An Introduction to the

Soils of Fiji

By David M. Leslie

SOIL AND CROP EVALUATION PROJECT 1997

AusAID

Soils of Fiji

The Soil and Crop Evaluation Project is a five year Project that has been jointly funded by Fiji, Australia, and New Zealand. The Project commenced in June 1993, with the overall objective to

"Contribute to a self-sufficiency in (Fiji, of) food crops, and an increase in export earnings by the definition and demonstration of crop nutrient requirements on the soils suitable for sustainable cropping systems in Fiji."

To achieve this overall objective, the Project had five Components, the objectives of which were:

1. To strengthen the capability of the Research Division to undertake appropriate farmer-oriented research

2. To provide the skills necessary for Research and Extension personnel to be better able to carry out their work

3. To undertake scientifically rigorous, high quality agronomic research which responds to the needs of farmers

4. To transfer appropriate technology from research to the farmer by the most appropriate means.

5. To direct and report on the Project to assure the achievement of the Project goals.

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Preface

When one stops to consider that Fiji is an agriculture based community it is little wonder that far sighted politicians and administrators chose soil as a key focal point of the Soil and Crop Evaluation Project in their efforts to improve productivity.

Perhaps for many, soil is something taken for granted, it is just there, either wet or dry, muddy or dusty. Fortunately more and more people are appreciating the immense complexity of even the most simple soils, developing an awareness of the incredibly complex range of chemical relationships within a soil, and its daunting range of physical characteristics. Attempting to understand how these interact with each other, and the bigger environment of not only weather, seasons, plants, animals, but also our man-made challenges is of profound importance for the sustainability of our agricultural economies.

Harnessing a knowledge of soils and matching it to the diversity of crops and land use is an exciting, and important challenge. I hope that the contents of this book will be challenging and exciting to future soil scientists, and enlightening to farmers. I also hope that the book will do much to inspire good soil management, and conservation practices. I feel sure that the synergy resulting, will flow on to bountiful crop yields and improved welfare for all concerned.

Bula vinaka

Kevin Dawes
First Secretary
Australian High Commission
SUVA

Acknowledgements

I am indebted, first and foremost, to AusAID through their bilateral assistance programme to Fiji for funding the publication of this book.

The book could not have been produced without the information collected during the NZODA funded national soil survey of Fiji conducted in the 1980s. Here I particularly wish to thank Vilitati Seru, friend and colleague, for his energy and experience during that assessment of Fiji's soil resources. Also, for the support provided to us by the laboratory staff at the Fiji Agricultural Chemistry Laboratory at Koronivia.

Throughout the preparation of the manuscript I have had the support and co-operation of Jai Kumar, Director of Research, MAFFA and have benefited from discussions, suggestions, and criticisms from Vilitati Seru, MAFFA, Simon Field, ACIL Australia Pty Ltd (previously SCEP Team Leader), and John Riches and Gerard Faber, SCEP project staff, Koronivia Research Station.

The graphics developed for the 45 representative soils involved new approaches and innovation in presenting the physical features of the soils. I am particularly grateful to Ruth Cairns for applying her graphic skills to this challenge and perseverance to achieve the end result.

I am most grateful of Megan Ogle-Mannering's reading through the manuscript, suggesting improvements, and for overall editing; Kirsty Wilson for excellent graphics, viz., Figs 1, 2, 3, 4, 9, 10, 11, 13, 15, 16, 17, 18; Lynn Forbes for Fig. 19; and to Greg Comfort, Manaaki Whenua Press, for general advice and liaison with the publishers.

And finally, to my wife, Margaret, who was responsible for all word-processing, the remaining figures and tables, and provided support and patience throughout the project. I owe her a very real debt of gratitude.

David Leslie

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Chapter 1: Introduction

Soil is one of Fiji's most important resources. Managed exploitation and sustainable production from the soil, now and into the future, will determine the nation's prosperity.

A knowledge of soil resources is a key element in planning rural development. Fiji is fortunate in having a modern comprehensive inventory of its soil resource. While this inventory can provide answers to questions asked by planners and decision-makers responsible for economic development, the information has been largely ignored by farmers, agricultural advisory officers, schools and technical colleges. This has been due to a lack of communication by the soil/ land use specialists responsible for generating the soil information, a poor understanding of the basic soil processes, difficulty with the technical language and soil classifications used, and other factors.

It is hoped that this book will improve communication between the specialists and the many users of soil information. The text has been written for students, but it will also be of use to agricultural advisory officers and farmers who wish to better understand and use the soil maps and reports that describe Fiji's soil resources.

The pages which follow contain basic information about the factors and processes that are important in soil formation, and information about the kinds of soil which occur in Fiji. The field and laboratory information collected and analysed during the national soil survey conducted during the 1980s (Leslie and Seru, 1997) provides understanding of how the soils have formed, how they will behave, and how they are classified.

This book explains the soils in a non-technical way. It also serves to alert readers to the value of Fijian soils, the need to protect and utilise them wisely, and the importance of continuing the established Melanesian traditions of conservation and sustainable land use.

To further the non-technical theme of the book, 45 representative soils, or 20% of the soil series recognised by Leslie and Seru (1997), are described in some detail (Appendix 1) with a key to their identification. This part of the book will hopefully serve as a useful introduction to the more technical reports that have now been published.

The Republic of Fiji is an enormous archipelago with diverse landscapes and climate. Contrasts between the wet and dry sides of the large islands, and between landscapes that reflect different rock types, and different erosion and depositional histories, are best appreciated from the air.

The archipelago, comprising over 840 islands, lies between 12 (Rotuma) and 22 (Ono-i-lau) degrees south and between longitude 175 east and 178 degrees west. The area included within these limits exceeds 650 000 km^2; but of this, 18 300 km^2; or less than 3%, is dry land. Islands vary in size from Viti Levu, the largest, which occupies 10 388 km^2 to small unnamed islets, some little more than rocks and sandy cays (motus). Vanua Levu, the second largest island, has an area of 5535 km^2; thus the area of the two main islands represents 87% of the total land area. About 105 islands are inhabited.

Fiji is the eastern outpost of the chain of high volcanic islands, of continental origin, that extends eastwards from New Guinea through the Solomon Islands and Vanuatu. Geologically, the islands of Fiji have formed from volcanic materials and sedimentary rocks, deposited towards the eastern margin of a massive oceanic plate or platform of great age. The Fiji landscape results from an intricate series of processes that constructed and shaped these rocks. These geological processes have operated over millions of years and are still active – earthquakes are not uncommon, and occur on active fault systems. In geological terms the extensive volcanic eruptions in Rotuma, Koro, and Taveuni Islands are youthful events, and raised limestone reef and alluvial terraces indicate crustal mobility.

