mg^{++}(me/100)	0.84	1.11	4.00	1.27	3.62
Ex.Na^{+}(me/100)	0.00	0.00	0.34	0.02	0.07
Ex.K^{+}(me/100)	0.15	0.25	0.25	0.15	0.19
Ex.Al^{+++}(me/100)	0.64	0.72	0.06	0.125	0.17
Ex.Acidity (,,)	3.03	3.54	3.46	2.56	4.39
T.E.B. (me/100)	3.43	4.35	15.87	5.86	15.11
C.E.C. (me/100)	6.46	7.89	19.33	8.42	19.50
B.S. (%)	53.09	55.13	82.10	69.60	77.49
pH (0.01M $CaCl_2$)	4.50	4.60	5.47	5.17	5.99
E.C. (mmhos/cm)	0.003	0.024	0.021	0.007	0.022
$CaCO_3$ (%)	0.00	0.00	0.005	0.01	0.008
Free Fe (%)	1.42	1.68	1.49	1.22	2.66
Sand (%)	62.19	59.54	37.62	54.99	43.25
Silt (%)	15.82	16.39	30.81	27.73	27.92
Clay (%)	21.99	24.06	31.57	17.27	28.83
F.C. (% vol)	19.14	21.13	35.29	29.75	36.33
W.P. (% vol)	7.86	9.53	18.28	9.40	15.85
A.W.C. (% vol)	11.28	11.60	17.01	20.35	20.48
B.D. (g/cm^3)	1.26	1.16	1.30	1.39	1.32
Tot.Porosity (%)	52.44	53.99	50.95	47.40	50.24
Water Poros. (%)	19.14	21.13	35.29	29.75	36.33
Air Porosity (%)	33.30	32.86	15.66	17.65	13.91

LAND SYSTEM C

PROPERTIES	SUMMIT	SHOULDER	FOOTSLOPE	TOESLOPE	BASE
O.M. (%)	0.276	0.305	0.318	0.508	0.329
C (%)	0.160	0.177	0.184	0.295	0.191
N (%)	0.026	0.029	0.022	0.036	0.024
C/N	6.15	6.10	8.192	8.19	7.96
Av.P (µg/g)	0.61	1.64	0.822	1.64	1.83
Av.K (µg/g)	56.49	85.90	52.30	73.21	34.33
Ex.CA^{++}(me/100)	3.21	4.45	9.50	12.57	5.75
Ex.Mg^{++}(me/100)	1.02	1.82	3.37	4.04	1.73
Ex.Na^{+}(me/100)	0.02	0.04	0.15	0.28	0.23
Ex.K^{+}(me/100)	0.17	0.31	0.18	0.27	0.11
Ex.Al^{+++}(me/100)	0.19	0.25	1.05	0.27	0.26
Ex.Acidity (,,)	2.85	3.46	5.18	4.08	2.19
T.E.B. (me/100)	4.42	6.62	13.20	17.16	7.82
C.E.C. (me/100)	7.27	10.08	18.37	21.24	10.01
B.S. (%)	60.80	65.67	70.73	80.79	78.12
pH (0.01M $CaCl_2$)	5.08	5.33	4.67	5.81	6.19
E.C. (mmhos/cm)	0.005	0.011	0.014	0.020	0.020
$CaCO_3$ (%)	0.00	0.00	0.00	0.13	0.15
Free Fe (%)	1.67	2.27	2.15	1.69	1.12
Sand (%)	58.18	50.82	48.69	40.36	68.67
Silt (%)	18.53	19.14	20.81	26.67	15.59
Clay (%)	23.29	30.04	30.49	32.97	15.74
F.C. (% vol)	21.98	23.73	28.33	33.32	24.43
W.P. (% vol)	9.83	11.85	13.62	16.35	10.15
A.W.C. (% vol)	12.15	11.88	14.71	16.97	14.28
B.D. (g/cm^3)	1.29	1.21	1.25	1.20	1.36
Tot.Porosity (%)	51.32	54.34	52.72	54.59	48.72
Water Poros. (%)	21.98	23.73	28.33	33.32	24.43
Air Porosity (%)	29.34	30.61	24.39	21.27	24.29

LAND SYSTEM D

PROPERTIES	SUMMIT	SHOULDER	FOOTSLOPE	TOESLOPE	BASE
O.M. (%)	0.331	0.396	0.394	0.333	0.254
C (%)	0.192	0.230	0.229	0.193	0.147
N (%)	0.032	0.029	0.031	0.028	0.020
C/N	6.00	7.93	7.39	6.89	7.35
Av.P (µg/g)	1.50	1.71	2.14	1.99	0.59
Av.K (µg/g)	92.67	40.15	188.45	84.59	42.51
Ex.Ca^{++}(me/100)	8.87	1.11	6.89	9.83	5.85
Ex.Mg^{++}(me/100)	3.07	0.14	2.03	3.36	1.77
Ex.Na^{+}(me/100)	0.05	0.00	0.07	0.25	0.14
Ex.K^{+}(me/100)	0.35	0.11	0.86	0.31	0.12
Ex.Al^{+++}(me/100)	1.30	0.30	0.02	0.05	0.12
Ex.Acidity (,,)	7.22	2.11	2.87	3.04	2.68
T.E.B. (me/100)	12.34	1.36	9.85	13.75	7.88
C.E.C.(me/100)	19.56	3.47	12.72	16.79	10.56
B.S. (%)	63.09	39.19	77.44	81.89	74.62
pH (0.01M $CaCl_2$)	4.54	4.41	5.75	6.17	5.14
E.C. (mmhos/cm)	0.020	0.013	0.029	0.034	0.015
$CaCO_3$ (%)	0.004	0.00	0.008	0.003	0.013
Free Fe (%)	2.26	2.01	1.79	1.59	0.89
Sand (%)	27.68	85.97	45.89	34.04	51.80
Silt (%)	34.12	9.29	28.99	37.27	31.92
Clay (%)	38.20	4.74	25.12	28.69	16.28
F.C. (% vol)	32.65	14.54	31.82	38.23	31.86
W.P. (% vol)	15.73	3.20	13.14	18.19	11.55
A.W.C. (% vol)	16.92	11.34	18.68	19.32	20.31
B.D. (g/cm^3)	1.12	1.52	1.32	1.31	1.33
Tot.Porosity (%)	57.72	42.64	50.23	50.68	49.83
Water Poros. (%)	32.65	14.54	31.82	38.23	31.86
Air Porosity (%)	25.07	28.10	18.41	12.45	17.97

LAND SYSTEM E

PROPERTIES	SUMMIT & SHOULDER	FOOTSLOPE	TOESLOPE	BASE
O.M. (%)	0.186	0.252	0.269	0.614
C (%)	0.108	0.146	0.156	0.356
N (%)	0.020	0.024	0.026	0.042
C/N	5.40	6.08	6.00	8.48
Av.P (µg/g)	0.55	0.65	5.08	3.39
Av.K (µg/g)	71.45	66.52	91.95	76.23
Ex.Ca^{++}(me/100)	3.87	9.05	26.73	16.70
Ex.Mg^{++}(me/100)	0.95	2.18	4.91	3.86
Ex.Na^{+}(me/100)	0.02	0.09	0.54	0.40
Ex.K^{+}(me/100)	0.24	0.23	0.35	0.28
Ex.Al^{+++}(me/100)	0.30	0.17	0.00	0.00
Ex.Acidity (,,)	2.79	3.70	2.93	4.02
T.E.B. (me/100)	5.08	11.55	32.53	21.24
C.E.C. (me/100)	7.87	15.25	35.46	25.26
B.S. (%)	64.55	75.74	91.74	84.08
pH (0.01M $CaCl_2$)	4.94	5.45	6.64	6.58
E.C. (mmhos/cm)	0.012	0.009	0.047	0.040
$CaCO_3$ (%)	0.00	0.00	1.35	0.013
Free Fe (%)	1.54	3.11	1.53	1.81
Sand (%)	64.25	47.80	28.25	21.24
Silt (%)	16.81	21.83	31.43	39.76
Clay (%)	18.94	30.37	40.32	39.00
F.C. (% vol)	21.95	31.42	43.57	41.79
W.P. (% vol)	10.81	16.75	22.73	25.41
A.W.C. (% vol)	11.14	14.67	20.84	16.38
B.D. (g/cm^3)	1.34	1.31	1.32	1.28
Tot.Porosity (%)	50.98	50.47	50.32	51.60
Water Porosity (%)	21.95	31.42	43.57	41.79
Air Porosity (%)	29.03	19.05	6.75	9.81

APPENDIX D

MORPHOLOGICAL, PHYSICAL AND CHEMICAL PROPERTIES OF SOILS OF THE FOUR FLOOD PLAINS

source: field and laboratory work; see SECTIONS 3.3 and 3.4 for methods of studies.

ABBREVIATIONS USED IN APPENDIX D

O.M.	=	Organic matter
Av.	=	Available
Ex.	=	Exchangeable
L.R.	=	Lime requirement
T.E.B.	=	Total exchangeable bases
C.E.C.	=	Cation exchange capacity
B.S.	=	Base saturation
E.C.	=	Electrical conductivity
F.C.	=	Field capacity
W.PT.	=	Wilting point
A.W.C.	=	Available water capacity
B.D.	=	Bulk density
T.P.	=	Total porosity
W.P.	=	Water porosity
A.P.	=	Air porosity

LAND SYSTEM F, FLOOD PLAIN OF R. DARAKESWAR

Location: left bank of R. Darakeswar, Katna village, Bishnupur police station, Bankura district, West Bengal.
Elevation: 50 m above m.s.l.
Slope angle: 0.0 degree.
Depth to water-table: 3.4 m on average.
Soil drainage: imperfect.
Vegetation and land use: entire area cultivated; 50% of the area multiple-cropped; rice, wheat, potato, oilseeds and vegetables main crops.
Soil erosion: nil.
Stoniness: class 0.
Rockiness: nil.
Flooding: regular and mild.

Surface soil sample no.	Morphological description
1	Light yellowish brown (2.5Y 6/3), dry to olive brown (2.5Y 4/3), moist; mottled red along rice roots; loam; coarse granular in structure; slightly sticky and plastic (wet), firm (moist), very hard (dry) in consist-:ence; many very fine, common fine roots; common earthworms and ants; a few small ironstone concretions.
2	Pale yellow (2.5Y 7/3), dry to light olive brown (2.5Y 5/3), moist; mottled brown along rice roots; loam; coarse granular in structure; slightly sticky and plastic (wet), firm (moist), hard (dry) in consistence; many very fine, a few fine roots; common earthworms; common medium ironstone concretions.
3	Light grey (2.5Y 7/2), dry to light brownish grey (2.5Y 6/2), moist; loam; coarse granular in structure; slightly sticky and slightly plastic (wet), very friable (moist), slightly hard (dry) in consistence; many very fine, common fine roots; common earthworms and ants; common medium ironstone concretions.
4	Pale brown (10 YR 6/3), dry to brown (10YR 5/3), moist; mottled red along rice roots; silt loam; medium crumb in structure; slightly sticky and slightly plastic (wet), friable (moist), hard (dry) in consistence; many very fine, common fine roots; common earthworms; common medium and coarse ironstone concretions.
5	White (7.5Y 8/2), dry to light grey (7.5Y 7/2), moist; common small distinct brown (7.5YR 7/7, dry and 5/7, moist) mottles; silt loam; medium granular in structure; slightly sticky and slightly plastic (wet), firm (moist), very hard (dry) in consistence; many very fine, a few fine roots; common earthworms and ants; a few small ironstone concretions.
6	Pale yellow (2.5Y 7/3), dry to light yellowish brown (2.5Y 6/3), moist; loam; medium crumb in structure; slightly sticky and plastic (wet), firm (moist), very

hard (dry) in consistence; common very fine and fine roots; many ants; common small ironstone concretions.

7 Light yellowish brown (10YR 6/4), dry to yellowish brown (10YR 5/4), moist; mottled red along rice roots; loam; medium crumb in structure; slightly sticky and plastic (wet), friable (moist), hard (dry) in consistence; many very fine, a few fine roots; common earthworms; common small ironstone concretions.

8 Pale yellow (2.5Y 7/4), dry to light olive brown (2.5Y 5/4), moist; mottled brown along rice roots; silty clay loam; medium crumb in structure; slightly sticky and plastic (wet), firm (moist), very hard (dry) in consistence; many very fine, common fine roots; common earthworms; common small ironstone concretions.

9 Light yellowish brown (2.5Y 6/3), dry to light olive brown (2.5Y 5/3), moist; mottled red along rice roots; silty clay loam; coarse granular in structure; sticky and plastic (wet), very firm (moist), hard (dry) in consistence; many very fine, a few fine roots; common earthworms; common medium ironstones.

10 Pale brown (10YR 6/3), dry to brown (10YR 4/3), moist; mottled red along rice roots; loam; medium granular in structure; slightly sticky and slightly plastic (wet), friable (moist), slightly hard (dry) in consistence; many very fine, a few fine roots; common earthworms; a few small ironstone concretions.

11 Light yellowish brown (2.5Y 6/4), dry to olive brown (2.5Y 4/3), moist; silty clay loam; coarse granular in structure; slightly sticky and slightly plastic (wet), firm (moist), slightly hard (dry) in consistence; many very fine, common fine roots; common earthworms and ants; a few small ironstone concretions.

12 Yellow (2.5Y 7/6), dry to olive yellow (2.5Y 6/6), moist; mottled yellowish red along rice roots; silty clay; medium granular in structure; slightly sticky and plastic (wet), firm (moist), very hard (dry) in consistence; many very fine, a few fine roots; common earthworms; a few small ironstone concretions.

LAND SYSTEM F

RIVER FLOOD PLAIN - DARAKESWAR

Sample No.	ORG.MTR. %	C %	N %	C/N	Av. P µg/g	Av. P kg/ha	Av. K µg/g	Av. K kg/ha
D.1	1.377	0.799	0.079	10.11	4.68	11.70	135.20	338.01
D.2	0.988	0.573	0.061	9.39	2.28	5.71	97.60	244.00
D.3	0.902	0.523	0.057	9.17	13.82	34.54	96.21	240.53
D.4	0.800	0.464	0.055	8.44	2.06	5.14	67.91	169.79
D.5	1.048	0.608	0.061	9.97	1.76	4.40	91.06	227.65
D.6	1.486	0.862	0.077	11.19	3.17	7.93	188.31	470.78
D.7	1.112	0.645	0.070	9.21	1.30	3.24	101.62	254.04
D.8	1.229	0.713	0.076	9.38	1.67	4.18	112.93	282.34
D.9	1.365	0.792	0.077	10.29	14.80	37.00	316.06	790.14
D.10	0.919	0.533	0.056	9.52	4.70	11.76	71.59	178.97
D.11	1.040	0.603	0.075	8.04	1.76	4.41	102.64	256.61
D.12	1.127	0.654	0.075	8.72	2.52	6.31	87.29	218.21

LAND SYSTEM F

RIVER FLOOD PLAIN - DARAKESWAR

Sample No.	$Ex.Ca^{++}$ me/100g	$Ex.Mg^{++}$ me/100g	$Ex.Na^{+}$ me/100g	$Ex.K^{+}$ me/100g	$Ex.Al^{+++}$ me/100g	Al saturation %	Ex.Acidity me/100g	L.R. kg/ha
D.1	13.26	3.89	0.30	0.56	0.10	0.42	5.72	7150.0
D.2	13.24	4.06	0.25	0.40	-	-	5.50	6875.0
D.3	10.21	2.80	0.17	0.39	0.10	0.57	4.09	5112.5
D.4	8.27	2.81	0.16	0.24	-	-	4.22	5275.0
D.5	12.62	3.87	0.22	0.38	-	-	5.69	7112.5
D.6	11.06	3.26	0.19	0.90	-	-	3.79	4737.5
D.7	12.65	3.94	0.19	0.45	-	-	5.50	6875.0
D.8	12.17	4.17	0.16	0.45	-	-	7.84	9800.0
D.9	18.40	5.00	0.32	1.24	-	-	3.05	3812.5
D.10	8.22	2.59	0.16	0.26	-	-	4.29	5362.5
D.11	11.50	4.22	0.26	0.44	-	-	6.63	8287.5
D.12	12.10	4.52	0.14	0.34	-	-	7.78	9725.0

LAND SYSTEM F

RIVER FLOOD PLAIN - DARAKESWAR

Sample No.	T.E.B. me/100g	C.E.C. me/100g	B.S. %	pH 1:2.5 H_2O	pH 1:2.5 0.01M $CaCl_2$	E.C. mmhos/cm	$CaCO_3$ %	Free Fe %
D.1	18.01	23.73	75.89	6.21	5.65	0.076	0	-
D.2	17.95	23.45	76.55	6.58	5.62	0.023	0.008	-
D.3	13.57	17.66	76.84	6.44	5.72	0.047	0	-
D.4	11.48	15.70	73.12	5.81	5.32	0.072	0	-
D.5	17.09	22.78	75.02	6.60	5.50	0.024	0	-
D.6	15.41	19.20	80.26	6.80	6.04	0.046	0	-
D.7	17.23	22.73	75.80	6.48	5.55	0.031	0	-
D.8	16.95	24.79	68.37	5.60	4.97	0.040	0	-
D.9	24.96	28.01	89.11	7.94	7.41	0.123	0.077	-
D.10	11.23	15.52	72.36	6.05	5.38	0.049	0	-
D.11	16.42	23.05	71.24	5.50	5.10	0.099	0	-
D.12	17.10	24.88	68.73	5.57	4.97	0.023	0	-

LAND SYSTEM F

RIVER FLOOD PLAIN - DARAKESWAR

Sample No.	Gravel %	Sand %	Silt %	Clay %	F.C. % VOL/VOL	W.PT. % VOL/VOL	A.W.C. % VO./VOL	A.W.C. cm/cm
D.1	5.8	27.99	46.30	25.71	38.01	14.65	23.36	0.23
D.2	6.1	28.65	44.89	26.46	41.03	24.52	16.51	0.16
D.3	4.5	36.62	46.39	16.99	34.71	12.62	22.09	0.22
D.4	3.2	32.87	52.44	14.69	36.84	9.72	27.12	0.27
D.5	9.2	21.57	52.11	26.32	39.39	23.15	16.24	0.16
D.6	3.5	31.82	48.98	19.20	36.31	19.22	17.09	0.17
D.7	6.8	23.97	49.28	26.75	41.52	21.47	20.05	0.20
D.8	6.1	15.34	50.82	33.84	40.15	14.00	26.15	0.26
D.9	3.5	16.52	49.47	34.01	42.00	23.93	18.07	0.18
D.10	2.5	38.52	46.71	14.77	33.89	16.12	17.77	0.18
D.11	5.2	16.35	52.96	30.69	38.85	19.03	19.82	0.20
D.12	8.3	14.06	41.23	44.71	46.99	22.05	24.94	0.25

LAND SYSTEM F

RIVER FLOOD PLAIN - DARAKESWAR

Sample No.	B.D. g/cm^3	T.P. %	W.P. %	A.P. %
D.1	1.15	56.60	38.01	18.59
D.2	1.21	54.34	41.03	13.31
D.3	1.12	57.74	34.71	23.03
D.4	1.23	53.58	36.84	16.74
D.5	1.16	56.23	39.39	16.84
D.6	1.13	57.36	36.31	21.05
D.7	1.23	53.58	41.52	12.06
D.8	1.10	58.49	40.15	18.34
D.9	1.12	57.74	42.00	15.74
D.10	1.19	55.09	33.89	21.20
D.11	1.12	57.74	38.85	18.89
D.12	1.25	52.83	46.99	5.84

LAND SYSTEM F, FLOOD PLAIN OF R. SILAI

Location: left bank of R. Silai, Bhiknagar village, Garhbeta police station, Midnapore district, West Bengal.
Elevation: 45 m above m.s.l.
Slope angle: 0.0 degree.
Depth to water-table: 4 m on average.
Soil drainage: imperfect.
Vegetation and land use: 85% of the area cultivated and 15% under sand with grass; most of the cultivated area multiple-cropped; rice, potato and oilseeds main crops.
Soil erosion: nil
Stoniness: class 0.
Rockiness: nil.
Flooding: occasionally very severe.