Fiji lies within the tropical belt but towards the southern margin, at distances ranging from 1800 to 2500 kilometres from the equator. Although Fiji's climate is described as tropical it is not uniform across the islands due to the relief of the high islands and the impact of the easterly maritime airstream – known as the 'South East Trades'. This airstream predominates throughout 8 months of the year. Seasonally, climate ranges from hot and dry to warm and wet. From April to November – the period of the SE Trades – the windward lowland regions of the main islands experience cloudy conditions, frequent rain, a moderate amount of sunshine, and even temperatures. The leeward lowland regions are dry, with clear skies, a limited temperature range, and abundant sunshine (Fig. 1). The smaller and low relief islands generally have a climate that approximates that of the leeward or dry regions. Mean monthly temperature ranges from 23°C in July and August to 27°C in January; humidity from 75% during winter to 88% in summer.

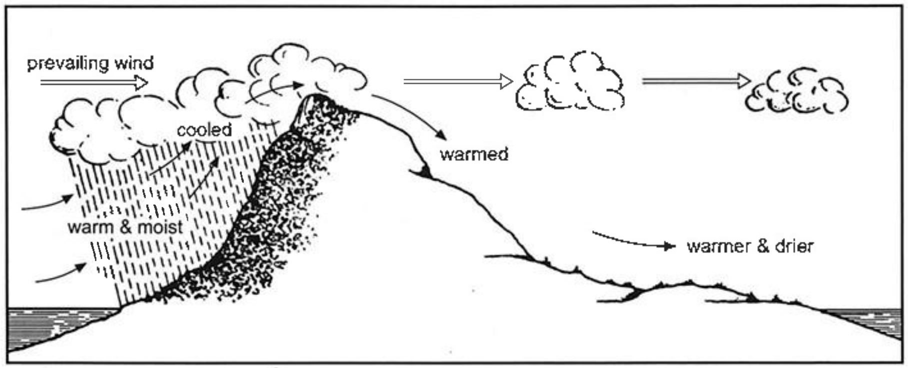


Fig. 1 Wet and dry zones result from the south east trade winds

Fiji at one time was virtually covered with forest. The present plant cover forms a complex mosaic comprising fernland, open grassland, reed grass, shrubland, a savannah-like transitional vegetation, and tall forest. It is largely human-induced. The broad categories of vegetation for Viti Levu and Vanua Levu are shown in Figs 2 and 3.

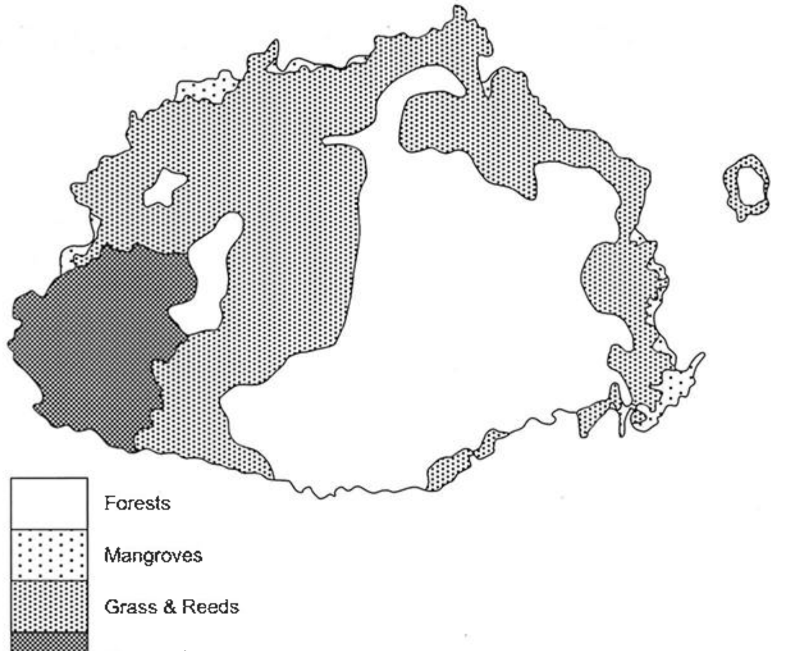
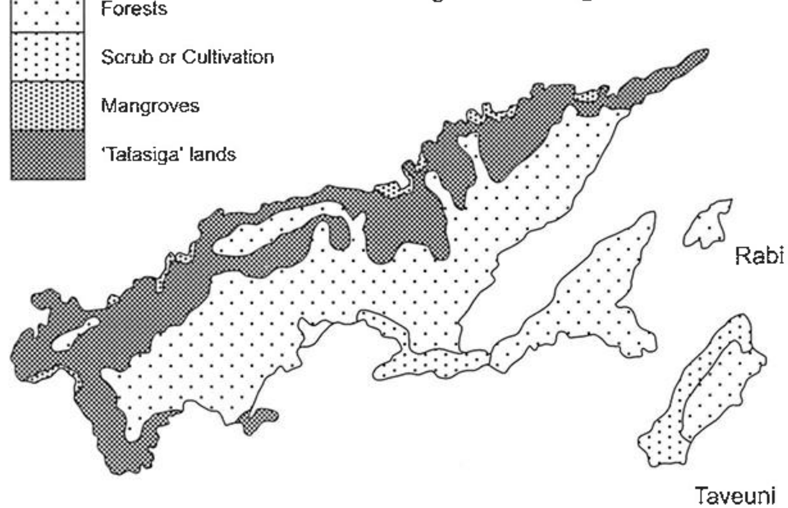


Fig. 2 Natural vegetation: Vitu Levu

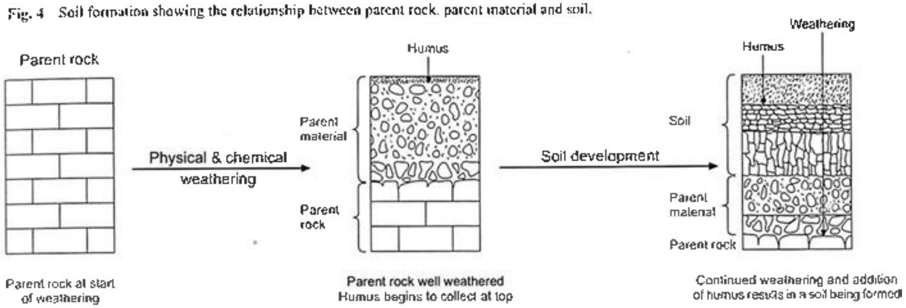
Fig. 3 Natural vegetation: Vanua Levu



2.1 How Soils Form

The raw material or rock from which a soil is made is called the ***bed rock***. Many ***soil-forming processes*** and ***soil-forming factors*** help to turn this bed rock into a soil. When a rock becomes 'rotten' or ***weathered*** the top layer turns firstly into a softer material, known as ***parent material***, in which small plants can take root. As the weathering goes on, more and bigger plants take root and the soft material becomes darker as ***organic matter*** or ***humus*** (material from the breakdown of dead leaves, etc.) builds up. Once this dark layer can be seen, even if it is quite thin, we have a soil. The residues from these weathering and decomposition soil processes and the newly formed materials combine to form the whole soil body with ***peds*** (soil structural aggregates/shapes) making up the soil profile (Fig. 4).

Fig. 4 Soil formation showing the relationship between parent rock, parent material and soil.



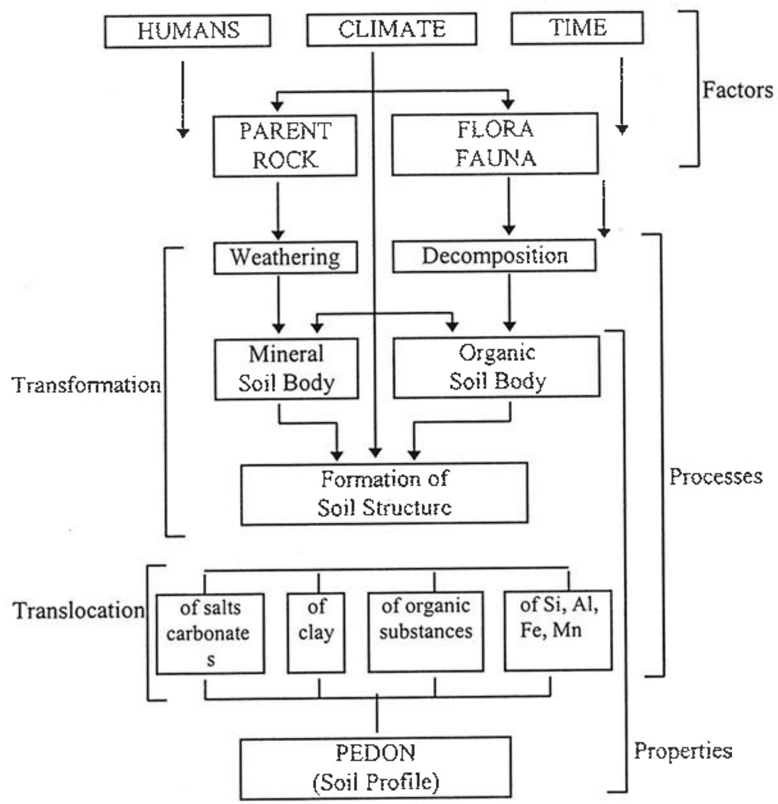
This section describes how various factors operate during soil formation and development to produce a range of soil types with specific (or diagnostic) properties.

The observable properties in the horizons of the soil profile can be measured and described in a standard way. These properties allow us to imagine the processes which took place in the history of soil formation and the factors which influenced the process type(s) and their rate of activity.

The formation and development of soils (***pedogenesis***) includes the operation of soil-forming ***processes***, which are determined by ***environmental factors***, resulting in the ***properties*** of the mature soil. The properties are exhibited in the ***soil profile*** which is characteristic of the ***soil type*** (Fig. 5).

FACTORS ⇔ PROCESSES ⇔ PROPERTIES

Fig. 5 Relationships between factors - processes - properties

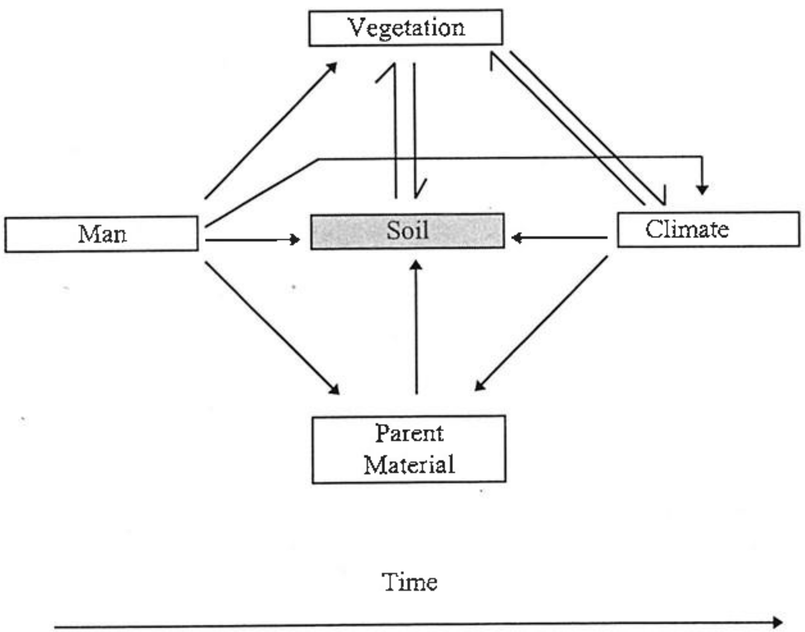


2.2 Soil-forming Factors

The most important soil-forming factors (Fig. 6) are:

- parent material
- climate
- relief (or topography)
- organisms, including human activity
- time

Figure 6 - Factors affecting soil formation



(i) **Parent material**

Soils can develop from weathering rock, but many are formed from materials that have been ***transported*** and ***deposited*** by the natural forces of ***water***, ***wind,*** and ***gravity***. Whether rock or deposited materials, the parent material provides the starting point for soil formation and development. The general distribution of different types of soil parent material in Fiji is quite complex.

- **Bedrock parent materials:** A large proportion of soil parent material is bedrock. The mineral composition and ***grain size*** (e.g., silt, sand) of the bedrock largely controls the type of soil that is formed. A simplified classification of bedrock parent material, based on ***silica*** content is presented in Fig. 7. ***Siliceous*** (acidic) parent materials (rhyolite, granite, quartz-rich tuffs) are relatively high in silica, while more basic parent materials (basalts, gabbros) are low in silica but high in ***ferromagnesium*** minerals. Under comparable weathering conditions the silica/ferromagnesium distribution of the parent material determines the rate at which the parent material weathers. A silica rich mineral assemblage is highly resistant to weathering with resistance decreasing proportionately to an increase in ferromagnesium content.

  The ferromagnesium minerals have large amounts of ***bases*** and materials available for clay formation and so the resulting soils are usually clayey and fertile. In contrast, the more siliceous parent materials are low in bases and clay-forming minerals, and soils formed from them have low clay content and low fertility.