Surface soil sample no.	Morphological description
1.	Very pale brown (10YR 7/3), dry to brown (10YR 5/3), moist; loamy sand; structureless, single grain; non-sticky and non-plastic (wet), very friable (moist), soft (dry) in consistence; many very fine, common fine roots; common ants; a few small ironstone concretions.
2	Very pale brown (10YR 7/4), dry to light yellowish brown (10YR 6/4), moist; sand; structureless, single grain; non-sticky and non-plastic (wet), very friable (moist), soft (dry) in consistence; common very fine and fine roots; common ants.
3	Light yellowish brown (10YR 6/4), dry to yellowish brown (10YR 5/4), moist; loamy sand; structureless, single grain; non-sticky and non-plastic (wet), very friable (moist), soft (dry) in consistence; many very fine, a few fine roots; common ants.
4	Very pale brown (10YR 7/4), dry to light yellowish brown (10YR 6/4), moist; sandy loam; structureless, single grain; non-sticky and non-plastic (wet), very friable (moist), soft (dry) in consistence; many very fine, a few fine roots; common ants and earthworms.
5	Very pale brown (10YR 7/4), dry to yellowish brown (10YR 5/4), moist; sandy loam; structureless, single grain; non-sticky and non-plastic (wet), very friable (moist), soft (dry) in consistence; many very fine, a few fine roots; common ants; a few small ironstone concretions.
6	Light yellowish brown (10YR 6/4), dry to yellowish brown (10YR 5/4), moist; mottled red along rice roots; loam; structureless, single grain; non-sticky and non-plastic (wet), friable (moist), slightly hard (dry) in consist-:ence; many very fine, common fine roots; common ants and earthworms; a few small ironstone concretions.
7	Pale yellow (2.5Y 7/4), dry to light yellowish brown (2.5Y 6/4), moist; mottled brown along rice roots; loam;

structureless, single grains; non-sticky and non-plastic (wet), very friable (moist), soft (dry) in consistence; many very fine, a few fine roots; common ants and earth-:worms.

8 Pale yellow (2.5Y 7/4), dry to light olive brown (2.5Y 5/4), moist; sandy loam; structureless, single grain; non-sticky and non-plastic (wet), very friable (moist), soft (dry) in consistence; many very fine, common fine roots; common ants; a few small ironstone concretions.

9 White (2.5Y 8/2), dry to light grey (2.5Y 7/2), moist; common small faint reddish yellow (7.5YR 7/6, dry and 6/6, moist) mottles; loamy sand; structureless, single grain; non-sticky and non-plastic (wet), very friable (moist), soft (dry) in consistence; many very fine, a few fine roots; common ants; a few small ironstone concretions.

10 White (5Y 8/1), dry to light grey (5Y 7/1), moist; common fine distinct brown (7.5YR 6/8, dry and 5/8, moist) mottles; sandy loam; structureless, single grain; non-sticky and non-plastic (wet), very friable (moist), slightly hard (dry) in consistence; many very fine, common fine roots; common ants and earthworms.

LAND SYSTEM F

RIVER FLOOD PLAIN - SILAI

Sample No.	O.M.%	C %	N %	C/N	Av.P µg/g	Av.P kg/ha	Av.K µg/g	Av.K kg/ha
S.1	0.452	0.262	0.031	8.45	16.49	41.22	53.28	133.21
S.2	0.174	0.101	0.014	7.21	1.20	3.01	40.13	100.33
S.3	0.278	0.161	0.018	8.94	6.38	15.95	44.20	110.50
S.4	0.383	0.222	0.030	7.40	26.27	65.68	150.98	377.45
S.5	0.434	0.252	0.026	9.00	4.83	12.08	64.41	161.03
S.6	0.438	0.254	0.028	9.07	5.57	13.92	62.79	156.98
S.7	0.705	0.409	0.046	8.89	5.77	14.42	62.28	155.69
S.8	0.490	0.284	0.035	8.11	10.31	25.79	73.83	184.57
S.9	0.278	0.161	0.020	8.05	0.80	2.01	17.07	42.69
S.10	0.560	0.325	0.037	8.78	1.21	3.03	40.46	101.14

Sample No.	$Ex.Ca^{++}$ me/100g	$Ex.Mg^{++}$ me/100g	$Ex.Na^{+}$ me/100g	$Ex.K^{+}$ me/100g	$Ex.Al^{+++}$ me/100g	Al satur-:ation %	Ex.Acidity me/100g	L.R. kg/ha
S.1	1.67	0.31	0.38	0.06	0.50	8.86	3.22	4025.0
S.2	1.95	0.52	0.01	0.09	-	-	1.00	1250.0
S.3	2.37	0.62	0.02	0.13	0.10	2.15	1.51	1887.5
S.4	2.23	0.70	0.04	0.62	-	-	3.32	4150.0
S.5	2.23	0.66	0.02	0.23	-	-	1.61	2012.5
S.6	3.51	1.14	0.06	0.22	-	-	3.34	4175.0
S.7	3.68	1.15	0.09	0.22	-	-	5.21	6512.5
S.8	2.94	0.77	0.06	0.28	-	-	3.34	4175.0
S.9	1.95	0.66	0.05	0.04	-	-	1.41	1762.5
S.10	2.66	0.89	0.05	0.12	-	-	2.63	3287.5

LAND SYSTEM F

RIVER FLOOD PLAIN - SILAI

Sample No.	T.E.B. me/100g	C.E.C. me/100g	B.S. %	pH 1:2.5 H_2O	pH 1:2.5 0.01M $CaCl_2$	E.C. mmhos/cm	$CaCO_3$ %	Free Fe %
S.1	2.42	5.64	42.91	4.98	4.25	0.033	0	-
S.2	2.57	3.57	71.99	6.60	5.77	0.013	0	-
S.3	3.14	4.65	67.53	5.81	4.93	0.027	0	-
S.4	3.59	6.91	51.95	4.71	4.30	0.128	0	-
S.5	3.14	4.75	66.10	5.74	5.01	0.027	0	-
S.6	4.93	8.27	59.61	5.30	4.72	0.043	0	-
S.7	5.14	10.35	49.66	5.18	4.41	0.041	0	-
S.8	4.05	7.39	54.80	5.23	4.72	0.056	0.007	-
S.9	2.70	4.11	65.69	6.08	5.22	0.017	0.006	-
S.10	3.72	6.35	58.58	5.37	4.74	0.042	0	-

Sample No.	Gravel %	Sand %	Silt %	Clay %	F.C. % VOL/VOL	W.PT. % VOL/VOL	A.W.C. % VOL/VOL	A.W.C. cm/cm
S.1	1.4	78.97	15.68	5.38	15.19	2.79	12.41	0.12
S.2	1.4	88.95	7.70	3.45	13.15	2.14	11.01	0.11
S.3	1.8	84.42	10.52	5.06	15.37	2.53	12.84	0.13
S.4	0	75.52	17.88	6.60	24.56	5.61	18.95	0.19
S.5	2.8	74.08	20.00	5.92	22.70	3.27	19.43	0.19
S.6	0.7	51.99	38.69	9.32	28.15	4.81	23.34	0.23
S.7	0	47.48	41.00	11.52	32.89	13.91	18.98	0.19
S.8	1.4	65.86	27.63	6.51	29.01	6.45	22.56	0.23
S.9	1.4	85.30	9.72	4.98	11.50	3.40	8.10	0.08
S.10	0	70.68	21.76	7.56	26.02	4.42	21.60	0.22

LAND SYSTEM F

RIVER FLOOD PLAIN - SILAI

Sample No.	B.D. g/cm^3	T.P. %	W.P. %	A.P. %
S.1	1.29	51.32	15.19	36.13
S.2	1.42	46.41	13.15	33.26
S.3	1.40	47.17	15.37	31.80
S.4	1.40	47.17	24.56	22.61
S.5	1.45	45.28	22.70	22.58
S.6	1.30	50.94	28.15	22.79
S.7	1.30	50.94	32.89	18.05
S.8	1.40	47.17	29.01	18.16
S.9	1.39	47.55	11.50	36.05
S.10	1.46	44.91	22.02	18.89

LAND SYSTEM F, FLOOD PLAIN OF R. KASAI

Location: left bank of R. Kasai, Payarabila village, Binpur police station, Midnapore district, West Bengal.
Elevation: 53 m above m.s.l.
Slope angle: 0.0 degree.
Depth to water-table: 3.5 m on average.
Soil drainage: imperfect.
Vegetation and land use: entire area cultivated; 50% of the area multiple-cropped; rice, potato, oilseeds, cabbage and other vegetables main crops.
Soil erosion: nil.
Stoniness: class 0.
Rockiness: nil.
Flooding: regular and mild.

Surface soil sample no.	Morphological description
1	Yellow (2.5Y 7/6), dry to light olive brown (2.5Y 5/4), moist; mottled yellowish red along rice roots; silt loam; medium crumb in structure; slightly sticky and plastic (wet), firm (moist), very hard (dry) in consistence; many very fine, common fine roots; common earthworms and ants; a few small ironstone concretions.
2	Very pale brown (10YR 7/3), dry to brown (10YR 5/3), moist; mottled red along rice roots; silt loam; medium crumb in structure; slightly sticky and slightly plastic (wet), friable (moist), slightly hard (dry) in consistence; many very fine, a few fine roots; common earthworms and ants; a few small ironstone concretions.
3	Yellow (2.5Y 8/6), dry to olive yellow (2.5Y 6/6), moist; mottled brown along rice roots; clay loam; medium crumb in structure; sticky and plastic (wet), very firm (moist), very hard (dry) in consistence; common very fine and fine roots; common earthworms and ants; a few small ironstone concretions.
4	Light yellowish brown (10YR 6/4), dry to yellowish brown (10YR 5/4), moist; mottled red along rice roots; silt loam; medium granular in structure; slightly sticky and slightly plastic (wet), firm (moist), hard (dry) in consistence; many very fine, common fine roots; common earthworms and ants.
5	Yellow (2.5Y 7/6), dry to light olive brown (2.5Y 5/6), moist; mottled brown along rice roots; silt loam; medium crumb in structure; slightly sticky and plastic (wet), firm (moist), hard (dry) in consistence; many very fine, a few fine roots; common earthworms and ants.
6	Pale yellow (2.5Y 7/4), dry to light olive brown (2.5Y 5/4), moist; mottled brown along rice roots; silt loam; medium crumb in structure; slightly sticky and plastic (wet), firm (moist), very hard (dry) in consistence; many very fine, common fine roots; common earthworms and

ants; a few small ironstone concretions.

7 Pale yellow (2.5Y 7/3), dry to light olive brown (2.5Y 5/3), moist; mottled yellowish red along rice roots; silt loam; medium crumb in structure; sticky and plastic (wet), firm (moist), very hard (dry) in consistence; many very fine, common fine roots; common earthworms and ants; a few small ironstone concretions.

8 Light yellowish brown (10YR 6/4), dry to dark yellowish brown (10YR 4/4), moist; mottled red along rice roots; silty clay loam; coarse granular in structure; slightly sticky and plastic (wet), friable (moist), hard (dry) in consistence; many very fine, a few fine roots; common earthworms and ants.

9 Yellowish brown (10YR 5/4), dry to dark yellowish brown (10YR 4/4), moist; mottled red along rice roots; silty clay loam; medium crumb in structure; slightly sticky and slightly plastic (wet), friable (moist), slightly hard (dry) in consistence; many very fine, common fine roots; common earthworms and ants; a few small ironstone concretions.

10 Pale yellow (2.5Y 7/3), dry to light olive brown (2.5Y 5/3), moist; mottled brown along rice roots; silt loam; coarse granular in structure; slightly sticky and slightly plastic (wet), firm (moist), slightly hard (dry) in consistence; many very fine, common fine roots; common earthworms and ants.

11 Light yellowish brown (10YR 6/4), dry to brown (10YR 5/3), moist; mottled red along rice roots; silt loam; coarse granular in structure; slightly sticky and slightly plastic (wet), friable (moist), slightly hard (dry) in consistence; many very fine, common fine roots; common earthworms and ants; a few small ironstone concretions.

12 Light yellowish brown (10YR 6/4), dry to yellowish brown (10YR 5/4), moist; loam; structureless, single grain; non-sticky and non-plastic (wet), very friable (moist), slightly hard (dry) in consistence; common very fine roots; common ants.

LAND SYSTEM F

RIVER FLOOD PLAIN - KASAI

Sample No.	O.M. %	C %	N %	C/N	Av.P µg/g	Av.P kg/ha	Av.K µg/g	Av.K kg/ha
K.1	1.326	0.769	0.077	9.99	1.61	4.02	65.03	212.57
K.2	3.503	2.032	0.183	11.10	105.99	264.99	319.03	797.57
K.3	1.446	0.839	0.095	8.83	2.27	5.68	95.08	237.70
K.4	1.241	0.720	0.076	9.47	1.54	3.85	77.99	194.99
K.5	1.529	0.887	0.088	10.08	0.87	2.18	91.54	228.86
K.6	1.331	0.772	0.079	9.77	8.79	21.98	99.88	249.71
K.7	1.479	0.858	0.087	9.86	8.82	22.04	140.25	350.62
K.8	1.326	0.769	0.081	9.49	3.06	7.64	134.70	336.75
K.9	1.624	0.942	0.098	9.61	8.24	20.59	139.37	348.43
K.10	1.350	0.783	0.085	9.21	13.20	32.99	172.57	431.43
K.11	1.205	0.699	0.080	8.74	19.57	48.93	112.72	281.79
k.12	0.510	0.296	0.033	8.97	2.85	7.13	54.98	137.46

LAND SYSTEM F

RIVER FLOOD PLAIN - KASAI

Sample No.	Ex.Ca^{++} me/100g	Ex.Mg^{++} me/100g	Ex.Na^{+} me/100g	Ex.K^{+} me/100g	Ex.Al^{+++} me/100g	Al satur-:ation %	Ex.Acidity me/100g	L.R. kg/ha
K.1	11.21	3.79	0.21	0.34	0	0	9.33	11662.5
K.2	15.55	4.42	0.36	1.26	-	-	3.91	4887.5
K.3	6.30	1.76	0.26	0.38	-	-	9.71	12137.5
K.4	8.53	3.12	0.28	0.29	-	-	5.64	7050.0
K.5	7.98	3.28	0.13	0.35	-	-	7.41	9262.5
K.6	12.69	3.66	0.21	0.43	-	-	4.99	6237.5
K.7	13.44	3.62	0.18	0.55	-	-	4.85	6062.5
K.8	13.79	4.05	0.22	0.58	-	-	5.80	7250.0
K.9	14.05	3.86	0.21	0.59	-	-	6.12	7650.0
K.10	11.10	3.13	0.26	0.76	0	0	5.14	6425.0
K.11	10.37	2.74	0.15	0.42	-	-	5.94	7425.0
K.12	8.47	1.74	0.04	0.17	-	-	1.83	2287.5

LAND SYSTEM F

RIVER FLOOD PLAIN - KASAI

Sample No.	T.E.B. me/100g	C.E.C. me/100g	B.S. %	pH 1:2.5 H_2O	pH 1:2.5 0.01M $CaCl_2$	E.C. mmhos/cm	$CaCO_3$ %	Free Fe %
K.1	15.55	24.88	62.50	6.56	5.53	0.027	0.009	-
K.2	21.59	25.50	84.67	7.16	6.84	0.378	0.138	-
K.3	8.70	18.41	47.26	5.02	4.30	0.044	0.071	-
K.4	12.22	17.86	68.42	5.74	5.34	0.151	0.024	-
K.5	11.74	19.15	61.30	5.74	4.83	0.037	0	-
K.6	16.99	21.98	77.30	6.85	5.95	0.040	0	-
K.7	17.79	22.64	78.58	6.73	6.11	0.071	0.024	-
K.8	18.64	24.44	76.27	6.40	5.86	0.097	0	-
K.9	18.71	24.83	75.35	5.99	5.64	0.133	0	-
K.10	15.25	20.39	74.79	6.11	5.69	0.225	0.015	-
K.11	13.68	19.62	69.72	5.93	5.23	0.077	0	-
K.12	10.42	12.25	85.06	7.50	6.53	0.023	0.008	-

LAND SYSTEM F

RIVER FLOOD PLAIN - KASAI

Sample No.	GRAVEL %	SAND %	SILT %	CLAY %	F.C. % VOL/VOL	W.PT. % VOL/VOL	A.W.C. % VOL/VOL	A.W.C. cm/cm
K.1	3.5	17.46	57.61	24.93	38.63	17.98	20.65	0.21
K.2	2.8	29.52	50.64	19.84	40.60	21.95	18.65	0.19
K.3	2.7	20.34	44.65	35.01	40.10	22.53	17.57	0.18
K.4	5.2	18.88	60.88	20.34	38.10	16.41	21.69	0.22
K.5	3.5	6.36	70.02	23.62	37.52	17.87	19.65	0.20
K.6	3.5	13.77	63.55	22.68	39.50	15.08	24.42	0.24
K.7	4.2	15.11	61.91	22.98	36.59	13.87	22.72	0.23
K.8	3.5	10.55	61.85	27.60	38.01	20.12	17.89	0.18
K.9	3.5	10.92	60.91	28.17	39.82	20.12	19.70	0.20
K.10	3.5	12.56	67.51	19.93	36.99	16.33	20.66	0.21
K.11	2.8	13.89	67.05	19.06	37.84	9.68	28.16	0.28
K.12	0	44.04	46.27	9.69	37.38	5.96	31.42	0.31

LAND SYSTEM F

RIVER FLOOD PLAIN - KASAI

Sample No.	B.D. g/cm^3	T.P. %	W.P. %	A.P. %
K.1	1.17	55.85	38.63	17.22
K.2	1.07	59.62	40.60	19.02
K.3	1.07	59.62	40.10	19.52
K.4	1.08	59.24	38.10	21.14
K.5	0.97	63.40	37.52	25.88
K.6	1.21	54.34	39.50	14.84
K.7	1.07	59.62	36.59	23.03
K.8	1.09	58.87	38.01	20.86
K.9	1.14	56.98	39.82	17.16
K.10	1.08	59.24	36.99	22.25
K.11	1.13	57.36	37.84	19.52
K.12	1.16	56.23	37.38	18.85

LAND SYSTEM F, FLOOD PLAIN OF R. SUBARNAREKHA

Location: left bank of R. Subarnarekha, Kutisai village, Sankrail police station, Midnapore district, West Bengal.
Elevation: 44 m above m.s.l.
Slope angle: 0.0 degree.
Depth to water-table: 4 m on average.
Soil drainage: imperfect.
Vegetation and land use: most of the area cultivated; pasture along stream bank; 65% of the cultivated area multiple-cropped; rice, sugarcane and wheat main crops.
Soil erosion: nil.
Stoniness: class 0.
Rockiness: nil.
Flooding: regular and mild.

Surface soil sample no.	Morphological description
1	Light yellowish brown (10YR 6/4), dry to yellowish brown (10YR 5/4), moist; loam; weak medium granular in structure; slightly sticky and slightly plastic (wet), friable (moist), hard (dry) in consistence; many very fine, common fine roots; common ants; a few small ironstone concretions.
2	Very pale brown (10YR 7/4), dry to light yellowish brown (10YR 6/4), moist; loam; weak medium crumb in structure; slightly sticky and slightly plastic (wet), very friable (moist), slightly hard (dry) in consistence; many very fine, common fine roots; common ants; a few small ironstone concretions.
3	Very pale brown (10YR 7/3), dry to brown (10YR 5/3), moist; loamy sand; structureless, single grain; non-sticky and non-plastic (wet), very friable (moist), soft (dry) in consistence; many very fine, common fine roots; common ants; a few small ironstone concretions.
4	Very pale brown (10YR 7/4), dry to yellowish brown (10YR 5/4), moist; loamy sand; structureless, single grain; non-sticky and non-plastic (wet), friable (moist), slightly hard (dry) in consistence; many very fine, common fine roots; common ants.
5	White (2.5Y 8/2), dry to light grey (2.5Y 7/2), moist; mottled reddish yellow along rice roots; sandy loam; medium granular in structure; non-sticky and non-plastic (wet), friable (moist), slightly hard (dry) in consistence; many very fine, common fine roots; common ants and earthworms.
6	White (5Y 8/1), dry to grey (5Y 6/1), moist; common fine prominent brown (7.5YR 7/8), dry and 5/6, moist) mottles; loam; weak medium crumb in structure; slightly sticky and slightly plastic (wet), friable (moist), slightly hard (dry) in consistence; many very fine, a few fine roots; common ants and earthworms; a few small ironstone concretions.

7 White (5Y 8/1), dry to light grey (5Y 7/1), moist; common fine distinct yellowish red (5YR 6/8, dry and 5/8, moist) mottles; loam; weak medium crumb in structure; slightly sticky and slightly plastic (wet), friable (moist), slightly hard (dry) in consistence; common very fine and fine roots; common ants and earthworms; a few small ironstone concretions.

8 White (N 8/0), dry to light grey (N 7/0), moist; common fine distinct brown (7.5YR 7/8, dry and 5/8, moist) mottles; loam; weak medium crumb in structure; slightly sticky and slightly plastic (wet), friable (moist), slightly hard (dry) in consistence; common very fine and fine roots; common ants.

9 Pale yellow (2.5Y 7/3), dry to light olive brown (2.5Y 5/3), moist; loam; weak medium crumb in structure; slightly sticky and slightly plastic (wet), friable (moist), slightly hard (dry) in consistence; many very fine, common fine roots; common ants; a few small ironstone concretions.

10 White (5Y 8/1), dry to light grey (5Y 7/1), moist; common medium prominent yellowish red (5YR 6/8, dry and 4/8, moist) mottles; loam; weak medium crumb in structure; slightly sticky and slightly plastic (wet), friable (moist), slightly hard (dry) in consistence; many very fine, common fine roots; common ants and earthworms; a few small ironstone concretions.

11 White (5Y 8/2), dry to light grey (5Y 7/2), moist; mottled brown along rice roots; loam; weak medium crumb in structure; slightly sticky and slightly plastic (wet), friable (moist), slightly hard (dry) in consistence; many very fine, common fine roots; common ants and earthworms.

LAND SYSTEM F

RIVER FLOOD PLAIN - SUBARNAREKHA

Sample No.	O.M. %	C %	N %	C/N	Av.P µg/g	Av.P kg/ha	Av.K µg/g	Av.K Kg/ha
SU.1	0.952	0.552	0.061	9.05	1.02	2.55	52.04	130.10
SU.2	0.795	0.461	0.057	8.09	3.06	7.66	118.45	296.13
SU.3	0.329	0.191	0.021	9.09	5.22	13.05	42.16	105.41
SU.4	0.243	0.141	0.018	7.83	1.31	3.27	34.21	85.52
SU.5	0.626	0.363	0.037	9.81	4.13	10.32	47.33	118.33
SU.6	1.036	0.601	0.063	9.54	1.98	4.95	31.51	78.77
SU.7	0.814	0.472	0.052	9.08	1.59	3.97	49.13	122.82
SU.8	1.339	0.777	0.081	9.59	2.96	7.40	47.96	119.90
SU.9	1.002	0.581	0.063	9.22	4.27	10.68	96.62	241.56
SU.10	1.289	0.748	0.074	10.11	3.22	8.04	153.23	383.08
SU.11	0.614	0.356	0.048	7.42	2.64	6.60	69.07	172.68

LAND SYSTEM F

RIVER FLOOD PLAIN - SUBARNAREKHA

Sample No.	Ex.Ca^{++} me/100g	Ex.Mg^{++} me/100g	Ex.N^{+} me/100g	Ex.K^{+} me/100g	Ex.Al^{+++} me/100g	Al satur-:ation %	Ex.Acidity me/100g	L.R. kg/ha
SU.1	6.08	1.93	0.13	0.17	0.20	1.45	5.51	6887.5
SU.2	7.64	2.46	0.12	0.44	-	-	3.78	4725.0
SU.3	2.09	0.52	0.04	0.13	-	-	1.61	2012.5
SU.4	3.07	0.81	0.02	0.10	-	-	1.51	1887.5
SU.5	3.49	0.93	0.06	0.15	0.20	2.84	2.42	3025.0
SU.6	4.79	1.46	0.12	0.08	-	-	4.78	5975.0
SU.7	4.82	1.64	0.06	0.16	-	-	4.91	6137.5
SU.8	4.24	1.51	0.12	0.17	-	-	8.47	10587.5
SU.9	5.36	1.80	0.13	0.39	-	-	5.59	6987.5
SU.10	5.38	1.93	0.15	0.61	-	-	6.33	7912.5
SU.11	4.64	1.46	0.06	0.25	-	-	4.67	5837.5

LAND SYSTEM F

RIVER FLOOD PLAIN - SUBARNAREKHA

Sample No.	T.E.B. me/100g	C.E.C. me/100g	B.S. %	pH 1:2.5 H_2O	pH 1:2.5 01M $CaCl_2$	E.C. mmhos/cm	$CaCO_3$ %	Free Fe %
SU.1	8.31	13.82	60.13	5.81	4.78	0.024	0	-
SU.2	10.66	14.44	73.82	6.58	5.82	0.039	0	-
SU.3	2.78	4.39	63.32	6.42	5.36	0.014	0	-
SU.4	4.00	5.51	72.59	6.52	5.62	0.015	0	-
SU.5	4.63	7.05	65.67	6.46	5.58	0.018	0.006	-
SU.6	6.45	11.23	57.43	5.77	4.68	0.015	0	-
SU.7	6.68	11.59	57.64	5.58	4.38	0.013	0	-
SU.8	6.04	14.51	41.63	5.03	4.20	0.023	0	-
SU.9	7.68	13.27	57.87	5.55	4.62	0.047	0.009	-
SU.10	8.07	14.40	56.04	5.45	4.66	0.047	0	-
SU.11	6.41	11.08	57.85	5.17	4.48	0.032	0	-

LAND SYSTEM F

RIVER FLOOD PLAIN - SUBARNAREKHA

Sample No.	GRAVEL %	SAND %	SILT %	CLAY %	F.C. % VOL/VOL	W.PT. % VOL/VOL	A.W.C. % VOL/VOL	A.W.C. cm/cm
SU.1	1.4	44.05	39.50	16.45	36.12	8.83	27.29	0.27
SU.2	2.8	46.04	36.36	17.60	35.33	8.74	26.59	0.27
SU.3	3.5	74.86	20.64	4.50	23.36	4.05	19.31	0.19
SU.4	0	78.67	15.37	5.96	16.86	4.37	12.49	0.12
SU.5	0	71.15	21.36	7.49	28.08	7.54	20.54	0.20
SU.6	0.7	47.05	41.00	11.95	35.88	7.36	28.52	0.28
SU.7	1.8	49.28	35.65	15.07	33.54	7.26	26.28	0.26
SU.8	0.4	44.78	36.73	18.49	39.19	8.89	30.30	0.30
SU.9	1.1	43.78	42.67	13.55	35.19	7.09	28.10	0.28
SU.10	1.4	43.40	41.15	15.45	36.11	16.64	19.47	0.19
SU.11	0.4	46.53	39.37	14.10	36.99	7.41	29.58	0.30

LAND SYSTEM F

RIVER FLOOD PLAIN - SUBARNAREKHA

Sample No.	B.D. g/cm^3	T.P. %	W.P. %	A.P. %
SU.1	1.24	53.21	36.12	17.09
SU.2	1.20	54.72	35.33	19.39
SU.3	1.37	48.30	23.36	24.94
SU.4	1.37	48.30	16.86	31.44
SU.5	1.42	46.41	28.08	18.33
SU.6	1.22	53.96	35.88	18.08
SU.7	1.23	53.58	33.54	20.04
SU.8	1.19	55.09	39.19	15.90
SU.9	1.17	55.85	35.19	20.66
SU.10	1.15	56.60	36.11	20.49
SU.11	1.34	49.43	36.99	12.44

MEAN OF SOIL PROPERTIES in THE FOUR RIVER FLOOD PLAINS

SOIL PROPERTIES	R. DARAKESWAR			R. SILAI			R. KASAI			R. SUBARNAREKHA			MEAN OF FOUR FLOOD PLAINS
	$\bar{x}$	s	cv	$\bar{x}$	s	cv	$\bar{x}$	s	cv	$\bar{x}$	s	cv	
O.M.	1.12	0.21	18.75	0.42	0.15	35.71	1.49	0.69	46.31	0.82	0.35	42.68	0.99
C	0.65	0.12	18.46	0.24	0.09	37.50	0.86	0.40	46.51	0.48	0.20	41.67	0.57
N	0.07	0.01	12.86	0.03	0.01	30.0	0.09	0.03	33.33	0.05	0.02	40.0	0.06
C/N	9.45	0.86	9.10	8.39	0.68	8.10	9.59	0.65	6.78	8.98	0.85	9.46	9.14
Av.P (µg)	4.54	4.70	103.52	7.88	8.02	101.78	14.73	29.29	198.85	2.85	1.32	46.32	7.59
Av.P (kg/ha)	11.36	11.74	103.34	19.71	20.05	101.72	36.83	73.23	198.83	7.13	3.31	46.42	18.98
Av.K (µg/g)	122.37	68.75	56.18	60.94	35.60	58.42	126.93	68.69	54.12	64.43	38.99	60.51	96.50
Av.K (kg/ha)	305.92	171.87	56.18	152.36	88.99	58.41	317.32	171.73	54.12	168.57	97.49	57.83	241.26
Ex. Ca	11.97	2.65	22.14	2.52	0.67	26.59	11.12	2.87	25.81	4.69	1.50	31.98	7.87
Ex.Mg	3.76	0.74	19.68	0.74	0.26	35.13	3.26	0.84	25.77	1.49	0.56	37.58	2.40
Ex.Na	0.21	0.06	28.57	0.08	0.11	137.5	0.21	0.08	38.09	0.09	0.04	44.44	0.15
Ex.K	0.50	0.29	58.0	0.20	0.17	85.0	0.51	0.28	54.90	0.24	0.17	70.83	0.37
Ex.ACIDITY	5.34	1.53	28.65	2.66	1.29	48.5	5.89	2.17	36.84	4.50	2.09	46.44	4.69
L.R.	6677.08	1912.57	28.64	3323.75	1609.46	48.42	7361.46	2710.47	36.82	5634.09	2613.96	46.39	5859.4
T.E.B.	16.45	3.57	21.70	3.54	0.94	26.55	15.11	3.85	25.48	6.52	2.20	33.74	10.79
C.E.C.	21.79	3.90	17.90	6.20	2.10	33.87	20.99	3.86	18.39	11.03	3.72	33.73	15.48
B.S.	75.27	5.57	7.40	58.88	9.13	15.51	71.77	10.76	14.99	60.36	8.75	14.50	67.05
pH (H_2O)	6.30	0.68	10.79	5.50	0.56	10.18	6.31	0.69	10.93	5.85	0.56	9.57	6.01
pH ($CaCl_2$)	5.59	0.67	11.98	4.81	0.46	9.56	5.65	0.69	12.21	4.92	0.56	11.38	5.27
E.C.	0.05	0.03	60.0	0.04	0.03	75.0	0.11	0.10	90.90	0.03	0.01	50.0	0.06
$CaCO_3$	0.01	0.02	314.29	0.001	0.003	300.0	0.02	0.04	170.83	0.001	3.11	311000.0	0.01
GRAVEL	5.39	2.37	41.29	1.09	0.94	85.45	3.22	1.27	38.25	1.23	1.16	93.55	2.97
SAND	25.36	8.63	34.03	72.32	13.84	19.14	17.78	10.14	57.03	53.60	13.88	25.89	40.68
SILT	48.46	3.49	7.20	21.06	11.60	55.08	59.40	8.21	13.82	33.62	9.66	28.73	41.66
CLAY	26.18	8.94	34.15	6.63	2.34	35.29	22.81	6.15	26.96	12.78	4.77	37.32	17.66

F.C.	39.14	3.59	9.17	21.85	7.51	34.37	38.42	1.30	3.38	32.42	6.83	21.07	33.47
W.PT.	18.37	4.88	26.56	4.93	3.45	69.98	16.49	4.89	29.65	8.02	3.28	40.90	12.35
A.W.C.(VOL/VOL)	20.77	3.87	18.63	16.92	5.37	31.74	21.93	4.21	19.20	24.41	5.62	23.02	21.12
A.W.C. (cm/cm)	0.21	0.04	19.05	0.17	0.05	29.41	0.22	0.04	18.18	0.24	0.06	25.00	0.21
B.D.	1.17	0.05	4.27	1.38	0.06	4.35	1.10	0.06	5.45	1.26	0.09	7.14	1.22
T.P.	55.94	1.97	3.52	47.89	2.35	4.91	58.36	2.37	4.06	52.31	3.53	6.75	53.91
W.P.	39.14	3.59	9.17	21.85	7.51	34.37	38.42	1.30	3.38	32.42	6.83	21.07	33.47
A.P.	16.80	4.69	27.92	26.03	7.44	28.58	19.94	2.95	14.79	19.89	4.95	24.89	20.44

APPENDIX E

DATA OF THE SLOPE PROFILE SURVEYS

source: field work; see SECTION 3.2 for methods of survey.

LAND SYSTEM A

GROUND SURFACE DISTANCE m	SLOPE ANGLE degree	HEIGHT ABOVE M.S.L. m	REMARKS
0	+4.50	35.19	R. Parang
15	+2.00	36.37	
30	+1.25	36.89	
45	+1.00	37.22	
60	+3.00	37.48	
75	-1.00	38.26	
90	-0.50	38.00	
105	-0.50	37.87	
120	0.00	37.74	
135	-0.75	37.74	
150	-0.25	37.54	
165	-0.25	37.48	
180	-1.00	37.41	
195	0.00	37.15	
210	+0.50	37.15	base
225	+0.25	37.28	profile
240	0.00	37.35	
255	-0.50	37.35	
270	-0.25	37.22	
285	-0.50	37.16	
300	-0.50	37.03	
315	-0.50	36.90	
330	-0.50	36.77	
345	-1.00	36.64	
360	-1.00	36.38	
375	0.00	36.12	
390	-0.25	36.12	
405	-1.00	36.05	
420	-0.50	35.79	
435	-1.00	35.66	
450	-1.25	35.40	
465	+0.25	35.07	
480	0.00	35.14	
495	-0.75	35.14	
510	0.00	34.94	
525	0.00	34.94	
540	-0.50	34.94	
555	-0.50	34.91	
570	0.00	34.78	
585	-0.50	34.78	
600	0.00	34.65	
615	-0.25	34.65	
630	-0.25	34.59	
645	0.00	34.52	
660	0.00	34.52	
675	-0.25	34.52	
690	0.00	34.46	
705	-0.75	34.46	
720	0.00	34.26	
735	+0.50	34.26	
750	+0.50	34.39	
765	+0.25	34.52	
780	0.00	34.58	
795	+0.25	34.58	
810	+0.25	34.65	
825	+0.25	34.71	toeslope
840	+0.25	34.78	profile
855	+0.25	34.84	
870	+0.25	34.91	
885	+1.50	34.97	
900	0.00	35.36	
915	+0.50	35.36	
930	+1.00	35.49	
945	+0.25	35.75	
960	+0.75	35.82	
975	0.00	36.02	
990	+1.50	36.02	
1005	+0.50	36.41	
1020	+1.00	36.54	
1035	+1.00	36.80	
1050	+1.00	37.06	
1065	+0.50	37.32	
1080	+0.75	37.45	
1095	+0.50	37.65	
1110	+1.50	37.78	footslope
1125	+0.50	38.17	profile
1140	+0.50	38.30	
1170	+2.00	38.56	
1185	+1.75	39.08	road
1200	+1.75	39.54	
1215	+2.50	40.00	40 m
1230	+2.50	40.65	contour
1245	+2.75	41.30	
1260	+3.50	42.02	forest
1275	+7.00	42.94	
1290	+10.00	44.77	
1305	+3.50	47.37	
1320	+2.00	48.29	
1335	+1.00	48.81	
1350	+1.00	49.07	
1365	0.00	49.33	
1380	+0.25	49.33	
1395	0.00	49.39	
1410	0.00	49.39	
1425	+0.25	49.39	
1440	0.00	49.46	
1455	+0.50	49.46	
1470	0.00	49.59	summit
1485		49.59	profile

LAND SYSTEM B

GROUND SURFACE DISTANCE m	SLOPE ANGLE degree	HEIGHT ABOVE M.S.L. m	REMARKS
0	+0.50	52.33	R.Champa
10	-0.50	52.42	
20	+0.83	52.33	
30	+0.50	52.47	
40	-2.67	52.56	
50	0.00	52.10	base
60	-0.50	52.10	profile
70	0.00	52.01	
80	+0.50	52.01	
90	+0.50	52.10	
100	+0.50	52.19	
110	+0.50	52.28	
120	+2.50	52.37	
130	+2.00	52.81	
140	+0.83	53.16	
150	0.00	53.30	
160	+1.50	53.30	
170	+2.83	53.56	
180	+0.33	54.05	toeslope
190	0.00	54.11	profile
200	+3.67	54.11	
210	+0.50	54.75	
220	+3.33	54.84	
230	-1.67	55.42	
240	+1.83	55.13	footslope
250	+1.00	55.54	profile
260	+2.50	55.62	
270	-0.67	56.06	
280	+2.17	55.94	
290	-0.83	56.32	
300	-0.83	56.18	
310	+5.00	56.04	
320	+4.00	56.91	
330	+0.50	57.61	
340	+0.50	57.70	
350	-0.67	57.79	
360	+2.00	57.67	
370	+1.00	58.02	
380	+2.00	58.19	
390	+1.33	58.54	
400	-0.67	58.77	
410	+0.33	58.65	
420	+5.00	58.71	
430	+1.17	59.58	
440	+1.25	59.78	
450	+1.00	60.00	60 m
460	-1.67	60.17	contour
470	0.00	59.88	
480	+1.00	59.88	shoulder
490	+3.83	60.05	profile
500	+1.00	60.72	
510	+2.33	60.89	
520	-0.33	61.30	
530	+2.50	61.24	
540	+2.00	61.68	
550	+1.00	62.03	
560	+1.50	62.20	
570	+1.00	62.46	
580	+0.33	62.63	
590	+0.50	62.69	
600	+1.17	62.78	
610	+2.67	62.98	
620	+1.17	63.44	
630	-2.00	63.64	road
640	+3.33	63.29	
650	-0.17	63.87	
660	-0.67	63.84	
670	+0.50	63.72	
680	0.00	63.81	
690	-1.00	63.81	canal
700	+1.00	63.64	
710	+0.50	63.81	
720	+0.17	63.90	
730	0.00	63.93	
740	0.00	63.93	
750	+0.50	63.93	
760	+0.33	64.02	
770	+0.17	64.08	
780	0.00	64.11	summit
790	-0.50	64.11	profile
800	+0.50	64.02	
810	0.00	64.11	
820	0.00	64.11	
830		64.11	

LAND SYSTEM C

GROUND SURFACE DISTANCE m	SLOPE ANGLE degree	HEIGHT ABOVE M.S.L. m	REMARKS	GROUND SURFACE DISTANCE m	SLOPE ANGLE degree	HEIGHT ABOVE M.S.L. m	REMARKS
0	0.00	77.89	R.Tamal	480	+2.00	84.10	
10	-0.33	77.89		490	+0.83	84.45	
20	-0.67	77.83		500	+1.00	84.59	
30	0.00	77.71		510	0.00	84.76	
40	+1.67	77.71	base	520	-3.67	84.76	
50	+1.50	78.00	profile	530	-0.67	84.12	
60	+0.50	78.26		540	+7.17	84.00	
70	+1.00	78.35		550	-2.00	85.37	
80	+1.00	78.52		560	+2.50	85.02	
90	+0.50	78.69		570	+0.17	85.46	
100	+3.33	78.78		580	+1.00	85.49	
110	+2.17	79.36		590	+4.00	85.66	
120	-0.17	79.74	toeslope	600	0.00	86.36	
130	0.00	79.71	profile	610	-1.00	86.36	
140	+1.67	79.71		620	-1.00	86.19	
150	-1.17	80.00	80 m	630	+1.33	86.02	
160	+0.83	79.80	contour	640	+1.00	86.25	
170	+4.00	79.94		650	+1.00	86.42	
180	+0.67	80.64		660	+2.17	86.59	
190	-0.50	80.76		670	0.00	86.97	
200	-0.67	80.67		680	+2.50	86.97	
210	-0.67	80.55	forest	690	-1.00	87.41	middle
220	-2.17	80.43		700	+5.00	87.24	footslope
230	+2.00	80.05		710	+2.50	88.11	profile
240	-4.00	80.40	lower	720	+1.50	88.55	
250	+1.00	79.70	footslope	730	-7.00	88.81	
260	+1.00	79.87	profile	740	-6.00	87.59	
270	+0.67	80.04		750	+7.00	86.55	
280	+1.00	80.16		760	+5.50	87.77	
290	+1.00	80.33		770	+0.50	88.73	
300	+0.67	80.50		780	+1.00	88.82	
310	+1.33	80.62		790	+1.50	88.99	
320	+2.83	80.85		800	+0.67	89.25	
330	+0.33	81.34		810	+1.33	89.37	
340	+0.50	81.40		820	+1.67	89.60	
350	+0.50	81.49		830	+0.50	89.89	
360	+1.00	81.58		840	0.00	89.98	
370	+0.67	81.75		850	-1.00	89.98	
380	+2.17	81.87		860	-1.00	89.81	
390	+1.50	82.25		870	+1.00	89.64	
400	+0.17	82.51		880	+1.50	89.81	
410	+1.00	82.54		890	+2.00	90.07	
420	0.00	82.71		900	+2.17	90.42	
430	-0.50	82.71		910	+1.50	90.80	
440	+0.50	82.62		920	+2.17	91.06	
450	-0.50	82.71		930	+2.00	91.44	upper
460	+6.50	82.62		940	+1.50	91.79	footslope
470	+2.00	83.75		950	+1.00	92.05	profile