  The composition of sedimentary rocks varies widely, depending on the composition of the parent rocks from which they were derived and the amount of weathering that has occurred. Hence soils derived from these vary widely. Sandstones tend to be siliceous while limestones and calcareous ***tuffs*** and ***marls*** are intermediate to basic.

Fig. 7 Parent material classification

	Igneous Rocks	Sedimentary Rocks	Silicious Content	Ferro-Magnesium Content	
SILICEOUS	Quartzite	Sandstones			
	Granite/ Rhyolite		>65%	<20%	Decreasing
	Dacite				↓ resistance
INTERMEDIATE			55-65%	20-40%	↓
	Andesite/ Diorite	Limestones and calcareous tuffs and marls			to ↓
			45-55%	>40%	weathering
	Basalt/ Gabbro				
BASIC					

Note: The term 'siliceous' is an equivalent word to "acidic"

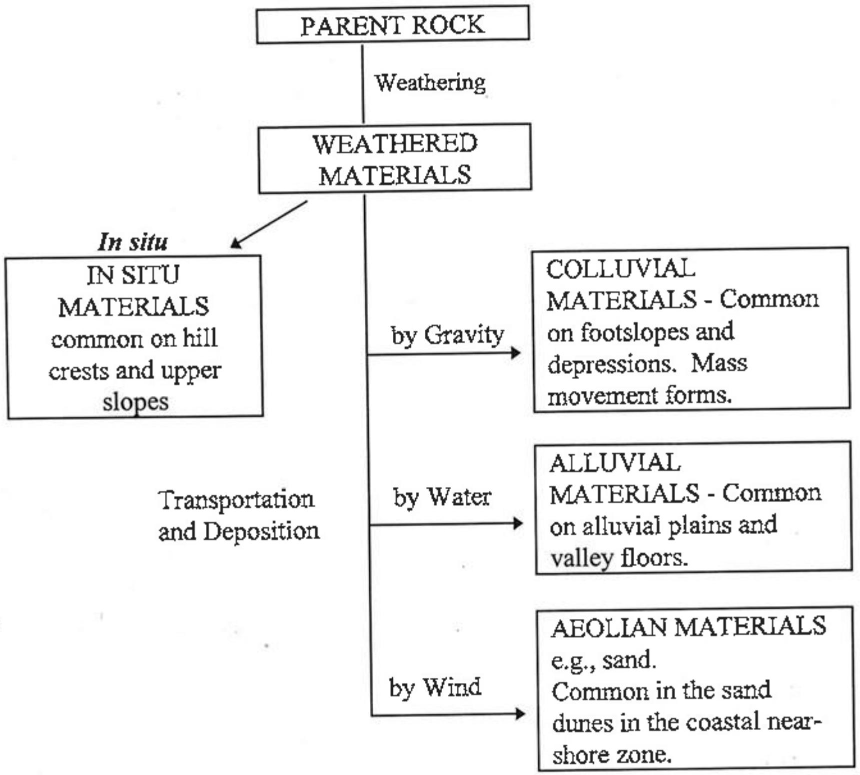
- **Transported parent materials:** Where soil parent material is not bedrock, it is mineral material that has been transported and deposited. The agents which transport materials in the Fiji environment are summarised in Fig. 8 and include gravity (***colluvial*** materials), water (***alluvial*** materials), and wind (***aeolian*** materials). The grain size and mineral composition of these transported materials greatly influence the type of soil formed on them. The distribution of these transported parent materials is governed by geological and landscape modifying processes (e.g., erosion) and history of an area.

Colluvium are deposits that accumulate on and at the base of hill slopes as a result of downslope movements (e.g., by soil creep) often triggered by excessive water in the soil profile. The movement of the colluvial deposits can be slow and semi-continuous or they may happen as a rapid major event (e.g., as an ***earthflow***, ***slump***). Soil profiles developed in colluvium may show signs (layering, including buried soils) of periodic phases of deposition (see ***Nasou*** series) and contain angular stones indicating they have moved only short distances (see ***Yaqara*** series).

Alluvium consists of layered sediments of different sizes deposited by rivers and streams. The size of the different sediments varies greatly – from large stones and boulders to fine silts and clays – depending on the size of the waterway, volume of water, and flood frequency. The coarse materials are rounded, indicating water transport of great distance (see ***Saliadrau***, ***Rewa*** and ***Sigatoka*** series).

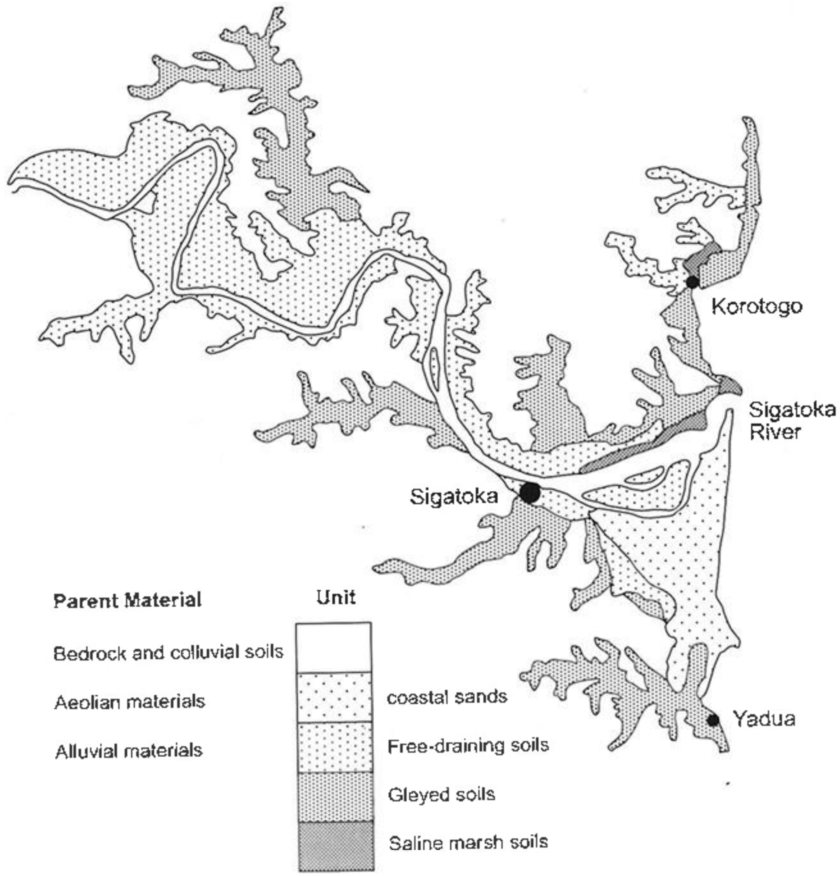
Aeolian materials consist of deposits arranged or transported by the wind. Narrow deposits of ***wind-blown sand*** occur at many locations on most islands. They are mainly from coralline sands and therefore are found adjacent to the coast (see ***Yasawa*** series). There are very small areas of black metallic sands (see ***Dawasamu*** soils). West of and adjacent to the mouth of the Sigatoka River a large area of alternating sandhills (up to 15 m in height) and sand plains has developed (see ***Volivoli*** series).