LAND SYSTEM C (continued)

GROUND SURFACE DISTANCE m	SLOPE ANGLE degree	HEIGHT ABOVE M.S.L. m	REMARKS
960	+2.17	92.22	
970	+1.67	92.60	
980	+1.50	92.89	
990	+2.50	93.15	
1000	+1.33	93.59	
1010	+0.67	93.82	
1020	+3.00	93.94	
1030	+0.50	94.46	
1040	+0.83	94.55	
1050	+1.17	94.69	
1060	+0.50	94.89	
1070	-0.50	94.98	
1080	0.00	94.89	
1090	0.00	94.89	
1100	+1.33	94.89	
1110	+1.00	95.12	
1120	+0.50	95.29	
1130	+1.33	95.38	
1140	+2.00	95.61	
1150	+0.83	95.96	
1160	+1.00	96.10	
1170	+0.50	96.27	
1180	0.00	96.36	
1190	+1.33	96.36	
1200	+1.17	96.59	
1210	+0.50	96.79	
1220	-0.67	96.88	
1230	0.00	96.76	
1240	+2.50	96.76	
1250	+3.17	97.20	shoulder
1260	+2.50	97.75	profile
1270	+1.50	98.19	
1280	+2.00	98.45	
1290	+1.50	98.80	
1300	+1.67	99.06	
1310	+1.33	99.35	
1320	+1.00	99.58	
1330	+1.00	99.75	
1340	+1.00	99.92	
1350	+1.00	100.09	
1360	+1.00	100.26	
1370	+1.00	100.43	
1380	+1.17	100.60	
1390	+1.17	100.80	
1400	+1.17	101.00	
1410	+0.67	101.20	
1420	+1.00	101.32	
1430	+0.50	101.49	

GROUND SURFACT DISTANCE m	SLOPE ANGLE degree	HEIGHT ABOVE M.S.L. m	REMARKS
1440	0.00	101.58	
1450	0.00	101.58	
1460	-0.50	101.58	summit
1470	0.00	101.49	profile
1480		101.49	

LAND SYSTEM D

GROUND SURFACE DISTANCE m	SLOPE ANGLE degree	HEIGHT ABOVE M.S.L. m	REMARKS
0	0.00	66.54	talweg
15	0.00	66.54	base
30	+0.25	66.54	profile
45	+0.25	66.60	
60	+0.25	66.67	
75	+4.00	66.73	
90	+2.00	67.78	
105	+1.50	68.30	
120	+1.50	68.69	
135	+0.25	69.08	
150	+1.00	69.15	
165	+0.25	69.41	toeslope
180	+1.50	69.47	profile
195	+0.50	69.86	
210	+0.50	69.99	
225	+1.50	70.12	
240	0.00	70.51	
255	+1.00	70.51	
270	0.00	70.77	
285	+0.50	70.77	
300	+0.50	70.90	
315	+1.50	71.03	
330	+1.25	71.42	
345	+1.25	71.75	
360	+1.25	72.08	footslope
375	+0.50	72.41	profile
390	+2.00	72.54	
405	+0.25	73.06	
420	+1.25	73.13	
435	+1.25	73.46	
450	+2.00	73.79	
465	+2.75	74.31	
480	+2.25	75.03	
495	+0.50	75.62	road
510	+1.75	75.75	
525	+2.25	76.21	
540	+2.25	76.80	
555	+1.50	77.39	
570	+2.50	77.78	
585	+2.50	78.43	
600	+1.75	79.08	
615	+1.75	79.54	
630	+2.75	80.00	80 m
645	+1.25	80.72	contour
660	+1.00	81.05	
675	+2.00	81.31	shoulder
690	+2.50	81.83	profile
705	+0.75	82.48	
720	+1.25	82.68	
735	+0.75	83.01	
750	+0.50	83.21	
765	+0.75	83.34	
780	+1.25	83.54	
795	0.00	83.87	
810	+1.00	83.87	
825	+0.25	84.13	
840	0.00	84.19	planted
855	+0.50	84.19	forest
870	+1.50	84.32	
885	+0.50	84.71	
900	0.00	84.84	
915	0.00	84.84	
930	+0.75	84.84	
945	+0.75	85.04	
960	+0.75	85.24	
975	+0.75	85.44	
990	+0.50	85.64	
1005	0.00	85.77	
1020	+0.75	85.77	
1035	+0.50	85.97	
1050	+0.25	86.10	summit
1065	0.00	86.17	profile
1080	0.00	86.17	
1095	+0.25	86.17	
1110	0.00	86.23	
1125	+0.50	86.23	
1140	0.00	86.36	
1155	+0.25	86.36	
1170	+0.25	86.43	
1185	0.00	86.49	
1200		86.49	

LAND SYSTEM E

GROUND SURFACE DISTANCE m	SLOPE ANGLE degree	HEIGHT ABOVE M.S.L. m	REMARKS
0	-0.25	76.20	talweg
15	0.00	76.13	
30	-0.25	76.13	
45	0.00	76.07	base
60	0.00	76.07	profile
75	+0.25	76.07	
90	0.00	76.13	
105	+0.75	76.13	
120	+1.25	76.33	
135	+1.75	76.66	
150	+2.25	77.12	
165	+0.25	77.71	
180	-0.75	77.78	
195	-1.50	77.58	
210	-0.75	77.19	
225	-0.50	76.99	
240	-0.50	76.86	
255	0.00	76.73	
270	-0.25	76.73	
285	-0.25	76.66	
300	0.00	76.60	
315	+0.75	76.60	
330	+1.50	76.80	
345	+2.00	77.19	
360	+1.50	77.71	
375	+0.25	78.10	toeslope
390	-0.50	78.16	profile
405	-1.00	78.03	
420	-1.75	77.77	
435	-2.50	77.31	
450	-0.50	76.66	
465	-0.25	76.53	
480	0.00	76.47	
495	0.00	76.47	
510	0.00	76.47	
525	-0.25	76.47	
540	0.00	76.40	
555	+0.50	76.40	
570	+0.25	76.53	
585	-1.00	76.60	
600	+1.25	76.34	
615	-0.25	76.67	
630	0.00	76.60	
645	+0.50	76.60	
660	+0.50	76.73	
675	+0.75	76.86	
690	+1.00	77.06	
705	+1.50	77.32	
720	+0.75	77.71	
735	+2.00	77.91	
750	+0.50	78.43	
765	+0.25	78.56	
780	+1.00	78.63	
795	+1.50	78.89	
810	+0.25	79.28	footslope
825	+0.75	79.34	profile
840	+3.50	79.54	
855	+1.00	80.46	
870	+1.00	80.72	
885	+1.00	80.98	
900	+0.50	81.24	
915	+0.25	81.37	
930	+0.75	81.44	
945	+1.00	81.64	bench
960	0.00	81.90	mark
975	+0.50	81.90	
990	+0.50	82.03	
1005	+0.75	82.16	
1020	+1.00	82.36	
1035	+1.50	82.56	
1050	+0.75	82.95	
1065	+0.50	83.15	
1080	+1.00	83.28	
1095	+1.50	83.54	
1110	+1.25	83.93	
1125	+1.00	84.26	
1140	+0.75	84.52	
1155	+0.50	84.72	
1170	+0.50	84.85	profile
1185	+0.50	84.98	for the
1200	+0.75	85.11	summit
1215	+0.50	85.31	and
1230	+0.50	85.44	shoulder
1245	+0.25	85.57	
1260	+0.25	85.63	
1275		85.70	canal

GULLY ERODED AREA

(MAIN SURVEY FOLLOWING SLOPE OF THE RIVER 'CLIFF')

GROUND SURFACE DISTANCE m	SLOPE ANGLE degree	HEIGHT ABOVE M.S.L. m	REMARKS
0	+0.50	38.07	stream
10	+7.25	38.16	
20	+2.50	39.43	
30	+0.75	39.87	
40	0.00	40.00	
50	+0.50	40.00	40 m
60	+1.00	40.09	contour
70	+0.75	40.26	
80	0,00	40.39	
90	+0.75	40.39	
100	+0.50	40.52	
110	+1.50	40.61	
120	+1.25	40.87	
130	+0.50	41.09	
140	+1.00	41.18	
150	0.00	41.35	Oherua
160	+1.00	41.35	road
170	+0.50	41.52	
180	+0.25	41.61	coppice
190	+0.75	41.66	forest
200	+0.50	41.79	
210	-0.25	41.88	
220	0.00	41.83	
230	0.00	41.83	
240	0.00	41.83	
250	-0.25	41.83	
260	-9.00	41.78	
270	+0.50	40.21	gully
280	+5.25	40.30	
290	+6.50	41.22	
300	+2.75	42.35	
310	+0.75	42.83	
320	-0.50	42.96	
330	+1.25	42.87	
340	-1.25	43.09	
350	+2.25	42.87	
360	+1.50	43.27	
370	+6.00	43.53	
380	+1.00	44.57	
390	+0.50	44.74	
400	+0.50	44.83	
410	-0.50	44.92	
420	-3.25	44.83	
430	-0.75	44.26	
440	+3.50	44.13	gully
450	+0.50	44.74	
460	-1.00	44.83	
470	+0.50	44.66	soil
480	+0.50	44.75	profile
490	+1.00	44.84	
500	+0.75	45.01	
510		45.14	

GULLY ERODED AREA

(SURVEY ACROSS GULLIES IN UPPER PART OF THE 'CLIFF')

GROUND SURFACE DISTANCE m	SLOPE ANGLE degree	HEIGHT ABOVE M.S.L. m	REMARKS
0	-1.25	45.25	
10	-2.00	45.01	500 m
20	-3.00	44.66	station
30	0.00	44.14	of main
40	-1.00	44.14	survey
50	-5.25	43.97	
60	+7.25	43.05	gully
70	+0.75	44.32	
80	-2.75	44.45	
90	+3.25	43.97	gully
100	-1.00	44.54	
110	-6.00	44.37	
120	-4.00	43.33	
130	-6.00	42.67	
140	-13.00	41.59	
150	+11.00	39.33	gully
160	+6.00	41.24	
170	+6.00	42.28	
180	+4.00	43.32	
190	-1.00	44.02	
200	-1.50	43.85	
210	-2.00	43.59	
220	-7.00	43.24	
230	-5.50	42.02	
240	+0.50	41.06	gully
250	-4.50	41.15	
260	-0.50	40.36	
270	+1.00	40.27	stream
280	+5.50	40.44	
290	+6.00	41.40	
300	+7.75	42.44	
310	+0.75	43.79	
320	+0.50	43.92	
330	-1.75	44.01	
340	-3.50	43.70	
350	+4.25	43.09	gully
360	+1.00	43.84	
370	+0.50	44.01	
380		44.10	

GULLY ERODED AREA

(SURVEY ACROSS GULLIES IN LOWER PART OF THE 'CLIFF')

GROUND SURFACE DISTANCE m	SLOPE ANGLE degree	HEIGHT ABOVE M.S.L. m	REMARKS
0	0.00	41.83	230 m
10	-2.00	41.83	station
20	-2.50	41.49	of main
30	-4.15	41.06	survey
40	+2.33	40.34	
50	+9.50	40.75	gully
60	-9.50	42.41	
70	-1.50	40.75	
80	0.00	40.49	gully
90	+2.50	40.49	
100	+7.00	40.93	
110	-2.83	42.15	
120	-1.50	41.66	
130	+0.75	41.40	gully
140	+2.25	41.53	
150	0.00	41.93	
160	-9.00	41.93	
170	-0.50	40.36	
180	-6.17	40.27	
190	+2.67	39.20	stream
200	+8.17	39.66	
210	+6.50	41.09	
220	0.00	42.22	
230	-4.17	42.22	
240	0.00	41.49	gully
250	+1.50	41.49	
260	+2.00	41.75	
270	+3.50	42.10	
280	+3.50	42.71	
290	+2.00	43.32	
300	+0.50	43.67	
310	+1.00	43.76	
320	+1.00	43.93	
330		44.10	

APPENDIX F

LAND QUALITIES OF 29 LAND FACETS

source: field, laboratory and library works; see SECTIONS 3.5 and 3.6.

MONTH	MEAN MAX. TEMP. degree C	MEAN MIN. TEMP. degree C	MEAN DAY LENGTH h	MEAN RELATIVE HUMIDITY %	HAIL No. of days	STORM No. of days	HEAVY RAINS No. of days	MEAN SUN-SHINE h
January	26.9	13.1	10.9	57	0.0	0.0	0.0	8.7
February	29.6	15.9	11.4	53	0.0	0.0	0.0	8.9
March	35.1	20.8	12.0	48	0.1	0.0	0.0	8.6
April	38.4	24.6	12.7	52	0.1	0.2	1.0	9.3
May	38.2	26.3	13.2	63	0.3	0.5	4.0	8.7
June	35.3	26.5	13.5	75	0.0	0.03	4.5	4.9
July	31.9	25.8	13.4	83	0.1	0.06	5.0	4.2
August	31.9	25.8	12.9	83	0.0	0.06	5.0	4.0
September	32.1	25.6	12.3	82	0.1	0.04	5.0	5.1
October	31.4	23.0	11.7	76	0.0	0.01	3.0	6.5
November	29.0	17.0	11.1	66	0.0	0.0	0.3	8.2
December	26.7	13.3	10.8	60	0.0	0.0	0.0	8.6
Annual	32.2	21.5	12.2	66	0.7	0.9	27.8	7.1

Note: These land qualities are uniform over all land facets.

	FACET	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
						WATER FOR PLANT UPTAKE (mm)								
1	A. SUMMIT	14	30	34	44	108	228	317	332	257	129	36	3	1532
2	A. SHOULDER	14	30	34	31	76	161	224	235	182	91	25	3	1106
3	A. FOOTSLOPE	14	30	34	44	109	230	320	335	260	130	36	3	1545
4	A. TOESLOPE	14	30	34	52	129	273	379	397	309	154	43	3	1817
5	A. BASE	14	30	34	49	123	258	360	376	292	146	40	3	1725
6	B. SUMMIT	13	28	33	44	108	204	309	306	239	113	25	4	1426
7	B. SHOULDER	13	28	33	38	94	179	270	268	209	99	22	4	1257
8	B. FOOTSLOPE	13	28	33	45	111	210	318	315	246	116	26	4	1465
9	B. TOESLOPE	13	28	33	48	119	225	341	337	264	124	28	4	1564
10	B. BASE	13	28	33	50	123	232	352	349	272	128	29	4	1613
11	C. SUMMIT	15	32	34	43	103	207	307	308	238	114	29	3	1433
12	C. SHOULDER	15	32	34	40	95	192	284	285	220	106	26	3	1332
13	C. FOOTSLOPE	15	32	34	45	108	218	323	324	250	120	30	3	1502
14	C. TOESLOPE	15	32	34	48	115	233	345	346	267	128	32	3	1598
15	C. BASE	15	32	34	49	119	240	356	357	275	132	33	3	1645
16	D. SUMMIT	12	27	32	45	110	192	308	291	233	107	23	4	1384
17	D. SHOULDER	12	27	32	37	90	158	254	240	192	88	19	4	1153
18	D. FOOTSLOPE	12	27	32	46	113	198	317	300	240	110	24	4	1423
19	D. TOESLOPE	12	27	32	50	123	216	346	328	262	120	26	4	1546
20	D. BASE	12	27	32	52	129	226	360	341	273	125	28	4	1609
21	E. SUMMIT	16	33	34	43	102	204	304	306	244	119	31	3	1439
22	E. SHOULDER	16	33	34	41	96	194	288	290	231	113	30	3	1369
23	E. FOOTSLOPE	16	33	34	45	107	215	320	322	257	125	33	3	1510
24	E. TOESLOPE	16	33	34	47	112	225	334	336	269	130	34	3	1573
25	E. BASE	16	33	34	49	118	237	354	356	284	138	37	3	1659
26	F. DARAKESWAR	12	27	33	46	113	205	318+	306+	241+	110+	25	4	1440+
27	F. SILAI	13	29	33	45	111	211	320+	315+	246+	115+	28	4	1470+
28	F. KASAI	15	32	34	45	108	218	324+	325+	258+	126+	32	3	1520+
29	F. SUBARNAREKHA	15	30	34	40	109	233	323+	336+	265+	134+	37	4	1560+

FACET	SOIL TEXTURE	SOIL STRUCTURE	SOIL CONSISTENCE	SOIL DEPTH
1	sandy loam	massive	friable	medium
2	nil	nil	nil	nil
3	loam	moderate crumb	friable	deep
4	silt loam	moderate crumb	friable	deep
5	loam	moderate crumb	friable	deep
6	loamy sand	single grain	very friable	deep
7	sandy loam	massive	friable	deep
8	sandy loam	moderate granular	friable	deep
9	loam	moderate granular	friable	deep
10	sandy clay loam	moderate granular	friable	deep
11	sandy loam	massive	friable	deep
12	sandy clay loam	massive	friable	deep
13	sandy clay loam	massive	friable	deep
14	clay loam	moderate crumb	friable	deep
15	clay loam	moderate crumb	very firm	deep
16	loam	massive	friable	deep
17	loamy sand	massive	very friable	shallow
18	loam	moderate crumb	friable	deep
19	loam	moderate crumb	friable	deep
20	sandy loam	moderate crumb	friable	deep
21	sandy loam	massive	friable	deep
22	sandy loam	massive	friable	deep
23	sandy loam	moderate granular	friable	medium
24	loam	moderate granular	firm	deep
25	clay loam	moderate granular	firm	deep
26	loam to silty clay	strong crumb	firm	deep
27	sand to loam	single grain	very friable	deep
28	silt loam	strong crumb	firm	deep
29	loamy sand to loam	weak crumb	friable	deep

FACET	SOIL DRAINAGE	pH (H_2O)	NUTRIENTS	PESTS	EROSION	FLOOD
1	well	5.5	low	termite	slight	nil
2	excessive	nil	nil	termite	moderate	nil
3	imperfect	5.1	low	nil	nil	nil
4	poor	4.9	low-medium	nil	nil	nil
5	poor	4.8	low-medium	nil	nil	very mild
6	well	5.3	low	termite	slight	nil
7	well	5.0	low	termite	moderate	nil
8	imperfect	5.9	low	nil	slight	nil
9	poor	5.0	low-medium	nil	nil	nil
10	poor	5.0	low-medium	nil	nil	very mild
11	well	5.8	low	termite	slight	nil
12	moderately well	5.3	low	termite	moderate	nil
13	imperfect	5.2	low	termite	severe	nil
14	poor	5.3	medium	nil	nil	nil
15	poor	5.1	medium	nil	nil	nil
16	moderately well	5.0	low-medium	termite	slight	nil
17	excessive	5.2	low	termite	moderate	nil
18	imperfect	5.0	low-medium	nil	nil	nil
19	imperfect	5.8	low-medium	nil	nil	nil
20	poor	5.3	low	nil	nil	nil
21	well	5.1	low	termite	slight	nil
22	well	5.1	low	termite	moderate	nil
23	imperfect	5.5	low	nil	moderate	nil
24	imperfect	6.4	low-medium	nil	nil	nil
25	poor	6.7	medium	nil	nil	nil
26	imperfect	6.3	medium	nil	nil	mild
27	imperfect	5.5	low-medium	nil	nil	severe
28	imperfect	6.3	medium	nil	nil	mild
29	imperfect	5.8	low-medium	nil	nil	mild

APPENDIX G

LAND REQUIREMENTS OF 154 LAND USE TYPES

source: compiled from publications indicated in SECTION 3.6; see SECTION 3.5 for explanation of land requirements and land use types.

The land use types (LUT) are listed firstly. A number is given to each land use type (1-154) which is referred to in this and following Appendices. The common and scientific names of plants and their growing periods are included in this list. The land requirements are presented in the following table. A letter symbol is given to each land requirement (a-m). The requirements for temperature, water and pH are directly entered in figures. The remaining requirements are expressed in codified forms. The keys are explained below. The optimum requirement conditions are indicated, followed by the range of tolerances, if any, within brackets. A symbol of _ is used when data are unavailable.

SYMBOL	LAND REQUIREMENT	CODE
a	Temperature (degree C)	
	mean maximum - mean minimum during growing period (annuals)	
	mean summer max. - mean winter min. (perennials)	
b	Photoperiod (Day length for flowering)	
	short day	sht
	long day	lng
	day neutral	ntl
	various cultivars	var
c	Water for plant uptake (mm)	
	lower limit - upper limit during growing period (annuals)	
	lower limit - upper limit per year (perennials)	
d	Other climatic conditions	
	relative humidity	rh%
	absence of storm	as
	absence of hail	ah
	absence of heavy rains	ar
	absence of drought	ad
	dry period during ripening	dr
	full sunshine	ss
e	Soil texture	
	sand	s
	silt	i
	clay	c
	loam	l

SYMBOL	LAND REQUIREMENT	CODE
f	Soil structure and Consistence	
	crumb on granular	cg
	any structure	any
	very friable	vf
	friable	f
	firm	fm
g	Soil depth	
	shallow	sh
	medium	md
	deep	dp
h	Soil drainage	
	excessive	ex
	somewhat excessive	sx
	well	wl
	moderatley well	mw
	imperfect	im
	poor	pr
	very poor	vp
i	pH (H_2O)	
	lower limit - upper limit	
j	Nutrients	
	low	lo
	medium	m
	high	h
k	Salinity, Alkalinity and Al-toxicity	
	total absence of salinity	tas
	moderate absence of salinity	mas
	total absence of alkalinity	taa
	moderate absence of alkalinity	maa
	total absence of Al-toxicity	tal
	moderate absence of Al-toxicity	mal
l	Pests and Diseases	
	absence of termites	at
	absence of poor drainage	apr
	absence of humid or wet weathers	aww
	absence of high pH	ahp
	absence of extreme acidity	aea
m	Soil erosion and Flood hazard	
	total absence of soil erosion	tae
	absence of severe soil erosion	ase
	total absence of flood	taf
	absence of severe flood	asf

LUT No.	COMMON NAME	SCIENTIFIC NAME	GROWING PERIOD
Current land use types:			
Rainfed annual food crop:			
1	Lowland rice	Oryza sativa	Jul-Nov
2	Upland rice	O. sativa	May-Sep
3	Pigeon pea	Cajanus cajan	Jun-Jan
4	Gram	Cicer arietinum	Nov-Mar
5	Horse gram	Dolichos uniflorus	Aug-Nov
6	Grass pea	Lathyrus sativus	Oct-Feb
7	Lentil	Lens esculenta	Nov-Feb
8	Mat bean	Phaseolus aconitifolius	Jul-Oct
9	Green gram	P. aureus	Dec-Feb
10	Black gram	P. mungo	Jul-Oct
11	Common bean	P. vulgaris	Aug-Oct
12	Cowpea	Vigna sinensis	Jun-Sep
13	Okra	Hibiscus esculentus	Jun-Aug
14	Edible arum	Colocasia esculenta	Jul-Dec
15	Yam	Dioscorea alata	May-Jan
16	Turmeric	Curcuma domestica	May-Jan
17	Ginger	Zingiber officinale	May-Jan
18	Straw mushroom	Volvariella spp.	Jul-Aug
Rainfed annual cash crop (current):			
19	Safflower	Carthamus tinctorius	Oct-Feb
20	Castor	Ricinus communis	Sep-Feb
Rainfed perennial food crop (current):			
21	Papaya	Carica papaya	4.0 yrs
22	Banana	Musa spp.	1.5 yrs
Rainfed perennial orchard (current):			
23	Cashew nut	Anacardium occidentale	30 yrs
24	Mango	Mangifera indica	40 yrs
25	Jack fruit	Artocarpus heterophyllus	40 yrs
26	Guava	Psidium guajava	30 yrs
27	Lime	Citrus aurantifolia	30 yrs
28	Custard apple	Annona squamosa	20 yrs
29	Jujube	Zizyphus mauritiana	25 yrs
30	Sapodilla	Manilkara achras	40 yrs
31	Bael	Aegle marmelos	30 yrs
32	Palmyra palm	Borassus flabellifer	60 yrs
33	Indian date	Phoenix sylvestris	50 yrs
Irrigated annual food crop (current):			
34	H.Y.V. rice	Oryza sativa	Dec-Apr

LUT No.	COMMON NAME	SCIENTIFIC NAME	GROWING PERIOD
35	Cole crops	Brassica oleracea	Nov-Feb
	Cauliflower	var. botrytis	
	Cabbage	var. capitata	
	Kohlrabi	var. gongyloides	
36	Root crops		Nov-Feb
	Radish	Raphanus sativus	
	Carrot	Daucus carota	
	Beet	Beta vulgaris	
	Turnip	Brassica rapa	
37	Cucurbits		Feb-Apr
	Wax gourd	Benincasa hispida	
	Little gourd	Coccinia cordifolia	
	Bottle gourd	Lagenaria siceraria	
	Ridge gourd	Luffa acutangula	
	Sponge gourd	L. cylindrica	
	Bitter gourd	Momordica charantia	
	Snake gourd	Trichosanthes cucumerina	
	Pointed gourd	T. dioica	
	Melon	Cucumis melo	
	Water melon	Citrullus lanatus	
	Pumpkin	Cucurbita spp.	
	Cucumber	Cucumis sativus	
38	Pea	Pisum sativum	Nov-Feb
39	Broad bean	Vicia faba	Nov-Feb
40	Chilli	Capsicum annuum	any
41	Brinjal	Solanum melongena	any
42	Tomato	Lycopersicon esculentum	Nov-Jan
43	Potato	Solanum tuberosum	Nov-Feb
44	Bulb crops		Nov-Feb
	Onion	Allium cepa	
	Garlic	A. sativum	
45	Wheat	Triticum aestivum	Dec-Mar
46	Spinach	Spinacia Oleracea	Dec-Jan
47	Notey	Amaranthus spp.	Apr-May
48	Pui	Basella alba	Apr-Jun
49	Hyacinth bean	Lablab niger	Apr-Jun

Irrigated annual cash crop (current):

50	Mustard	Brassica juncea	Nov-Feb
	Rapeseed	B. campestris	
51	Sesame	Sesamum indicum	Feb-May
52	Linseed	Linum usitatissimum	Nov-Mar
53	Tobacco	Nicotiana tabacum	Oct-Feb
		N. rustica	

LUT No.	COMMON NAME	SCIENTIFIC NAME	GROWING PERIOD
Irrigated perennial cash crop (current):			
54	Sugarcane	Saccharum spp.	1.5 yrs
55	Betel vine	Piper betle	30 yrs
Natural pasture (current):			
56	-	Eragrostis viscosa	annual
57	-	E. tremula	annual
58	-	E. coarctata	perenl.
59	-	E. poaeiodes	annual
60	-	Bothriochloa pertusa	perenl.
61	-	Schizachyrium brevifolium	annual
62	-	Perotis indica	annual
63	-	Aristida adscensionis	annual
64	-	Elyonurus royleanus	annual
65	Durba	Cynodon dactylon	perenl.
66	-	Stylosanthes gracilis	-
67	-	Desmodium triflorum	-
68	-	Tephrosia purpurea	-
69	-	Cassia occidentalis	-
70	-	Alysicarpus monilifer	-
Planted grass and bamboo (current):			
71	Babui	Eulaliopsis binata	perenl.
72	-	Dendrocalamus strictus	perenl.
73	-	Bambusa arundinacea	perenl.
Natural forest (current):			
74	Sal	Shorea robusta	perenl.
75	Arjun	Terminalia arjuna	perenl.
76	Asan	T. tomentosa	perenl.
77	Bohera	T. bellerica	perenl.
78	Mahua	Bassia latifolia	perenl.
79	Kend	Diospyros melanoxylon	perenl.
80	Palas	Butea frondosa	perenl.
81	Silk-cotton	Bombax malabaricum	perenl.
82	Nim	Melia azadirachta	perenl.
83	Piasal	Pterocarpus marsupium	perenl.
84	Sidha	Lagerstroemia parviflora	perenl.
Forest plantation (current):			
85	Eucalypt	Eucalyptus spp.	perenl.
86	Akasmoni	Acacia auriculiformis	perenl.
87	Sal	Shorea robusta	perenl.

LUT No.	COMMON NAME	SCIENTIFIC NAME	GROWING PERIOD
Potential land use types:			
Rainfed annual food crop:			
88	Sweet potato	Ipomoea batatas	Jun-Dec
89	Soya bean	Glycine max	Jul-Nov
90	Bambara nut	Voandzeia subterranea	Jun-Sep
91	Job's tears	Coix lachryma-jobi	Jun-Oct
92	Barnyard millet	Echinochloa frumentacea	Jul-Sep
93	Finger millet	Eleusine coracana	Jul-Oct
94	Common millet	Panicum miliaceum	Jul-Oct
95	Little millet	P. sumatrense	Jun-Sep
96	Kodo millet	Paspalum scrobiculatum	Jun-Nov
97	Bulrush millet	Pennisetum typhoides	Jul-Oct
98	Foxtail millet	Setaria italica	Jun-Sep
99	Sorghum	Sorghum bicolor	Jun-Nov
100	Maize	Zea mays	Jun-Sep
101	Cluster bean	Cyamopsis tetragonoloba	Jun-Sep
102	Lima bean	Phaseolus lunatus	Jul-Dec
Rainfed annual cash crop (potential):			
103	Cotton	Gossypium spp.	Jul-Jan
104	Niger seed	Guizotia abyssinica	Jun-Oct
105	Groundnut	Arachis hypogea	Jul-Nov
106	Sunn hemp	Crotalaria juncea	Jun-Oct
107	Kenaf (mesta)	Hibiscus cannabinus	Jun-Oct
108	Roselle (mesta)	H. sabdariffa	Jun-Nov
109	Tosa juta	Corchorus olitorius	May-Sep
Rainfed perennial food crop (potential):			
110	Cassava	Manihot esculenta	2 yrs
Rainfed perennial cash crop (potential):			
111	Sisal	Agave sisalana	10 yrs
112	Cantala	A. cantala	8 yrs
113	Henequen	A. fourcroydes	25 yrs
Rainfed perennial orchard (potential):			
114	Avocado	Persea americana	25 yrs
115	Passion fruit	Passiflora edulis	6 yrs
116	Granadilla	P. quadrangularis	6 yrs
117	Citron	Citrus medica	30 yrs
118	Grapefruit	C. paradisi	30 yrs
119	Orange	C. sinensis	25 yrs
120	Tangerine	C. reticulata	30 yrs
121	Pummelo	C. grandis	35 yrs
122	Pineapple	Ananas comosus	4 yrs
123	Jam	Eugenia jambolana	25 yrs
124	Bullock's heart	Annona reticulata	30 yrs
125	Phalsa	Grewia asiatica	25 yrs
126	Tamarind	Tamarindus indica	50 yrs

LUT No.	COMMON NAME	SCIENTIFIC NAME	GROWING PERIOD
Irrigated annual food crop (potential):			
127	Barley	Hordeum vulgare	Dec-Mar
Irrigated annual cash crop (potential):			
128	Sunflower	Helianthus annuus	Dec-Mar
129	White jute	Corchorus capsularis	Mar-Jul
Irrigated perennial cash crop (potential):			
130	Black pepper	Piper nigrum	30 yrs
131	Ramie	Boehmeria nivea	20 yrs
Irrigated perennial orchard (potential):			
132	Papaya	Carica papaya	4 yrs
133	Banana	Musa spp.	1.5 yrs
Improved pasture (potential):			
134	Para grass	Brachiaria mutica	perenl.
135	Rhodes grass	Chloris gayana	perenl.
136	Marvel grass	Dichanthium annulatum	perenl.
137	Blue panic g.	Panicum antidotale	perenl.
138	Guinea grass	P. maximum	perenl.
139	Dinanath g.	Pennisetum pedicellatum	perenl.
140	Golden Timothy	Setaria sphacelata	perenl.
141	Sudan grass	Sorghum arundinaceum	annual
142	Lucerne	Medicago sativa	perenl.
143	Egypt clover	Trifolium alexandrinum	Nov-Mar
144	Kudzu	Pueraria phaseoloides	perenl.
145	Cluster bean	Cyamopsis tetragonoloba	Jun-Sep
146	Rice bean	Phaseolus calcaratus	Dec-Feb
147	Goa bean	Psophocarpus tetragonolobus	Jun-Feb
148	Hyacinth bean	Lablab niger	perenl.
Forest plantation (potential):			
149	Kapok	Ceiba pentandra	80 yrs
150	Subabul	Leucaena leucocephala	perenl.
151	Casuarina	Casuarina equisetifolia	perenl.
152	Silk-cotton	Bombax malabaricum	perenl.
153	Babul	Acacia arabica	perenl.
154	Siris	Albizzia lebbek	perenl.

LUT	a	b	c	d	e	f
1	30-22(38-20)	sht	1500-2000(500-2500)	ad,ss	il(s-c)	any
2	33-26(36-23)	-	1400-1800(1000-2500)	ad	l(ls-c)	any
3	30-20(34-16)	sht	800-1400(500-2000)	ss	sl(s-c)	any
4	24-10(28-8)	-	100-200(75-250)	ah,ar	l(s-c)	cg
5	32-22(34-18)	-	500-600(400-800)	ar	sl(s-c)	any
6	28-16(30-12)	-	150-250(100-300)	-	cl(sl-c)	cg
7	24-10(28-5)	-	100-200(50-300)	-	l(sl-c)	cg
8	34-24(36-22)	sht	500-750(200-1200)	ar	sl(s-cl)	any,f
9	26-12(28-10)	var	100-300(50-400)	rh55,ar	l(s-c)	cg
10	30-22(34-20)	var	700-900(400-1200)	-	cl(l-c)	cg,fm
11	26-10(32-5)	ntl	300-500(200-600)	ar,ad	l(s-c)	cg,f
12	32-24(34-20)	-	700-1100(500-1300)	ad	l(ls-c)	cg
13	32-24(36-16)	ntl	600-900(500-1000)	-	l(s-c)	cg
14	32-20(36-16)	ntl	1000-1500(750-2000)	-	l(ls-cl)	cg,f
15	30-24(32-20)	sht	1400-1600(800-3000)	dr	sl(s-l)	cg,f
16	30-22(32-20)	-	1500-2000(1000-2500)	ss	l(sl-cl)	cg
17	30-22(32-20)	-	1500-2000(1000-2500)	dr,ss	l(sl-cl)	cg,f
18	31-24(35-20)	-	1000-1500(400-2500)	rh80,ad	-	-
19	26-12(28-10)	sht	150-250(100-300)	rh60,ar	l(s-c)	cg
20	30-20(35-18)	-	500-750(400-1000)	rh60,ar	l(s-cl)	cg
21	34-20(38-8)	ntl	1200-2000(800-3000)	ad,as,ss	l(sl-cl)	any
22	32-22(38-15)	ntl	2000-2500(1300-3500)	ad,as,ss	l(sl-c)	any
23	36-14(40-10)	-	1200-2000(500-3800)	dr	sl(s-l)	any
24	36-14(42-10)	-	1000-1700(250-2500)	dr,ah	l(s-c)	any
25	38-14(42-10)	-	1000-2000(800-3000)	-	l(sl-cl)	any
26	36-14(40-8)	-	1000-1600(800-2000)	-	l(sl-cl)	any
27	36-14(40-10)	ntl	750-1350(500-2500)	ad,as	l(s-cl)	any,f
28	38-12(40-10)	-	750-1500(500-1800)	-	sl(s-l)	any
29	38-12(42-8)	-	800-1500(500-1800)	-	l(s-c)	any
30	36-14(38-12)	-	1000-2000(700-3000)	-	l(s-c)	any
31	38-12(42-5)	-	1000-1600(700-3000)	-	cl(sl-c)	any
32	38-12(42-8)	-	1000-1500(700-1800)	-	l(s-c)	any

LUT	g	h	i	j	k	l	m
1	dp(md)	pr(mw-vp)	5-7(3-10)	m(lo)	mas,maa	-	asf
2	dp(md)	wl(ex-pr)	5-7(4-8)	m(lo)	-	-	taf,ase
3	dp	wl(ex-im)	6-7(5-8)	m(lo)	-	-	asf
4	dp	mw(wl-im)	6-7(5-8)	m(lo)	-	-	-
5	dp	wl(ex-im)	6-7(5-8)	lo	maa	apr	asf
6	dp	im(wl-vp)	5-7(4-8)	m(lo)	-	-	-
7	dp	wl(pr)	6-7(5-8)	m(lo)	maa	-	-
8	dp(md)	wl(sx-mw)	-	m(lo)	-	-	asf
9	dp	wl(sx-mw)	-	m(lo)	-	-	-
10	dp(md)	mw(wl-im)	6-7(5-8)	m	-	-	-
11	dp	wl(sx-im)	5-6(5-7)	m	tas,tal	aww	-
12	dp	mw(sx-im)	5-6(4-7)	m(lo)	-	-	-
13	dp	mw(wl-im)	-	m	-	-	ase
14	dp(md)	mw(wl-im)	-	m	-	-	ase
15	dp	wl(ex-im)	-	h(m)	-	-	taf
16	dp	wl(ex-im)	6-7(5-7)	h(m)	taa	-	taf,ase
17	dp	wl(ex-im)	-	h(m)	-	-	taf,ase
18	-	ex(wl)	-	-	-	-	taf
19	dp	wl(wl-im)	-	m(lo)	mas	-	-
20	dp	wl(sx-im)	-	m	-	aww	ase
21	dp	wl(sx-im)	6-7(5-8)	h(m)	-	apr	-
22	dp	wl(sx-im)	6-7(5-8)	h(m)	tas	aea	-
23	dp(sh)	wl(ex-mw)	5-7(4-8)	lo	-	-	taf
24	dp(sh)	mw(wl-pr)	6-7(5-8)	m	maa	-	-
25	dp	wl(ex-im)	-	h(m)	-	-	-
26	dp(md)	wl(ex-im)	5-6(4-8)	h(lo)	-	-	-
27	dp	wl(ex-im)	5-7(4-8)	m	tas	aww	-
28	dp(md)	wl(ex-mw)	-	m(lo)	-	-	-
29	dp(md)	wl(ex-im)	-	m(lo)	maa	-	-
30	dp	mw(wl-im)	-	m	-	-	-
31	dp(md)	im(wl-pr)	-	m(lo)	-	-	-
32	dp	im(ex-pr)	-	m(lo)	-	-	-

LUT	a	b	c	d	e	f
33	40-8(44-5)	-	700-1500(500-1800)	-	l(s-c)	any
34	28-14(32-10)	ntl	1300-1700(1000-2000)	ad	l(sl-c)	any
35	26-10(30-6)	ntl	400-500	ad,rh70	l(s-c)	cg,f
36	25-10(30-6)	-	300-500	-	sl(s-c)	cg,f
37	38-24(42-20)	-	700-800(500-1000)	rh50,ss	sl(s-c)	any,f
38	26-10(30-6)	ntl	300-500	ad	l(sl-c)	cg,f
39	22-14(28-10)	-	300-500	-	l(sl-c)	cg
40	(40-10)	var	500-600	ad	l(ls-c)	cg,f
41	(40-10)	var	500-600	ad	l(ls-c)	cg,f
42	26-10(30-6)	ntl	300-500	ar,ss	l(ls-c)	cg,f
43	26-10(32-5)	var	400-600	ad	sl(s-cl)	cg,f
44	26-10(30-5)	var	300-500	ad,ar	l(ls-cl)	cg,f
45	26-10(30-2)	var	500-700(250-1000)	dr	l(sl-c)	cg
46	26-12(30-8)	-	200-300	ad	l(sl-c)	cg
47	36-24(40-22)	-	500-600(300-800)	ad	l(sl-c)	cg
48	36-24(38-22)	-	700-800(500-1000)	ad	l(sl-c)	cg
49	36-24(38-26)	-	700-800(500-1000)	ad	l(sl-c)	any
50	26-12(30-8)	-	250-400	-	l(s-c)	cg
51	32-20(36-15)	-	400-500(300-600)	ar	l(s-c)	cg
52	27-14(30-10)	-	200-300(100-400)	-	l(sl-c)	cg
53	30-18(35-15)	var	400-600(250-750)	ar,ah,as	sl(ls-c)	cg,f
54	36-20(42-15)	var	2000-3000(1500-4000)	ad,as,ss	l(ls-c)	cg,f
55	34-22(36-18)	-	2000-3000(1800-3500)	ad,as	l(sl-cl)	cg,f
56	38-12(42-8)	-	1000-1500(500-1600)	ss	sl(s-cl)	any
57	38-12(42-8)	-	1000-1500(500-1600)	ss	sl(s-cl)	any
58	38-12(42-8)	-	1000-1500(500-1600)	ss	sl(s-cl)	any
59	38-12(42-8)	-	1000-1500(500-1600)	ss	sl(s-cl)	any
60	38-12(42-8)	-	1000-1500(500-1600)	ss	sl(s-cl)	any
61	38-12(42-8)	-	1000-1500(500-1600)	ss	sl(s-cl)	any
62	38-12(42-8)	-	1000-1500(500-1600)	ss	sl(s-cl)	any
63	38-12(42-8)	-	1000-1500(500-1600)	ss	sl(s-cl)	any
64	38-12(42-8)	-	1000-1500(500-1600)	ss	sl(s-cl)	any