Fig. 8 Origin of parent materials



Tephra is ***airfall material*** that is ejected from volcanoes, into the atmosphere and then re-deposited across the landscape. Layers of tephra are common only on the 'young' volcanic islands of Rotuma, Taveuni (see ***Waiqere*** series) and part of Koro. These transport processes may bring quite different parent materials to lie side by side in the landscape (Fig. 9).

Fig. 9 Generalised soil landscapes - Sigatoka District, showing the effects of parent materials on soil distribution



The range of soil forming parent materials in Fiji is wide and includes:

- Siliceous
  Acid volcanic rocks; granitised rocks; siltstones, sandstones and silicified sedimentary rocks, as represented by ***Koronivia*, *Lutu*,** and ***Dogotuki*** series.

- Intermediate
  Older crystalline limestones; younger coral limestones; marls and calcareous mudstones; andesites, as represented by ***Momi*, *Samabula*,** and ***Dobuilevu*** series.

- Basic
  Basalts and other basic volcanic rocks; young andesitic and basaltic volcanic ash, as represented by ***Tavua*, *Waiqere*,** and ***Taveuni*** series.

- Colluvial, alluvial, aeolian and ***littoral*** soils derived from each of the above.

Many of the soil-forming parent materials cover only a small land area with some widely dispersed throughout Fiji and others more widespread, outcropping only to a limited extent. The two major groups of soil-forming parent materials are:

- the tuffaceous sedimentary rocks that occupy 36% of the landscape, and
- basic volcanic rocks that occupy 48% of the landscape.

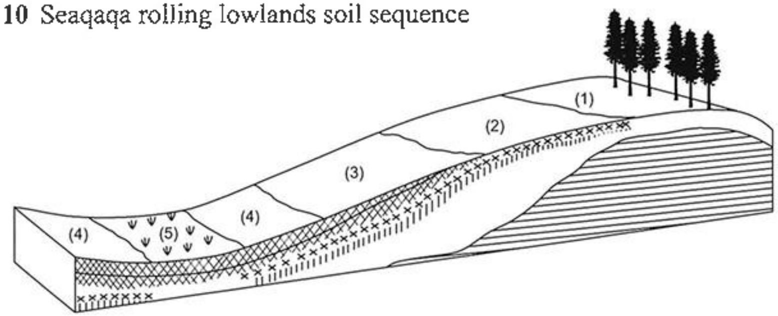
(ii) Climate

Climate is a key soil-forming factor. As well as the direct influence of rainfall and temperature on soil formation, climate will of course affect vegetation (organisms) and combine with the landscape (relief) in influencing soil-water relationships. Rainfall is also responsible for the 'washing out' (***leaching***) of key mineral elements and the movement of clay from surface soil horizons to accumulate lower down in the soil profile. The drier the climate, the less water is available for these soil processes to operate. The 'speed' of weathering slows as temperature decreases (e.g., with increase in altitude) but the rate of organic matter (humus) accumulation, and activity of ***soil biota*** (worms, insects, etc.) increases.

(iii) Relief

The shape of the land (its ***topography***) and, in particular, its ***slope*** or ***steepness*** can have a major influence (Fig. 10). They affect the amount of water available for weathering, 'leaching out' of nutrients from surface soil horizons and other chemical and biological changes. Free draining, often shallow soils occur in hill crests and backslopes but on lower slopes and in depressions water accumulates and we find transported soil materials (***colluvium***) and deeper soils. The amount of water, soil nutrients, clay, etc. that accumulates at any site is dependent on the volume of water moving into the soil profile and out again. Land shape, slope, and soil ***permeability*** in turn determine the volumes and pace of soil water movement.

Fig. 10 Seaqaqa rolling lowlands soil sequence



Soil Series (1) Korovou (2) Batiri (3) Naduri (4) Tabia (5) Natua

Legend Oxic horizon; Argillic horizon; Cambic horizon; Regolith; In situ andesite

(iv) Biological Factors

Biological, including human, activities are perhaps the most complex of the soil-forming factors. Together with climatic elements, organisms have been a major influence on weathering. They can determine the type of soil occurring at a specific site, in particular, changes in the surface soil horizons.

Plants affect soils in a number of ways. They protect the top layer of the soil against erosion. Their roots go into the soil and make many small channels down which water can get into the deeper layers. At the same time plants shade the soil from the sun's heat and stop the water from evaporating back into the atmosphere too quickly. Their dead leaves, twigs, and roots, etc. which we call ***plant litter***, break down and add ***organic matter*** and nutrients to the soil. These greatly alter soil structure and improve the soil's general condition, allowing more vigorous plant growth. Plants influence soil acidity, particularly in the surface soil horizon, by removing nutrients and changing the soil water content.

Soils are affected by the ***animals*** that live in them (such as earthworms and beetles) as well as those that live on them (such as chickens). Animals within the soil speed up the breakdown of dead plant matter and mix it with the rest of the soil. Animals living on top of the soil affect it in other ways; for example, chickens mix it up by scratching in it but also help to make the soil richer by returning droppings to it.

The very smallest of living things in a soil are the ***micro-organisms***. They cannot be seen by eye, but they also help in the breakdown of dead plants and animals. They help to change dead things into ***organic matter*** and then into foods or ***nutrients*** that living plants can use again.

Humans affect soils directly through cultivation and indirectly by new plantings or vegetation removal. If the soil is cultivated for crops changes occur. For example, deep cultivation mixes up the top and lower horizons of the profile. This usually, but not always, has good results. When a soil has been cultivated for a long time it may become quite different in colour texture, etc. Clearance of the vegetative cover can cause erosion by exposing the soil surface to the climatic elements. Draining and irrigating soils can also either slow or speed up soil formation. So drainage of poorly drained land, conservation farming techniques, irrigation and addition of nutrients and organic matter can increase soil productivity and stability. Manuring (organic and mineral fertilisers) also changes the soil by content for plant growth and micro-organism activity.