LUT	g	h	i	j	k	l	m
33	dp	mw(ex-pr)	-	m(lo)	-	-	-
34	dp	pr(wl-vp)	5-7(4-8)	h(m)	mas	-	-
35	dp	wl(sx-mw)	6-7(5-8)	h(m)	mas	-	ase
36	dp	wl(sx-mw)	-	h(m)	-	-	ase
37	dp(md)	wl(ex-mw)	6-7(5-8)	h(m)	-	apr,aww	taf
38	dp	wl(sx-mw)	5-6(5-7)	h(m)	tas,taa	-	ase
39	dp	wl(sx-mw)	-	h(m)	tas	-	ase
40	dp(md)	wl(sx-mw)	6-7(4-8)	m	-	apr	ase
41	dp(md)	wl(sx-im)	6-7(4-8)	m	-	apr	ase
42	dp(md)	wl(sx-mw)	5-7(4-8)	h(m)	-	apr,aww	-
43	dp(md)	wl(sx-mw)	5-6(4-7)	h(m)	mas	aww,ahp	ase
44	dp(md)	wl(sx-mw)	5-7	h(m)	mas	aww	ase
45	dp	wl(sx-mw)	6-7(5-8)	h(m)	mas	-	-
46	dp(md)	wl(sx-mw)	-	m	-	-	-
47	dp(md)	wl(sx-mw)	-	m(lo)	-	-	-
48	dp(md)	wl(sx-mw)	-	m(lo)	-	-	-
49	dp	wl(sx-mw)	-	m(lo)	-	aww	-
50	dp	wl(sx-mw)	6-7(5-8)	m	-	-	-
51	dp(md)	wl(sx-mw)	6-7(5-8)	m	tal	-	-
52	dp	wl(sx-im)	6-7(5-8)	m	-	-	-
53	dp	wl(sx-mw)	5-6(4-7)	m(lo)	tas,tal	aww	-
54	dp	mw(wl-im)	6-7(5-8)	h	mas	at	ase
55	dp	wl(sx-mw)	-	h	-	apr	-
56	dp(sh)	wl(ex-im)	5-6(4-7)	lo	-	-	taf
57	dp(sh)	wl(ex-im)	5-6(4-7)	lo	-	-	taf
58	dp(sh)	wl(ex-im)	5-6(4-7)	lo	-	-	taf
59	dp(sh)	wl(ex-im)	5-6(4-7)	lo	-	-	taf
60	dp(sh)	wl(ex-im)	5-6(4-7)	lo	-	-	taf
61	dp(sh)	wl(ex-im)	5-6(4-7)	lo	-	-	taf
62	dp(sh)	wl(ex-im)	5-6(4-7)	lo	-	-	taf
63	dp(sh)	wl(ex-im)	5-6(4-7)	lo	-	-	taf
64	dp(sh)	wl(ex-im)	5-6(4-7)	lo	-	-	taf

LUT	a	b	c	d	e	f
65	38-12(42-8)	-	1400-2000(500-5000)	ss	l(s-c)	any
66	38-12(42-8)	-	1000-1500(500-1600)	ss	sl(s-cl)	any
67	38-12(42-8)	-	1000-1500(500-1600)	ss	sl(s-cl)	any
68	38-12(42-8)	-	1000-1500(500-1600)	ss	sl(s-cl)	any
69	38-12(42-8)	-	1000-1500(500-1600)	ss	sl(s-cl)	any
70	38-12(42-8)	-	1000-1500(500-1600)	ss	sl(s-cl)	any
71	38-10(40-6)	-	1400-1700(750-2000)	ss	l(s-cl)	any
72	36-12(40-8)	-	1400-1700(800-2000)	ss	l(s-c)	any
73	36-14(40-12)	-	1500-2000(1000-3000)	ss	l(s-c)	any
74	34-18(42-8)	-	1250-2000(1000-3750)	-	sl(ls-c)	any
75	34-18(42-8)	-	1200-1800(800-2000)	-	l(s-c)	any
76	34-18(42-8)	-	1200-2200(800-3000)	-	l(s-c)	any
77	34-18(42-8)	-	1200-2000(1000-4000)	-	l(s-c)	any
78	34-18(42-10)	-	1000-1600(800-2000)	-	l(ls-c)	any
79	34-18(42-10)	-	1000-1500(800-2000)	-	sl(ls-cl)	any
80	34-18(42-10)	-	1000-1500(600-1800)	-	l(ls-c)	any
81	36-12(40-8)	-	1250-1500(600-4000)	-	sl(s-c)	any
82	34-18(42-10)	-	1000-1600(500-1800)	-	sl(ls-c)	any
83	34-18(42-10)	-	1200-1500(800-2000)	-	sl(ls-c)	any
84	34-18(42-10)	-	1200-2000(1000-3000)	-	l(s-c)	any
85	36-10(40-5)	-	1000-2000(800-2500)	-	sl(ls-c)	any
86	36-10(40-10)	-	1000-2000(800-2500)	-	sl(ls-c)	any
87	34-18(42-8)	-	1250-2000(1000-3750)	-	sl(ls-c)	any
88	30-24(34-19)	sht	600-1000(400-1300)	dr,ss	sl(s-cl)	cg,f
89	30-20(35-15)	var	600-900(400-1100)	ad	l(ls-c)	cg,f
90	34-26(40-24)	-	500-750(250-1000)	ss	sl(s-c)	any,f
91	32-24(34-20)	-	1000-1500(750-2000)	ad	l(sl-c)	any
92	32-26(34-20)	-	600-800(400-1000)	-	l(s-c)	any
93	32-23(35-18)	sht	500-600(300-1000)	ar	sl(s-cl)	any
94	34-25(38-20)	-	300-600(100-800)	ar	sl(s-c)	any
95	32-26(34-20)	-	600-800(400-1000)	-	l(s-c)	any
96	32-24(35-22)	-	400-800(100-1000)	-	sl(s-l)	any

LUT	g	h	i	j	k	l	m
65	dp(md)	im(wl-pr)	6-7(4-8)	m(lo)	-	-	asf
66	dp(sh)	wl(ex-im)	5-6(4-7)	lo	-	-	taf
67	dp(sh)	wl(ex-im)	5-6(4-7)	lo	-	-	taf
68	dp(sh)	wl(ex-im)	5-6(4-7)	lo	-	-	taf
69	dp(sh)	wl(ex-im)	5-6(4-7)	lo	-	-	taf
70	dp(sh)	wl(ex-im)	5-6(4-7)	lo	-	-	taf
71	dp	im(wl-pr)	5-6(5-7)	m(lo)	-	-	-
72	dp(md)	im(wl-pr)	5-6(4-7)	m(lo)	-	-	-
73	dp(md)	im(wl-pr)	5-6(4-7)	m(lo)	-	-	-
74	dp(sh)	wl(ex-pr)	5-6(4-8)	m(lo)	-	-	-
75	dp	im(wl-pr)	6-7(5-8)	m(lo)	-	-	-
76	dp	im(wl-pr)	6-7(5-8)	m(lo)	-	-	-
77	dp	im(wl-pr)	6-7(5-8)	m(lo)	-	-	-
78	dp	im(wl-pr)	6-7(5-8)	m(lo)	-	-	-
79	dp(sh)	wl(ex-im)	5-6(4-8)	lo	-	-	taf
80	dp(sh)	im(wl-pr)	6-8(5-9)	lo	-	-	-
81	dp	wl(ex-im)	5-6(4-8)	m(lo)	-	-	-
82	dp	wl(ex-im)	6-7(5-9)	m(lo)	-	-	-
83	dp	wl(ex-im)	5-6(4-8)	m(lo)	-	-	-
84	dp	im(wl-pr)	6-7(5-8)	m(lo)	-	-	-
85	dp(sh)	wl(ex-im)	5-7(4-8)	m(lo)	-	-	-
86	dp(md)	wl(ex-im)	5-7(4-8)	m(lo)	-	-	-
87	dp(sh)	wl(ex-pr)	5-6(4-8)	m(lo)	-	-	-
88	dp(md)	wl(ex-im)	5-6(5-7)	m	tas,taa	-	asf
89	dp	mw(wl-pr)	6-7(5-7)	h(m)	mas,tal	-	ase
90	dp(sh)	wl(ex-im)	-	lo	-	-	taf
91	dp	im(wl-vp)	-	h(m)	-	-	-
92	dp(md)	im(wl-vp)	-	m(lo)	-	-	-
93	dp(md)	wl(sx-mw)	6-8(5-11)	m	-	-	taf
94	dp(md)	wl(sx-mw)	-	m(lo)	-	-	taf
95	dp(md)	im(wl-vp)	-	m(lo)	-	-	-
96	dp(md)	wl(sx-mw)	6-7(5-8)	m(lo)	-	-	taf

LUT	a	b	c	d	e	f
97	34-25(37-20)	ntl	300-500(250-1000)	ar	l(s-c)	any
98	32-24(35-16)	ntl	400-700(200-900)	ar,ad	l(s-c)	any
99	32-25(38-20)	var	300-700(200-1000)	-	l(s-c)	any
100	32-22(41-10)	var	600-900(400-4000)	ad,ah	l(sl-cl)	cg,f
101	34-24(38-20)	-	500-800(300-1000)	-	sl(s-c)	any
102	30-20(32-18)	var	700-1000(500-1400)	dr	l(s-c)	cg
103	34-22(40-18)	var	700-1000(500-2000)	ar,ss,dr	sl(ls-cl)	cg
104	30-22(34-20)	-	1000-1250(400-1400)	ad,ar	l(s-c)	cg
105	32-24(34-18)	ntl	700-900(500-1250)	dr	sl(ls-cl)	cg,vf
106	32-24(34-22)	sht	700-1000(400-1200)	-	sl(ls-cl)	any,f
107	33-25(35-23)	sht	600-700(500-1200)	ar,ss	l(sl-cl)	any,f
108	32-24(34-22)	sht	700-900(600-1300)	-	l(sl-cl)	any,f
109	33-25(38-20)	-	1000-1400(800-1600)	ad,rh80	l(sl-c)	cg,f
110	27-16(38-8)	-	1200-2000(500-5000)	dr	sl(s-cl)	any,f
111	34-18(38-16)	ntl	1000-1500(750-1800)	ad,ss,ar	sl(s-c)	any,f
112	32-20(34-18)	-	1500-2500(1000-3000)	-	l(s-c)	any,f
113	32-18(34-16)	-	600-1000(400-1500)	ar,ss	sl(s-c)	any,f
114	32-20(34-18)	-	1100-1300(1000-1400)	ad,ar,as	sl(ls-l)	any,f
115	34-16(36-12)	sht	800-3000(700-1500)	ar	l(ls-cl)	any,f
116	34-16(36-12)	sht	1200-1600(1000-1800)	-	l(sl-cl)	any,f
117	36-12(40-8)	ntl	1200-2000(500-2500)	ad,as	l(sl-cl)	any,f
118	36-10(40-3)	ntl	1000-1500(750-4000)	ad,as,ar	sl(s-c)	any,f
119	36-10(40-3)	ntl	1000-1500(750-4000)	ad,as	sl(s-c)	any,f
120	30-8(38-3)	ntl	1000-2000(750-4000)	ad,as	sl(s-c)	any,f
121	34-18(38-16)	ntl	1500-2000(1200-2500)	ad,as	l(sl-c)	any,f
122	34-15(38-8)	ntl	1000-1500(600-2500)	rh80,ar	sl(s-c)	any,f
123	36-14(40-8)	-	1300-1700(800-2000)	-	l(s-c)	any
124	36-12(40-8)	-	1000-1400(500-1800)	-	l(sl-cl)	any
125	38-10(40-8)	-	800-1200(500-1500)	-	l(sl-cl)	any
126	38-10(42-8)	-	750-1800(500-2500)	-	l(s-c)	any
127	26-10(30-2)	-	300-600(200-800)	dr	l(s-cl)	cg
128	25-18(30-15)	ntl	600-900(100-1000)	ad,ar,dr	l(s-c)	cg,f

LUT	g	h	i	j	k	l	m
97	dp(md)	wl(sx-mw)	-	m(lo)	-	aww	taf,ase
98	dp(md)	wl(sx-mw)	-	m(lo)	-	-	taf
99	dp	mw(wl-im)	6-7(5-8)	m	mas,tal	-	ase
100	dp	wl(sx-mw)	6-7(5-8)	h	tas,tal	-	taf,ase
101	dp(md)	wl(ex-im)	-	m(lo)	-	-	-
102	dp(md)	wl(sx-mw)	6-7(5-8)	m	-	-	taf
103	dp	wl(ex-im)	7-8(5-9)	m(lo)	-	-	ase
104	dp(md)	wl(ex-im)	-	lo	-	-	-
105	dp	wl(ex-mw)	5-7	m	tas,tal	at	taf
106	dp	wl(ex-im)	6-7(5-8)	m(lo)	-	-	-
107	dp	wl(ex-im)	6-7	m	-	apr	-
108	dp	wl(ex-im)	6-7	m	-	apr	-
109	dp	wl(ex-mw)	6-7	h	tas	apr,aea	taf
110	dp	wl(ex-mw)	-	m(lo)	-	-	taf
111	dp	wl(ex-mw)	6-7(5-8)	m	tas	aea	taf
112	dp(md)	mw(wl-im)	-	m(lo)	-	-	-
113	dp(sh)	wl(ex-im)	6-8	m(lo)	-	-	asf
114	dp	wl(sx-mw)	6-7(5-8)	h(m)	tas	apr	-
115	dp	wl(sx-mw)	6-7(5-8)	m(lo)	-	-	-
116	dp	wl(ex-mw)	6-7(5-8)	m(lo)	-	-	-
117	dp	wl(sx-im)	6-7(5-8)	m	tas	apr	-
118	dp	wl(sx-im)	6-7(5-8)	m	tas	apr,aww	-
119	dp	wl(sx-im)	6-7(5-8)	m	tas	apr	-
120	dp	wl(ex-mw)	6-7(5-8)	h	tas	apr	-
121	dp	im(wl-pr)	6-7(5-8)	m	tas	-	-
122	dp(md)	wl(ex-im)	5-7(4-7)	h(m)	-	apr	ase
123	dp	mw(wl-pr)	-	m	-	-	-
124	dp(md)	mw(wl-im)	-	m(lo)	-	-	-
125	dp	mw(wl-im)	-	m(lo)	-	-	-
126	dp	mw(ex-pr)	-	m(lo)	-	-	-
127	dp	wl(sx-mw)	6-7(5-8)	m	mas,maa	-	-
128	dp(md)	wl(sx-mw)	6-7(5-8)	m	mas	-	-

LUT	a	b	c	d	e	f
129	34-24(36-22)	-	1000-1400(800-1600)	ad,rh80	l(sl-c)	cg,f
130	36-16(40-10)	-	2500-3000(2000-5000)	ad,as	cl(l-c)	cg,f
131	32-20(36-16)	-	1500-2000(1000-3000)	ad,ar	l(sl-cl)	cg,f
132	34-20(38-8)	ntl	1200-2000(800-3000)	ad,as,ss	l(sl-cl)	any
133	32-22(38-15)	ntl	2000-2500(1300-3500)	ad,as,ss	l(sl-c)	any
134	34-18(38-15)	-	2500-3500(1700-4000)	ad	cl(sl-c)	any
135	34-16(38-10)	-	1000-1300(750-1500)	ad	sl(s-cl)	any
136	36-12(40-8)	-	1000-1500(250-2000)	-	l(s-c)	any
137	34-16(38-12)	-	1500-2000(500-3000)	ad	sl(s-cl)	any
138	34-12(38-10)	-	1000-1750(500-3000)	ad	l(s-cl)	any
139	38-12(40-10)	-	1000-1600(500-2000)	ad	sl(s-cl)	any
140	34-10(38-6)	-	1400-1800(900-2000)	ad	l(sl-cl)	any
141	38-18(40-15)	-	800-1000(300-1200)	-	l(sl-c)	any
142	36-8(40-4)	-	1200-1600(800-2000)	rh60,ss	l(sl-cl)	any
143	24-10(28-6)	-	500-600(400-800)	-	l(sl-c)	any
144	36-14(40-8)	-	1200-1600(1000-1800)	-	sl(s-cl)	any
145	34-24(38-20)	-	500-800(300-1000)	-	sl(s-c)	any
146	28-16(30-10)	sht	200-400(50-600)	ad	l(s-c)	any
147	30-24(32-22)	-	1250-2000(1000-3000)	-	l(sl-cl)	any
148	38-12(42-8)	-	600-900(500-1200)	ss	sl(ls-cl)	any
149	34-19(36-16)	-	1250-1500(1000-2000)	ss,as	sl(ls-cl)	any
150	36-14(40-10)	-	1250-1500(750-2000)	-	sl(s-c)	any
151	34-14(40-10)	-	1500-2000(1000-4000)	ss	ls(s-cl)	any
152	36-12(40-8)	-	1250-1500(600-4000)	-	sl(s-c)	any
153	40-12(42-8)	-	1000-1500(200-2000)	-	l(s-c)	any
154	36-14(40-10)	-	1400-1800(800-2500)	-	l(s-c)	any

LUT	g	h	i	j	k	l	m
129	dp	mw(wl-pr)	6-7	h	tas	-	asf
130	dp	wl(sx-mw)	5-7	h	-	-	-
131	dp(md)	wl(sx-mw)	-	h	-	-	taf
132	dp	wl(sx-im)	6-7(5-8)	h(m)	-	apr	-
133	dp	wl(sx-im)	6-7(5-8)	h(m)	tas	aea	-
134	dp	pr(im-vp)	6-7(5-9)	h(m)	maa	-	-
135	dp	wl(ex-mw)	6-8(6-9)	m	-	-	taf
136	dp	mw(wl-pr)	7-8(5-9)	m(lo)	-	-	-
137	dp	wl(ex-im)	5-7(5-8)	m	taa	-	-
138	dp	wl(sx-mw)	-	h(m)	-	-	taf
139	dp(md)	mw(ex-pr)	-	m(lo)	-	-	-
140	dp	wl(sx-im)	-	h(m)	-	at	-
141	dp	wl(ex-mw)	5-7	h(m)	mas	-	-
142	dp	wl(sx-im)	6-7(5-8)	h(m)	mas,tal	-	asf
143	dp	wl(sx-im)	-	h(m)	mas	-	-
144	dp(md)	wl(ex-im)	-	m(lo)	-	-	-
145	dp(md)	wl(ex-im)	-	m(lo)	tas	-	-
146	dp(md)	wl(ex-im)	-	m(lo)	-	-	-
147	dp(md)	wl(sx-mw)	-	m(lo)	-	-	taf
148	dp	wl(sx-mw)	-	m(lo)	-	-	taf
149	dp	wl(sx-mw)	-	h(m)	-	at	-
150	dp(sh)	wl(sx-im)	6-8(5-9)	m(lo)	-	-	-
151	dp	wl(ex-mw)	5-8(5-9)	m(lo)	-	-	-
152	dp	wl(ex-im)	-	m(lo)	-	-	-
153	dp(sh)	im(wl-pr)	6-8(5-9)	m(lo)	mas	-	-
154	dp	im(wl-pr)	6-7(5-8)	m(lo)	-	-	-

APPENDIX H

LAND SUITABILITY CLASSIFICATION

source: laboratory work; see SECTION 3.5 and TABLE 3.5 for method of classification and explanation of symbols, see Appendix G for indentification of the land use types numbered 1-154, see first page of this Appendix for identification of the land facets numbered 1-29.

	FACET	1	2	3	4	5	6	7	8
1	A. Summit	N2s	S2ms	S2s	N2s	S2s	N2s	N2s	S2s
2	A. Shoulder	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s
3	A. Footslope	S2mn	S2m	S3o	S2t	S3o	S2s	S2t	S3o
4	A. Toeslope	S1	N2o	N2o	S2t	N2o	S1	S2t	N2o
5	A. Base	S1	N2o	N2o	S2t	N2o	S1	S2t	N2o
6	B. Summit	N2s	S3m	S2sr	N2s	S2s	N2s	N2s	S2s
7	B. Shoulder	N2s	S3m	S2rn	N2s	S2rn	N2s	N2s	S2n
8	B. Footslope	S2mn	S2m	S3o	S2t	S3o	S2s	S2t	S3o
9	B. Toeslope	S1	N2o	N2o	S2t	N2o	S1	S2t	N2o
10	B. Base	S1	N2o	N2o	S2t	N2o	S1	S2t	N2o
11	C. Summit	N2s	S3m	S2n	N2s	S2rn	N2s	N2s	S2n
12	C. Shoulder	N2s	S3m	S2n	N2s	S2rn	N2s	N2s	S2n
13	C. Footslope	S2mn	S2me	S3o	N2s	S3o	S2s	N2s	S3o
14	C. Toeslope	S1	N2o	N2o	S2t	N2o	S1	S2t	N2o
15	C. Base	S1	N2o	N2o	S2t	N2o	S1	S2t	N2o
16	D. Summit	N2s	S3m	S2sn	N2s	S2rn	N2s	N2s	S2n
17	D. Shoulder	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s
18	D. Footslope	S2m	S2m	S3o	S2t	S3o	S1	S2t	S3o
19	D. Toeslope	S2m	S2m	S3o	S2t	S3o	S1	S2t	S3o
20	D. Base	S1	N2o	N2o	S2t	N2o	S2s	S2t	N2o
21	E. Summit	N2s	S3m	S2n	N2s	S2rn	N2s	N2s	S2n
22	E. Shoulder	N2s	S3m	S2n	N2s	S2rn	N2s	N2s	S2n
23	E. Footslope	S2mn	S2m	N2s	S3s	S3o	S2s	S3s	S3o
24	E. Toeslope	S2m	S2m	S3o	S2t	S3o	S1	S2t	S3o
25	E. Base	S1	N2o	N2o	S2t	N2o	S1	S2t	N2o
26	F. Darakeswar	S1	N2of	S3of	S2t	S3of	S1	S2t	S3of
27	F. Silai	S2sf	N2of	S2of	S3s	S2of	S2s	S3s	S2of
28	F. Kasai	S1	N2of	S3of	S2t	S3of	S1	S2t	S3of
29	F. Subarnarekha	S1	N2of	S2of	S2ts	S2of	S2s	S2ts	S2of

FACET	9	10	11	12	13	14	15	16	17	18
1	N2s	N2s	S3s	S3s	S3s	S3s	S3s	S3s	S3s	S2o
2	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s	S1
3	S2n	S2o	S2to	S2on	S2o	S2on	S3o	S3o	S3o	N2o
4	S2n	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o
5	S2n	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o
6	N2s	N2s	S2ts	S3s	S3s	S3s	S2mn	S3s	S3s	S2o
7	N2s	N2s	S2ts	S2s	S2s	S3m	S2mn	S3ms	S3ms	S1
8	S2sn	S3s	S2to	S2os	S2os	S2os	S3o	S3o	S3o	N2o
9	S2n	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o
10	S2n	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o
11	N2s	N2s	S2ts	S2s	S2s	S2sn	S2mn	S3s	S3s	S2o
12	N2s	N2s	S2ts	S2s	S2s	S2ms	S2mn	S3ms	S3ms	S3o
13	N2s	N2s	S2to	S2os	S3e	S3e	S3o	S3oe	S3oe	N2o
14	S2n	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o
15	S2n	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o
16	N2s	N2s	S2ts	S2sn	S2sn	S2m	S2m	S3s	S3s	S3o
17	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s	S1
18	S2n	S2o	S2to	S2o	S2o	S2o	S3o	S3o	S3o	N2o
19	S2n	S2o	S2to	S2o	S2o	S2o	S3o	S3o	S3o	N2o
20	S2sn	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o
21	N2s	N2s	S2ts	S2sn	S2sn	S2s	S2ms	S3s	S3s	S2o
22	N2s	N2s	S2ts	S2sn	S2sn	S2ms	S2ms	S3s	S3s	S1
23	S3s	S3os	S3s	S3s	S3s	S2on	S3os	S3os	S3os	N2o
24	S2n	S2o	S2to	S2on	S2on	S2on	S3o	S3o	S3o	N2o
25	S2n	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o
26	S1	S2o	S2to	S2o	S2o	S2o	S3of	S3of	S3of	N2of
27	S2s	S3s	S2to	S3s	S3s	S3s	S3of	S3of	S3of	N2of
28	S1	S2o	S2to	S2o	S2o	S2o	S3of	S3of	S3of	N2of
29	S2sn	S2s	S2to	S2os	S2os	S2os	S3of	S3of	S3of	N2of

FACET	19	20	21	22	23	24	25	26	27	28
1	N2s	S3s	S3s	S3ms	S2s	S2sn	S3s	S2sn	S3s	S2sn
2	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s
3	S2n	S2mn	S2on	S2on	N2o	S2on	S3o	S2on	S2on	S3o
4	S3o	N2o	N2o	N2o	N2o	S3o	N2o	N2o	N2o	N2o
5	S2o	N2o	N2o	N2o	N2o	S3o	N2o	N2o	N2o	N2o
6	N2s	S3m	S3s	S3ms	S1	S2sn	S3s	S3s	S3s	S2sn
7	N2s	S3m	S2sn	S3m	S1	S2sn	S2sn	S2sn	S2sn	S2n
8	S2s	S3mn	S2os	S2on	N2o	S2on	S3o	S2os	S2os	S3o
9	S2n	N2o	N2o	N2o	N2o	S3o	N2o	N2o	N2o	N2o
10	S3o	N2o	N2o	N2o	N2o	S3o	N2o	N2o	N2o	N2o
11	N2s	S3m	S2sn	S3m	S1	S2sn	S2sn	S2sn	S2sn	S2n
12	N2s	S3m	S2sn	S3m	S1	S2sn	S2sn	S2sn	S2sn	S2n
13	N2s	S3me	S2os	S2on	N2o	S2on	S3o	S2os	S2os	S3o
14	S1	N2o	N2o	N2o	N2o	S3o	N2o	N2o	N2o	N2o
15	S3o	N2o	N2o	N2o	N2o	S3o	N2o	N2o	N2o	N2o
16	N2s	S3m	S2n	S3m	S2o	S2n	S2on	S2m	S2m	S2os
17	N2s	N2s	N2s	N2s	S3s	N2s	N2s	N2s	N2s	N2s
18	S1	S3m	S2on	S2on	N2o	S2o	S3o	S2o	S2o	S3o
19	S1	S2m	S2on	S2on	N2o	S2o	S3o	S2o	S2o	S3o
20	S3o	N2o	N2o	N2o	N2o	S3o	N2o	N2o	N2o	N2o
21	N2s	S3m	S2sn	S3m	S1	S2sn	S2sn	S2sn	S2sn	S2n
22	N2s	S3m	S2sn	S3m	S1	S2sn	S2sn	S2sn	S2sn	S2n
23	S3s	S3s	S3s	S3s	N2o	S2os	S3os	S2on	S3s	S3o
24	S1	S2mn	S2on	S2on	N2o	S2on	S3o	S2o	S2o	S3o
25	S3o	N2o	N2o	N2o	N2o	S3o	N2o	N2o	N2o	N2o
26	S1	S2m	S2o	S2o	N2of	S2o	S3o	S2o	S2o	S3o
27	S2s	S3s	S3s	S3s	N2of	S2os	S3os	S3s	S3s	S3o
28	S1	S2m	S2o	S2o	N2of	S2o	S3o	S2o	S2o	S3o
29	S2s	S2ms	S2o	S2os	N2of	S2os	S3os	S2os	S2os	S3o

FACET	29	30	31	32	33	34	35	36	37	38	39
1	S2sn	N2s	S2sn	S3s	S3s	N2s	N2s	N2s	S2sn	N2s	N2s
2	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s
3	S2on	S2on	S2sn	S2n	S2n	S2rn	S2rn	S2sn	S2sn	S2rn	S2tn
4	N2o	N2o	S3o	S2o	S2o	S2rn	S3o	S3o	S3o	S3o	S3o
5	N2o	N2o	S3o	S2o	S2o	S2rn	S2rn	S2sn	S2sn	S2rn	S2tn
6	S2sn	S3s	S3s	S2sn	S2sn	N2s	S3s	S3s	S2sn	S3s	S3s
7	S2sn	S2sn	S2sn	S2sn	S2sn	N2s	S3s	S3s	S2rn	S3s	S3s
8	S2os	S2os	S2sn	S2sn	S2sn	S2sn	S2sn	S2n	S2n	S2sn	S2ts
9	N2o	N2o	S3o	S2o	S2o	S2rn	S2rn	S2sn	S2sn	S2rn	S2tn
10	N2o	N2o	S3o	S2o	S2o	S2rn	S3o	S3o	S3o	S3o	S3o
11	S2sn	S2sn	S2sn	S2sn	S2sn	N2s	S3s	S3s	S2rn	S3s	S3s
12	S2sn	S2sn	S2sn	S2sn	S2sn	N2s	S3s	S3s	S2rn	S3s	S3s
13	S2os	S2os	S2sn	S2sn	S2sn	S3s	S3se	S3se	S2rn	S3se	S3se
14	N2o	N2o	S3o	S2o	S2o	S2n	S2rn	S2sn	S2sr	S2n	S2tn
15	N2o	N2o	S3o	S2o	S2o	S2n	S3o	S3o	S3o	S3o	S3o
16	S2o	S2n	S1	S1	S1	N2s	S3s	S3s	S2sn	S3s	S3s
17	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s
18	S2o	S2o	S1	S1	S1	S2n	S2rn	S2sn	S2sn	S2rn	S2tn
19	S2o	S2o	S1	S1	S1	S2n	S2n	S2sn	S2sn	S2n	S2tn
20	N2o	N2o	S3o	S2o	S2o	S2n	S3o	S3o	S3o	S3o	S3o
21	S2sn	S2sn	S2sn	S2sn	S2sn	N2s	S3s	S3s	S2rn	S3s	S3s
22	S2sn	S2sn	S2sn	S2sn	S2sn	N2s	S3s	S3s	S2rn	S3s	S3s
23	S2os	N2s	S2sn	S3s	S3s	S3s	N2s	N2s	S2rn	N2s	N2s
24	S2o	S2on	S2n	S1	S1	S2n	S2n	S2sn	S3sn	S2n	S2tn
25	N2o	N2o	S3o	S2o	S2o	S2n	S3o	S3o	S3o	S3o	S3o
26	S2o	S2o	S1	S1	S1	S1	S1	S2s	S2s	S1	S2t
27	S2os	S3s	S3s	S2s	S2s	S3s	S2sn	S2n	S2rn	S2sn	S2ts
28	S2o	S2o	S1	S1	S1	S1	S1	S2s	S2s	S1	S2t
29	S2os	S2o	S2s	S2s	S2s	S3s	S2sn	S2n	S2rn	S2sn	S2ts

FACET	40	41	42	43	44	45	46	47	48	49	50
1	S3s	S3s	S3s	S3s	S3s	N2s	S3s	S3s	S3s	S3s	N2s
2	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s
3	S2m	S2m	S2n	S2sn	S2m	S2m	S2n	S2n	S2n	S2n	S2m
4	S2m	S2m	S3o	S3o	S3o	S3o	S3o	S2n	S2n	S2n	S3o
5	S2m	S2m	S2n	S2sn	S2m	S2m	S2n	S2n	S2n	S2n	S2m
6	S3s	S3s	S3s	S3s	S3s	S3s	S3s	S3s	S3s	S3s	S3s
7	S3s	S3s	S3s	S3s	S3s	S3s	S3s	S3s	S3s	S3s	S3s
8	S2sn	S2sn	S2sn	S2n	S2n	S2sn	S2sn	S2sn	S2sn	S2sn	S2sn
9	S2m	S2m	S2n	S2n	S2m	S2m	S2n	S2n	S2n	S2n	S2m
10	S2r	S2r	S3o	S3o	S3o	S3o	S3o	S1	S1	S1	S3o
11	S3s	S3s	S3s	S3s	S3s	S3s	S3s	S3s	S3s	S3s	S3s
12	S3s	S3s	S3s	S3s	S3s	S3s	S3s	S3s	S3s	S3s	S3s
13	S3se	S3se	S3s	S3se	S3se	S3s	S3s	S3s	S3s	S3s	S3s
14	S2r	S2r	S2n	S2s	S2sn	S2m	S2n	S1	S1	S1	S2r
15	S2r	S2r	S3o	S3o	S3o	S3o	S3o	S1	S1	S1	S3o
16	S3s	S3s	S3s	S3s	S3s	S3s	S3s	S3s	S3s	S3s	S3s
17	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s
18	S2r	S2r	S2n	S2sn	S2m	S2m	S2n	S1	S1	S1	S2r
19	S1	S1	S2n	S2sn	S2n	S2n	S2n	S1	S1	S1	S1
20	S2sn	S2sn	S3o	S3o	S3o	S3o	S3o	S2sn	S2sn	S2sn	S3o
21	S3s	S3s	S3s	S3s	S3s	S3s	S3s	S3s	S3s	S3s	S3s
22	S3s	S3s	S3s	S3s	S3s	S3s	S3s	S3s	S3s	S3s	S3s
23	S2sn	S2sn	S2sn	S2sn	S2n	N2s	S2sn	S2sn	S2sn	S2sn	N2s
24	S2n	S2n	S2n	S2sn	S2n	S2n	S2n	S2n	S2n	S2n	S2n
25	S1	S1	S3o	S3o	S3o	S3o	S3o	S1	S1	S1	S3o
26	S1	S1	S1	S2r	S1	S1	S1	S1	S1	S1	S1
27	S2sn	S2sn	S2sn	S2n	S2sn	S2sn	S2sn	S2sn	S2sn	S2sn	S2sn
28	S1	S1	S1	S2r	S1	S1	S1	S1	S1	S1	S1
29	S2sn	S2sn	S2sn	S2n	S2n	S2sn	S2sn	S2n	S2n	S2n	S2sn

FACET	51	52	53	54	55	56	57	58	59	60	61
1	S3s	N2s	N2s	N2s	N2s	S1	S1	S1	S1	S1	S1
2	N2s	N2s	N2s	N2s	N2s	S3s	S3s	S3s	S3s	S3s	S3s
3	S2m	S2m	S2sn	S2m	S2n	S3o	S3o	S3o	S3o	S3o	S3o
4	S2m	S3o	S3o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o
5	S2m	S2m	S2s	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o
6	S3s	S3s	S3s	S3s	S3s	S1	S1	S1	S1	S1	S1
7	S3s	S3s	S3s	S3s	S3s	S1	S1	S1	S1	S1	S1
8	S2n	S2sn	S2n	S2sn	S2n	S3o	S3o	S3o	S3o	S3o	S3o
9	S2m	S2m	S2s	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o
10	S2r	S3o	S3o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o
11	S3s	S3s	S3s	S3s	S3s	S1	S1	S1	S1	S1	S1
12	S3s	S3s	S3s	S3s	S3s	S1	S1	S1	S1	S1	S1
13	S3s	S3s	S3s	S3se	S3s	S3o	S3o	S3o	S3o	S3o	S3o
14	S2r	S2r	S2s	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o
15	S2r	S3o	S3o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o
16	S3s	S3s	S3s	S3s	S3s	S1	S1	S1	S1	S1	S1
17	N2s	N2s	N2s	N2s	N2s	S2s	S2s	S2s	S2s	S2s	S2s
18	S2r	S2r	S2s	S2m	S2n	S3o	S3o	S3o	S3o	S3o	S3o
19	S1	S1	S2s	S2n	S2n	S3o	S3o	S3o	S3o	S3o	S3o
20	S2n	S3o	S3o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o
21	S3s	S3s	S3s	S3s	S3s	S1	S1	S1	S1	S1	S1
22	S3s	S3s	S3s	S3s	S3s	S1	S1	S1	S1	S1	S1
23	S2m	N2s	N2s	N2s	N2s	S3o	S3o	S3o	S3o	S3o	S3o
24	S2n	S2n	S2s	S2n	S2n	S3o	S3o	S3o	S3o	S3o	S3o
25	S1	S3o	S3o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o
26	S1	S1	S2s	S1	S1	N2f	N2f	N2f	N2f	N2f	N2f
27	S2sn	S2sn	S1	S2sn	S2sn	N2f	N2f	N2f	N2f	N2f	N2f
28	S1	S1	S2s	S1	S1	N2f	N2f	N2f	N2f	N2f	N2f
29	S2n	S2sn	S1	S2sn	S2sn	N2f	N2f	N2f	N2f	N2f	N2f

FACET	62	63	64	65	66	67	68	69	70	71	72
1	S1	S1	S1	S2s	S1	S1	S1	S1	S1	S3s	S3s
2	S3s	S3s	S3s	N2s	S3s	S3s	S3s	S3s	S3s	N2s	N2s
3	S3o	S3o	S3o	S1	S3o	S3o	S3o	S3o	S3o	S2n	S2n
4	N2o	N2o	N2o	S2o	N2o	N2o	N2o	N2o	N2o	S3o	S2o
5	N2o	N2o	N2o	S2o	N2o	N2o	N2o	N2o	N2o	S3o	S2o
6	S1	S1	S1	S2s	S1	S1	S1	S1	S1	S2sn	S2sn
7	S1	S1	S1	S2ms	S1	S1	S1	S1	S1	S2mn	S2mn
8	S3o	S3o	S3o	S1	S3o	S3o	S3o	S3o	S3o	S2n	S2n
9	N2o	N2o	N2o	S2o	N2o	N2o	N2o	N2o	N2o	S3o	S2o
10	N2o	N2o	N2o	S2o	N2o	N2o	N2o	N2o	N2o	S3o	S2o
11	S1	S1	S1	S2s	S1	S1	S1	S1	S1	S2n	S2n
12	S1	S1	S1	S2ms	S1	S1	S1	S1	S1	S2mn	S2mn
13	S3o	S3o	S3o	S1	S3o	S3o	S3o	S3o	S3o	S2n	S2n
14	N2o	N2o	N2o	S2o	N2o	N2o	N2o	N2o	N2o	S3o	S2os
15	N2o	N2o	N2o	S2o	N2o	N2o	N2o	N2o	N2o	S3o	S2os
16	S1	S1	S1	S1	S1	S1	S1	S1	S1	S2n	S2n
17	S2s	S2s	S2s	N2s	S2s	S2s	S2s	S2s	S2s	N2s	N2s
18	S3o	S3o	S3o	S1	S3o	S3o	S3o	S3o	S3o	S1	S1
19	S3o	S3o	S3o	S1	S3o	S3o	S3o	S3o	S3o	S1	S1
20	N2o	N2o	N2o	S2o	N2o	N2o	N2o	N2o	N2o	S3o	S2o
21	S1	S1	S1	S2s	S1	S1	S1	S1	S1	S2n	S2n
22	S1	S1	S1	S2ms	S1	S1	S1	S1	S1	S2mn	S2mn
23	S3o	S3o	S3o	S1	S3o	S3o	S3o	S3o	S3o	S3s	S3s
24	S3o	S3o	S3o	S1	S3o	S3o	S3o	S3o	S3o	S2n	S2n
25	N2o	N2o	N2o	S2o	N2o	N2o	N2o	N2o	N2o	S3o	S2os
26	N2f	N2f	N2f	S1	N2f	N2f	N2f	N2f	N2f	S1	S1
27	N2f	N2f	N2f	S2sf	N2f	N2f	N2f	N2f	N2f	S2n	S2sn
28	N2f	N2f	N2f	S1	N2f	N2f	N2f	N2f	N2f	S1	S1
29	N2f	N2f	N2f	S1	N2f	N2f	N2f	N2f	N2f	S2n	S2n

FACET	73	74	75	76	77	78	79	80	81	82	83
1	S3s	S2s	S3s	S3s	S3s	S3s	S2s	S3s	S3s	S2s	S2s
2	N2s	S3ms	N2s	N2s	N2s	N2s	S3s	N2s	N2s	N2s	N2s
3	S2n	S2o	S1	S1	S1	S1	S2o	S1	S2o	S2o	S2o
4	S2o	S3o	S2o	S2o	S2o	S2o	N2o	S2o	N2o	N2o	N2o
5	S2o	S3o	S2o	S2o	S2o	S2o	N2o	S2o	N2o	N2o	N2o
6	S3s	S1	S2s	S2s	S2s	S2s	S1	S3s	S1	S1	S1
7	S3m	S1	S2s	S2s	S2s	S2s	S1	S2s	S1	S1	S1
8	S2ms	S2o	S1	S1	S1	S1	S2o	S1	S2o	S2o	S2o
9	S2o	S3o	S2o	S2o	S2o	S2o	N2o	S2o	N2o	N2o	N2o
10	S2o	S3o	S2o	S2o	S2o	S2o	N2o	S2o	N2o	N2o	N2o
11	S2ms	S1	S2s	S2s	S2s	S2s	S1	S2s	S1	S1	S1
12	S2ms	S1	S2s	S2s	S2s	S2s	S1	S2s	S1	S1	S1
13	S2sn	S2o	S1	S1	S1	S1	S2o	S1	S2o	S2o	S2o
14	S2o	S3o	S2o	S2o	S2o	S2o	N2o	S2o	N2o	N2o	N2o
15	S2o	S3o	S2o	S2o	S2o	S2o	N2o	S2o	N2o	N2o	N2o
16	S2m	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
17	N2s	S2ms	S3s	S3s	S3s	S3s	S2s	S2s	S3s	S3s	S3s
18	S2m	S2o	S1	S1	S1	S1	S2o	S1	S2o	S2o	S2o
19	S1	S2o	S1	S1	S1	S1	S2o	S1	S2o	S2o	S2o
20	S2o	S3o	S2o	S2o	S2o	S2o	N2o	S2o	N2o	N2o	N2o
21	S2ms	S1	S2s	S2s	S2s	S2s	S1	S2s	S1	S1	S1
22	S2ms	S1	S2s	S2s	S2s	S2s	S1	S2s	S1	S1	S1
23	S3s	S2s	S2s	S2s	S2s	S2s	S2o	S2s	S2os	S2os	S2os
24	S2n	S2o	S1	S1	S1	S1	S2o	S1	S2o	S2o	S2o
25	S2o	S3o	S2o	S2o	S2o	S2o	N2o	S2o	N2o	N2o	N2o
26	S1	S2o	S1	S1	S1	S1	S3f	S1	S2o	S2o	S2o
27	S2sn	S2o	S2s	S2s	S2s	S2s	S3f	S2s	S2os	S2os	S2os
28	S1	S2o	S1	S1	S1	S1	S3f	S1	S2o	S2o	S2o
29	S2sn	S2o	S1	S1	S1	S1	S3f	S1	S2o	S2o	S2o