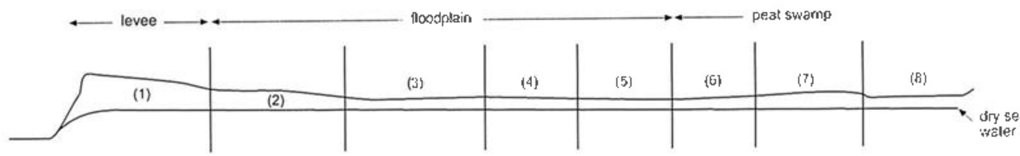
(v) Time

The final factor to describe is ***time***. The soil type is influenced by the amount of time over which the soil-forming processes have been acting.

Time is important to all of the soil-forming processes. The amount by which a soil has developed or changed depends on how long the soil forming processes have been acting. Weathering and soil development do not happen suddenly, but gradually and over great periods of time. However, factors other than time, such as climate, influence the speed of soil development.

In Fiji, soils vary in age from several thousand years to less than a hundred. Soils of different ages in Fiji are best represented in the alluvial systems where they commonly occur close to each other. Rewa, Tokotoko, and Melimeli series occur together on the Rewa alluvial surface (Fig. 11). Older soils (see ***Koronivia*** series) are generally redder in colour with advanced horizon development.

Fig. 11 Rewa delta alluvial sequence



Soil Series: (1) Toga (2) Rewa (3) Navua (4) Tokotoko (5) Nausori (6) Waitovu (7) Melimeli (8) Waidamu

Soil parent materials are modified over time by various processes acting together to produce soils whose properties exhibit the results of these (Fig. 12). These processes include:

Fig. 12 Water as a factor in soil development

Action of Water

Drainage (percolation)	**Ascent (evaporation)**	**Run-off (erosion)**	**Impeded Drainage (stagnation)**
Movement of • soluble salts • carbonates • clay • humus • oxides	Concentration of salts, carbonates	• Erosion • Colluvial deposition	• Reduction and oxidation processes • Humus accumula-tion

3.1 Movement of Water through the Soil Profile

In all areas of Fiji at some period of the year, water having fallen as rain will move down through the soil profile and may leach out with it any soluble materials present in the soil. This process is associated with:

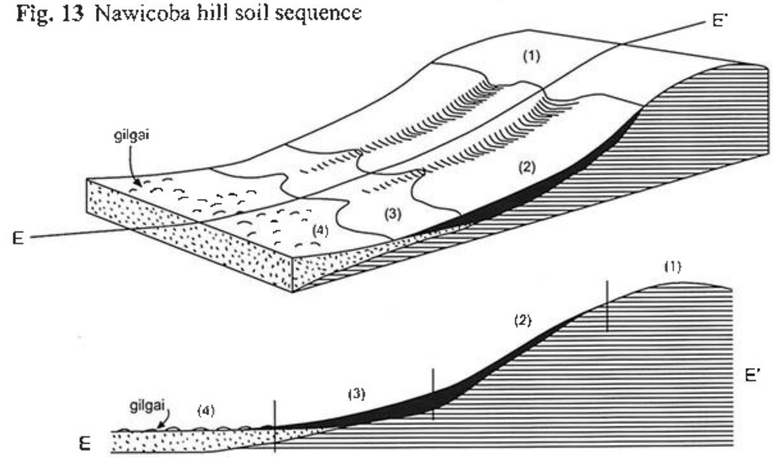
- ***Leaching*** of the more soluble ***ions*** such as calcium, magnesium, sodium, nitrate, and sulphate in water draining from the base of the soil profile.

- Clay movement (***translocation***). Solid materials can also be moved downwards through the soil profile. The movement is termed ***clay eluviation*** and the deposition of the suspended clay particles is referred to as ***clay illuviation***. Often the accumulation forms a clay enriched subsurface horizon termed a ***Bt horizon*** (see ***Koronivia, Nukudamu*** series).

- Movement and accumulation of organic matter (***humus***); silicon compounds and iron or aluminium minerals.

The rate and extent to which such processes happen is governed by the ratio of ***rainfall*** to ***evaporation*** and by ***soil permeability***. For example, highly permeable soils, such as sands (see ***Yasawa, Dawasamu, Volivoli*** series) will be more readily leached by a given quantity of water than impermeable soils. The pace of these processes will also be influenced by ***relief*** and landscape position. The combination of ***leaching*** and ***weathering*** has marked effects on the sequence of soil profile development. Weathering products and clays tend to be moved from the free draining soils upslope, to the less well drained soils downslope (Fig. 13). Overall the amount of solid particles, humus and leached elements is governed by the amount of water moving in and out of the soil profile.

Fig. 13 Nawicoba hill soil sequence



Soil Series (1) Olo (2) Dakadaka (3) Emuri (4) Nika

Legend In situ andesite ■ Colluvium Alluvium

3.2 Soil Drainage

The height of the water table or impeded drainage, and the period of time soils are wet or waterlogged dramatically affect colour. Freely-drained soils, that are wet for only short periods, tend to have yellow-brown to reddish-brown subsoil (see ***Rewa*** series). Red is generally associated with oxidised iron. Many wet soils are only saturated for a few months and these commonly have yellow and grey background colours and mottled red, orange, white or grey – a feature of poorly drained subsoils (see ***Tokotoko, Deuba*** series).

Very poorly drained soils which are wet for most of the time – the truly ***gleyed*** soils – have background colours dominated by grey olive/blue-green. Iron has been totally removed from these soils (see ***Toguru*** series).

Segregation of iron and manganese can also occur in soils which experience alternating short periods of waterlogging followed by longer periods of drying. When saturated, there is a shortage of oxygen (***anaerobic*** conditions), and iron and manganese become reduced and mobile. As the soil dries, these elements are deposited as nodules or as coatings on to peds. Where the process is more intense a hard, narrow cemented layer(s), referred to as an iron pan (a Bfm horizon), develops; often there are several pans included in the soil profile and the weathered parent material (see ***Namosau*** series).

3.3 Weathering

Weathering of bedrock and release of ***primary minerals*** (potential plant nutrients) is an ongoing soil process. It leads to the formation of secondary minerals such as clays and oxides. Some primary minerals resistant to weathering, such as quartz, can stay in soil unaltered. The assemblage of secondary minerals formed in soils is governed by the products available from weathering and the degree of weathering and leaching.

- ***Weakly weathered***: a high content of ***bases*** and ***montmorillonite***-like clays (see ***Emuri*** series).
- ***Moderately weathered***: a relatively low content of bases; aluminium and silicon dominant and kaolinitic-like clays (see ***Sote*** series).
- ***Strongly weathered***: few bases; relatively low silicon content; aluminium or iron oxides dominant (see ***Namosau*** series).