FACET	84	85	86	87	88	89	90	91	92	93	94
1	S3s	S2s	S2s	S2s	S2sn	S3s	S1	S3s	S2sn	S2cs	S2cs
2	N2s	N2s	N2s	S3ms	N2s	N2s	S3s	N2s	N2s	N2s	N2s
3	S1	S2o	S2o	S2o	S3o	S2tn	S3o	S2n	S2n	N2o	N2o
4	S2o	N2o	N2o	S3o	N2o	S3o	N2o	S2n	S1	N2o	N2o
5	S2o	N2o	N2o	S3o	N2o	S3o	N2o	S2n	S1	N2o	N2o
6	S2s	S2s	S2s	S1	S2sn	S3s	S1	S3s	S2n	S2cn	S2cn
7	S2s	S1	S1	S1	S2sn	S3s	S1	S2sn	S2n	S2cn	S2cn
8	S1	S2o	S2o	S2o	S3o	S2tn	S3o	S2n	S2n	N2o	N2o
9	S2o	N2o	N2o	S3o	N2o	S3o	N2o	S2n	S1	N2o	N2o
10	S2o	N2o	N2o	S3o	N2o	S3o	N2o	S2n	S1	N2o	N2o
11	S2s	S1	S1	S1	S2sn	S3s	S1	S2sn	S2n	S2cn	S2cn
12	S2s	S1	S1	S1	S2sn	S3s	S1	S2sn	S2n	S2cn	S2cn
13	S1	S2o	S2o	S2o	S3o	S3se	S3o	S2sn	S2n	N2o	N2o
14	S2o	N2o	N2o	S3o	N2o	S3o	N2o	S2n	S1	N2o	N2o
15	S2o	N2o	N2o	S3o	N2o	S3o	N2o	S2n	S1	N2o	N2o
16	S1	S1	S1	S1	S2os	S3s	S1	S2sn	S2n	S2cn	S2cn
17	S3s	S3s	N2s	S2ms	N2s	N2s	S2s	N2s	N2s	N2s	N2s
18	S1	S2o	S2o	S2o	S3o	S2tn	S3o	S2n	S1	N2o	N2o
19	S1	S2o	S2o	S2o	S3o	S2tn	S3o	S2n	S1	N2o	N2o
20	S2o	N2o	N2o	S3o	N2o	S3o	N2o	S2n	S2n	N2o	N2o
21	S2s	S1	S1	S1	S2sn	S3s	S1	S2sn	S2n	S2cn	S2cn
22	S2s.	S1	S1	S1	S2sn	S3s	S1	S2sn	S2n	S2cn	S2cn
23	S2s	S2os	S2os	S2s	S3o	S3s	S3o	S3s	S2sn	N2o	N2o
24	S1	S2o	S2o	S2o	S3o	S2tn	S3o	S2n	S1	N2o	N2o
25	S2o	N2o	N2o	S3o	N2o	S3o	N2o	S2n	S1	N2o	N2o
26	S1	S2o	S2o	S2o	S3os	S2t	S3of	S1	S1	N2of	N2of
27	S2s	S2os	S2os	S2o	S3of	S3s	S3of	S2sn	S1	N2of	N2of
28	S1	S2o	S2o	S2o	S3os	S2t	S3of	S1	S1	N2of	N2of
29	S1	S2o	S2o	S2o	S3o	S2ts	S3of	S2sn	S1	N2of	N2of

FACET	95	96	97	98	99	100	101	102	103	104	105
1	S2sn	S2sn	S3c	S2cs	S3s	S3s	S2n	S2sn	S3s	S2s	S2sd
2	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s
3	S2n	N2o	N2o	N2o	S2on	N2o	S2o	N2o	S2or	S2o	N2o
4	S2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o
5	S2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o
6	S2sn	S2m	S3c	S2cn	S3s	S3s	S2sn	S2sn	S2sn	S2s	S2sd
7	S2sn	S2m	S3c	S2cn	S2sn	S2sn	S2n	S2sn	S2m	S2s	S2sd
8	S2sn	N2o	N2o	N2o	S2on	N2o	S2o	N2o	S2or	S2os	N2o
9	S2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o
10	S2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o
11	S2sn	S2m	S3c	S2cn	S2sn	S2sn	S2n	S2sn	S2m	S2s	S2sd
12	S2sn	S2m	S3c	S2cn	S2sn	S2sn	S2n	S2sn	S2m	S2s	S2sd
13	S2sn	N2o	N2o	N2o	S3e	N2o	S2o	N2o	S2oe	S2os	N2o
14	S2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o
15	S2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o
16	S1	S2n	S3c	S2cn	S2m	S2m	S2n	S2sn	S2m	S2s	S2od
17	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s
18	S1	N2o	N2o	N2o	S2o	N2o	S2o	N2o	S2or	S2o	N2o
19	S1	N2o	N2o	N2o	S2o	N2o	S2o	N2o	S2or	S2o	N2o
20	S2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o
21	S2sn	S2m	S3c	S2cn	S2sn	S2sn	S2n	S2sn	S2m	S2s	S2sd
22	S2sn	S2m	S3c	S2cn	S2sn	S2sn	S2n	S2sn	S2m	S2s	S2sd
23	S2sn	N2o	N2o	N2o	S3s	N2o	S2o	N2o	N2s	S2os	N2o
24	S1	N2o	N2o	N2o	S2o	N2o	S2o	N2o	S2o	S2o	N2o
25	S2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o
26	S1	N2of	N2of	N2of	S2o	N2of	S2o	N2of	S2o	S2o	N2of
27	S2s	N2of	N2of	N2of	S2os	N2of	S2os	N2of	S2o	S2o	N2of
28	S1	N2of	N2of	N2of	S2o	N2of	S2o	N2of	S2o	S2o	N2of
29	S2s	N2of	N2of	N2of	S2o	N2of	S2o	N2of	S2o	S2o	N2of

FACET	106	107	108	109	110	111	112	113	114	115	116
1	S3s	S3s	S3s	S3s	S3ts	S3s	S2s	S2c	N2s	N2s	N2s
2	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s
3	S2on	S2on	S2on	N2o	N2o	N2o	S2o	S3o	N2o	N2o	N2o
4	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o
5	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o
6	S3s	S3s	S3s	S3sn	S3t	S2cn	S2m	S2c	S3t	S3t	S3t
7	S2rn	S2sn	S2sn	S3sn	S3t	S2cn	S2m	S2c	S3t	S3t	S3t
8	S2on	S2on	S2on	N2o	N2o	N2o	S2o	S3o	N2o	N2o	N2o
9	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o
10	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o
11	S2rn	S2sn	S2sn	S3sn	S3t	S2cn	S2m	S2c	S3t	S3t	S3t
12	S2rn	S2sn	S2sn	S3sn	S3t	S2cn	S2m	S2c	S3t	S3t	S3t
13	S2on	S2o	S2o	N2o	N2o	N2o	S2o	S3o	N2o	N2o	N2o
14	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o
15	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o
16	S2rn	S2rn	S2rn	S3sn	S3t	S2oc	S2m	S2c	S3t	S3t	S3t
17	N2s	N2s	N2s	N2s	N2s	N2s	S3ms	S2c	N2s	N2s	N2s
18	S2o	S2o	S2o	N2o	N2o	N2o	S2o	S3o	N2o	N2o	N2o
19	S2o	S2o	S2o	N2o	N2o	N2o	S2o	S3o	N2o	N2o	N2o
20	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o
21	S2rn	S2sn	S2sn	S3sn	S3t	S2cn	S2m	S2c	S3t	S3t	S3t
22	S2rn	S2sn	S2sn	S3sn	S3t	S2cn	S2m	S2c	S3t	S3t	S3t
23	S3s	S3s	S3s	N2o	N2o	N2o	S2o	S3o	N2o	N2o	N2o
24	S2o	S2o	S2o	N2o	N2o	N2o	S2o	S3o	N2o	N2o	N2o
25	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o	N2o
26	S2o	S2o	S2o	N2of	N2of	N2of	S2o	S3of	N2o	N2o	N2o
27	S3s	S3s	S3s	N2of	N2of	N2of	S2o	S3of	N2o	N2o	N2o
28	S2o	S2o	S2o	N2of	N2of	N2of	S2o	S3of	N2o	N2o	N2o
29	S2o	S2o	S2o	N2of	N2of	N2of	S2o	S3of	N2o	N2o	N2o

FACET	117	118	119	120	121	122	123	124	125	126	127
1	S3s	S3s	S3s	S3t	S3s	S3tc	S3s	S2sn	S3s	S3s	N2s
2	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s
3	S3o	S3o	S3o	N2o	S2tn	S3tc	S2n	S2o	S2on	S2n	S2m
4	N2o	N2o	N2o	N2o	S2to	N2o	S2o	N2o	N2o	S2o	S3o
5	N2o	N2o	N2o	N2o	S2to	N2o	S2o	N2o	N2o	S2o	S2m
6	S3s	S2tc	S2ts	S3t	S2tm	S3tc	S2sn	S2sn	S3s	S2sn	S3s
7	S2sn	S2tc	S2tn	S3t	S3m	S3tc	S2ms	S2sn	S2sn	S2n	S3s
8	S3o	S3o	S3o	N2o	S2tm	S3tc	S2sn	S2os	S2os	S2n	S2sn
9	N2o	N2o	N2o	N2o	S2to	N2o	S2o	N2o	N2o	S2o	S2m
10	N2o	N2o	N2o	N2o	S2to	N2o	S2o	N2o	N2o	S2o	S3o
11	S2sn	S2tc	S2tn	S3t	S2tm	S3tc	S2sn	S2sn	S2sn	S2n	S3s
12	S2sn	S2tc	S2tn	S3t	S3m	S3tc	S2sn	S2sn	S2sn	S2n	S3s
13	S3o	S3o	S3o	N2o	S2ts	S3tc	S2sn	S2os	S2os	S2n	S3s
14	N2o	N2o	N2o	N2o	S2to	N2o	S2o	N2o	N2o	S2o	S2m
15	N2o	N2o	N2o	N2o	S2to	N2o	S2o	N2o	N2o	S2o	S3o
16	S2on	S2tc	S2to	S3t	S2tm	S3tc	S1	S1	S1	S1	S3s
17	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s
18	S3o	S3o	S3o	N2o	S2tm	S3tc	S1	S2o	S2o	S1	S2m
19	S3o	S3o	S3o	N2o	S2t	S3tc	S1	S2o	S2o	S1	S2n
20	N2o	N2o	N2o	N2o	S2to	N2o	S2o	N2o	N2o	S2o	S3o
21	S2sn	S2tc	S2tn	S3t	S3m	S3tc	S2sn	S2sn	S2sn	S2n	S3s
22	S2sn	S2tc	S2tn	S3t	S3m	S3tc	S2sn	S2sn	S2sn	S2n	S3s
23	S3os	S3os	S3os	N2o	S3s	S3tc	S3s	S2o	S3s	S3s	N2s
24	S3o	S3o	S3o	N2o	S2t	S3tc	S1	S2o	S2o	S1	S2n
25	N2o	N2o	N2o	N2o	S2to	N2o	S2o	N2o	N2o	S2o	S3o
26	S3o	S3o	S3o	N2o	S2t	S3tc	S1	S2o	S2o	S1	S1
27	S3o	S3o	S3o	N2o	S3s	S3tc	S2s	S3os	S3s	S1	S2sn
28	S3o	S3o	S3o	N2o	S2t	S3tc	S1	S2o	S2o	S1	S1
29	S3o	S3o	S3o	N2o	S3s	S3tc	S2s	S3os	S3s	S1	S2sn

FACET	128	129	130	131	132	133	134	135	136	137	138
1	S3s	N2s	N2s	S3tc	S3s	S3s	N2m	S3s	S3s	S3s	S3s
2	N2s	N2s	N2s	N2s	N2s	N2s	N2ms	N2s	N2s	N2s	N2s
3	S2rn	S2tn	S2n	N2o	S2on	S2on	N2m	N2o	S2rn	S2os	N2o
4	S3o	S2to	N2o	N2o	N2o	N2o	S3m	N2o	S2on	N2o	N2o
5	S2rn	S2to	N2o	N2o	N2o	N2o	S3m	N2o	S2o	N2o	N2o
6	S3s	S3s	S3s	S3tc	S3s	S3s	N2ms	S2rn	S2sn	S2mn	S2sn
7	S3s	S3s	S3s	S3tc	S2sn	S2sn	N2m	S2rn	S2sn	S2mn	S2sn
8	S2sn	S2ts	S2n	N2o	S2os	S2on	N2m	N2o	S2sn	S2on	N2o
9	S2rn	S2to	N2o	N2o	N2o	N2o	S3m	N2o	S2o	N2o	N2o
10	S3o	S2to	N2o	N2o	N2o	N2o	S3m	N2o	S2o	N2o	N2o
11	S3s	S3s	S3s	S3tc	S2sn	S2sn	N2m	S2rn	S2sn	S2mn	S2sn
12	S3s	S3s	S3s	S3tc	S2sn	S2sn	N2m	S2rn	S2sn	S2mn	S2sn
13	S3s	S3s	S3s	N2o	S2os	S2os	N2m	N2o	S2sn	S2on	N2o
14	S2r	S2to	N2o	N2o	N2o	N2o	S3m	N2o	S2o	N2o	N2o
15	S3o	S2to	N2o	N2o	N2o	N2o	S3m	N2o	S2o	N2o	N2o
16	S3s	S3s	S3s	S3tc	S2n	S2n	N2m	S2rn	S2rn	S2mn	S2n
17	N2s	N2s	N2s	N2s	N2s	N2s	N2ms	N2s	N2s	N2s	N2s
18	S2r	S2tn	S2n	N2o	S2on	S2on	N2m	N2o	S1	S2os	N2o
19	S2r	S2tn	S2n	N2o	S2on	S2on	N2m	N2o	S1	S2os	N2o
20	S3o	S2to	N2o	N2o	N2o	N2o	S3m	N2o	S2on	N2o	N2o
21	S3s	S3s	S3s	S3tc	S2sn	S2sn	N2m	S2rn	S2sn	S2mn	S2sn
22	S3s	S3s	S3s	S3tc	S2sn	S2sn	N2m	S2rn	S2sn	S2mn	S2sn
23	S2sn	N2s	N2s	N2o	S3s	S3s	N2m	N2o	S3s	S3s	N2o
24	S2n	S2tn	S2n	N2o	S2on	S2on	N2m	N2o	S2n	S2os	N2o
25	S3o	S2to	N2o	N2o	N2o	N2o	S3m	N2o	S2on	N2o	N2o
26	S1	S2t	S1	N2of	S2o	S2o	S3m	N2of	S1	S2os	N2of
27	S2sn	S2ts	S2sn	N2of	S3s	S3s	N2s	N2of	S2sn	S2on	N2of
28	S1	S2t	S1	N2of	S2o	S2o	S3m	N2of	S1	S2os	N2of
29	S2sn	S2ts	S2sn	N2of	S2os	S2os	N2s	N2of	S2sn	S2on	N2of

FACET	139	140	141	142	143	144	145	146	147	148	149
1	S2s	S3s	S3s	S3s	S3s	S2sn	S2n	S2sn	S2sn	S3s	S3s
2	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s
3	S2n	S2on	N2o	S2on	S2n	S2o	S2o	S2n	N2o	N2o	N2o
4	S2o	N2o	N2o	N2o	S3o	N2o	N2o	S3o	N2o	N2o	N2o
5	S2o	N2o	N2o	N2o	S2n	N2o	N2o	S2n	N2o	N2o	N2o
6	S2sn	S3s	S3s	S2sn	S3s	S2sn	S2sn	S2sn	S2sn	S2sn	S2tn
7	S2n	S2md	S2sn	S2sn	S2sn	S2n	S2n	S2n	S2ms	S2n	S2tn
8	S2n	S2on	N2o	S2on	S2sn	S2o	S2o	S2n	N2o	N2o	N2o
9	S2o	N2o	N2o	N2o	S2n	N2o	N2o	S2n	N2o	N2o	N2o
10	S2o	N2o	N2o	N2o	S3o	N2o	N2o	S3o	N2o	N2o	N2o
11	S2n	S2sd	S2sn	S2sn	S2sn	S2n	S2n	S2n	S2sn	S2n	S2tn
12	S2n	S2md	S2sn	S2sn	S2sn	S2n	S2n	S2n	S2ms	S2n	S2tn
13	S2n	S2on	N2o	S2on	S2sn	S2o	S2o	S2n	N2o	N2o	N2o
14	S2o	N2o	N2o	N2o	S1	N2o	N2o	S1	N2o	N2o	N2o
15	S2o	N2o	N2o	N2o	S3o	N2o	N2o	S3o	N2o	N2o	N2o
16	S2n	S2md	S2n	S2n	S2n	S2n	S2n	S2n	S2mn	S2on	S2to
17	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s	N2s
18	S1	S2on	N2o	S2o	S1	S2o	S2o	S1	N2o	N2o	N2o
19	S1	S2on	N2o	S2o	S1	S2o	S2o	S1	N2o	N2o	N2o
20	S2o	N2o	N2o	N2o	S3o	N2o	N2o	S3o	N2o	N2o	N2o
21	S2n	S2sd	S2sn	S2sn	S2sn	S2n	S2n	S2n	S2sn	S2n	S2tn
22	S2n	S2md	S2sn	S2sn	S2sn	S2n	S2n	S2n	S2ms	S2n	S2tn
23	S2n	S3s	N2o	S3s	S3s	S2os	S2o	S2sn	N2o	N2o	N2o
24	S1	S2on	N2o	S2on	S2n	S2o	S2o	S2n	N2o	N2o	N2o
25	S2o	N2o	N2o	N2o	S3o	N2o	N2o	S3o	N2o	N2o	N2o
26	S1	S2o	N2o	S3f	S1	S2o	S2o	S1	N2of	N2of	N2o
27	S2s	S3s	N2o	S3f	S2sn	S2os	S2os	S2sn	N2of	N2of	N2o
28	S1	S2o	N2o	S3f	S1	S2o	S2o	S1	N2of	N2of	N2o
29	S1	S2os	N2o	S3f	S2n	S2o	S2o	S2n	N2of	N2of	N2o

FACET	150	151	152	153	154
1	S2s	S3s	S3s	S2s	S3s
2	N2s	N2s	N2s	N2s	N2s
3	S2o	N2o	S2o	S1	S1
4	N2o	N2o	N2o	S2o	S2o
5	N2o	N2o	N2o	S2o	S2o
6	S1	S2tm	S1	S2s	S2s
7	S1	S2tm	S1	S2s	S2ms
8	S2o	N2o	S2o	S2s	S2s
9	N2o	N2o	N2o	S2o	S2o
10	N2o	N2o	N2o	S2o	S2o
11	S1	S2tm	S1	S2s	S2s
12	S1	S2tm	S1	S2s	S2ms
13	S2o	N2o	S2o	S2s	S2s
14	N2o	N2o	N2o	S2o	S2o
15	N2o	N2o	N2o	S2o	S2o
16	S1	S2tm	S1	S1	S2m
17	S3s	N2s	S3s	S3s	N2s
18	S2o	N2o	S2o	S1	S1
19	S2o	N2o	S2o	S1	S1
20	N2o	N2o	N2o	S2o	S2o
21	S1	S2tm	S1	S2s	S2s
22	S1	S2tm	S1	S2s	S2ms
23	S2o	N2o	S2s	S2s	S3s
24	S2o	N2o	S2o	S1	S1
25	N2o	N2o	N2o	S2o	S2o
26	S2o	N2o	S2o	S1	S1
27	S2os	N2o	S2os	S2s	S2s
28	S2o	N2o	S2o	S1	S1
29	S2o	N2o	S2o	S1	S1