3.4 Accumulation of Soil Components

- In some soils ***calcium carbonate*** accumulates at depth in the soil profile (a Bk horizon). This occurs where there is a 'dry' climate and leaching is weak. Therefore, the soluble compounds of soils are not removed from the soil profile. Any calcareous materials will accumulate at the depth to which water penetrates and the soil here will be dominated by calcium (sometimes also magnesium) ions.
- In other soils the parent material may have high natural levels of calcium carbonate, for example, limestone (including reef limestone) calcareous marls, and base-rich rocks (basalts). With these parent materials calcareous soils form, even in wet zones but, with leaching over time, the calcium carbonate will ultimately be lost from the soil (see ***Cikobia, Samabula*** series).
- ***Gypsum*** accumulates when calcium and sulphate reach high concentrations in the soil (see ***Soso*** series).
- The accumulation of salts (***salinisation***) common in arid regions such as parts of Australia, for example, is not common in the free-draining soils in Fiji. However, soluble salts do accumulate in the soils of the saline coastal marshes due to daily waterlogging by saline water originating from the sea (see ***Soso*** series).

3.5 Wetting and Drying

Seasonal wetting and drying is a crucial factor in those soils that shrink (in dry season) and swell (in wet season) with changes in moisture content. These soils invariably have a clay fraction dominated by montmorillonite and display unique micro-relief and profile features. These include surface hollows and mounds (gilgai), surface cracks (prismatic soil structure) and a 'self-mulching' surface soil horizon (see ***Emuri*** series).

3.6 Accumulation of Organic Matter

Biological soil-forming processes include:

- The accumulation of plant materials in various stages of decomposition at the surface under wet conditions forming a distinctive profile of peat (see ***Melimeli*** series).

- In well drained, nutrient rich soils, thorough mixing of humus with the surface mineral matter by earthworms and other organisms to form a dark-coloured Ah horizon (see ***Taveuni, Manuka*** series).

- Development of soil structure, channels and pores by plant roots, soil animal activity, and decomposing organic matter.

- Numerous other biological changes affecting nutrient cycling, particularly those involving nitrogen.

Chapter 4: What Does a Soil Look Like?

Over time the development of a soil results in the appearance of layers which we call ***horizons***. These horizons can easily be seen by looking at soil and ***parent material*** in a ditch, pit, or river or roadside cutting. The face exposed by such a cut is termed a ***soil profile***.

The soil profile extends from the ground surface down to the parent material. In 'older' soils that have been strongly weathered, the soil may be very deep with multiple horizons developed by soil-forming processes that have operated over a long period of time. In young soils, where there has been only a short time for weathering, the parent material may be close to the surface and the soil very thin.

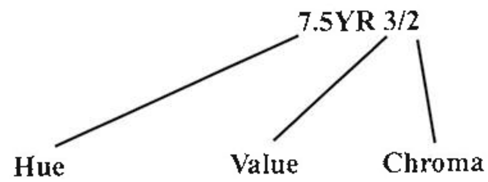
The soil surveyor who makes a soil map digs many small pits across the land to expose the soil profiles in different landscape positions and landforms. The parent material layers and horizons of each profile are then studied and compared (***correlated***) with those from other profiles.

When we study soil profiles we look at many properties in each horizon. The soil surveyor describes the soil's ***colour***, ***texture***, ***consistence***, and ***structure*** plus many other measurable features of the soil profile. The main soil morphological properties are described in more detail in the tables of Appendix 2.

Soil samples from selected profiles, representing the main soil groups, are also collected for physical and chemical analysis. The interpretation of the results of these analyses are used with field information to determine soil classifications, assess soil fertility and define land use options.

4.1 Soil Colour

Colour is the most obvious property of the soil. While not important itself, the colour of a soil tells us much about the conditions under which it has formed, as well as about the parent material and likely behaviour. For example, topsoils are dark coloured because of humus and, usually, the darker they are the more humus is present (see ***Manuka*** series). The amount of humus, in turn, depends on the climate and vegetation. Poorly drained soils tend to be pale yellow or grey, often with orange mottles (see ***Deuba*** series). Red in a well drained soil shows that the soil is old and weathered and probably rich in iron (see ***Bua*** series). Standard charts have been developed to determine soil colour (Munsells Color Company, 1975) which is written as a code combining ***hue*** (spectral colour normally in terms of red and yellow), ***value*** (dark and light) and ***chroma*** (intensity of colouration). For example:



Soil horizons can be mottled. ***Mottles*** are patches of colour different from the background or main colour of the horizon. They are most commonly associated with poorly drained soils (see ***Tokotoko*** series) which become seasonally wet, but are sometimes associated with weathering (see ***Tuva*** series).

4.2 Soil Texture

The **mineral** part of a soil (that is, the part that comes from rock and not from plants) results from the breaking down of the parent material. Texture is the feel of the soil, reflecting the proportion of sand, silt, and clay-sized particles, as well as the amount of organic matter mixed with them. A guide to assessing soil texture is given in Appendix 3. The texture is worked out in the field by rubbing the moist soil between finger and thumb. Sandy soils feel gritty, silts smooth, and most clays are sticky and plastic (i.e., they can easily be moulded into shapes when moist). Textures of Fiji soils, when measured in the field, are also influenced by organic matter, type of clay and degree of soil structural development. Textural classes and groups are shown diagrammatically in Appendix 4.

4.3 Soil Consistence

Soil consistence tells us how well the soil holds together, or how hard it is to break up and crush. If the soil is ***loose*** it will fall apart easily with little or no pressure. If a small amount of pressure is needed the soil is said to be ***friable***, while if a lot of pressure is needed it is ***firm*** or ***very firm***. A very firm soil will crush only under very strong pressure.

4.4 Soil Structure

The way in which soil mineral particles and organic matter are arranged and the spaces between them is called the ***soil structure.*** Lumps of particles are called ***peds*** or ***aggregates***. They are described by their size (fine, medium, or coarse), their shape (Table 1), and how strongly they are formed (weakly, moderately, or strongly).

Peds are important because spaces are left between them and within them. These spaces are necessary for root growth and for the movement of water and air in the soil. Unless a soil is well structured, crop yields will be low and erosion of the soil may occur. The structure of many soils can be damaged by over-cropping, excessive cultivation, or by the movement of, for example, tractors over the soil when it is too wet.

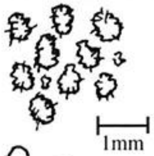
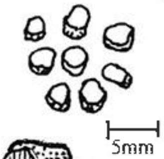
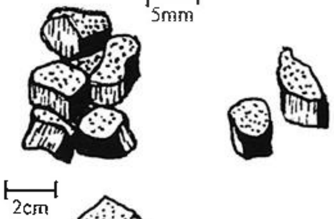
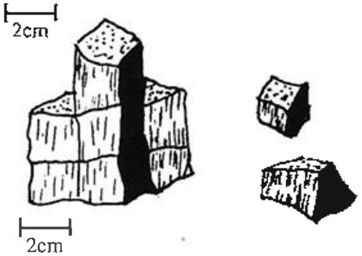
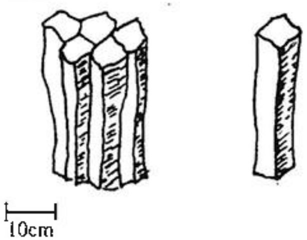
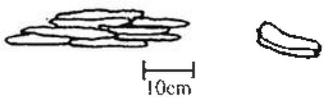
4.5 Other Profile Features

- ***Pans*** are hardened and/or cemented layers in the soil which present resistance to the spade when digging under normal conditions. Difference in moisture conditions do not affect the hardness of the pan. The most common type of pan is that caused by cementation due to iron oxides (see ***Namosau*** series). Pans usually have low permeability and commonly restrict root penetration.

- ***Concretions and segregations*** are obvious mineral accumulations in certain horizons and represent the concentration of calcium carbonate, gypsum, iron, or manganese. They vary in size, shape, colour, and hardness. Segregations tend to be soft, and concretions hard.

- ***Coarse fragments*** are particles which are greater than 2 mm in diameter and bigger than sand, silt, or clay particles. Commonly they are angular rock fragments (see ***Yaqara*** series) or rounded gravels and boulders (see ***Yasawa*** series).

Table 1: Shape and properties of soil structure types (peds)

Shape	Structure	Properties		Typical soil illustrating structure
	Crumb	Like breadcrumbs. Up to 5 mm across. Porous.	Soak up water easily; roots penetrate easily and wrap around peds	Nadi or Cikobia
	Granular	Like breadcrumbs but more rounded and non-fitting. Up to 10 mm across.	“	Navai
	Nut	Like small nuts - block-like but with a mixture of flattened and rounded faces. Peds fit less closely; up to 5 mm across.	“	Sote
	Blocky	Block-like with sharpish edges. Can be any size. Peds fit very closely together.	“	Tavua
	Prismatic	Standing like columns flattened at top; vertical dimension of peds much greater than horizontal dimension. Can be any size. Peds fit together.	Water and roots penetrate more slowly down cracks between peds.	Nika
	Platy	Layered like plates where horizontal dimension of peds far greater than vertical dimension. Can be any size. Peds fit together.	Impedes water and root penetration.	Dobuilevu

Chapter 5: The Soil Profile and its Description

5.1 Introduction

Following the discussion of soil properties given in the previous section, we are now able to describe a soil profile in more technical detail. For instance, a simple profile description of ***Cikobia*** soil series (Appendix 1) would focus on three distinguishing features – 22 cm of dark reddish-brown clay overlying 75 cm of red clayey material with boulders, overlying an unknown depth of hard white rock. By making a series of further detailed observations (such as colour, texture, structure, presence or absence of mottles, concretions, coarse fragments, organic or clay coatings) throughout the profile we are able to separate out a number of horizons and give each a distinct notation, using the letters and numbers defined below. For ***Cikobia*** series these are A, Bw1, Bw2, R.

5.2 Horizon Notations

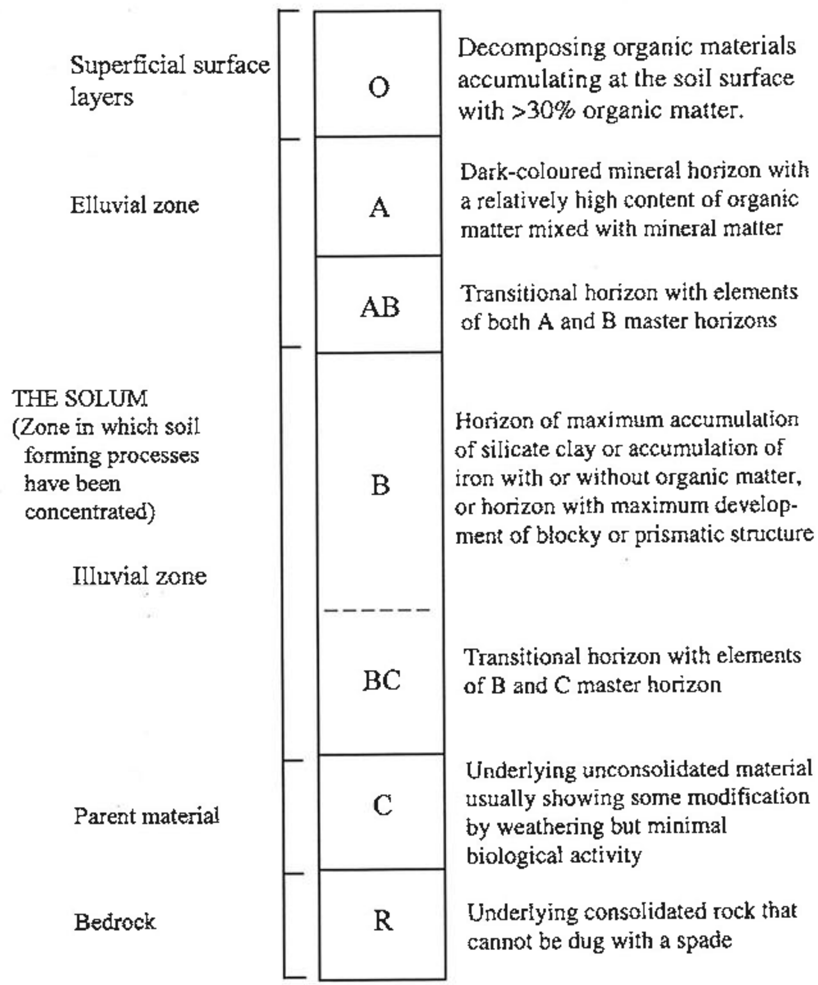
Horizon notation is a scheme of symbols used for labelling soil horizons. The type and sequence of horizons is one of the key features used in comparing and classifying soils. The different types of soil horizons are identified by notations that indicate the relationships between horizons within the soil profile (Fig. 14).

There are accepted procedures for assigning horizon designations. Capital letters are used to designate master horizons; lower-case letters are used as suffixes to show specific characteristics of the master horizon and as prefixes to show buried horizons; Arabic numerals are used not only as suffixes to indicate vertical subdivisions within a horizon but also as prefixes to separate different layers of materials or recognise boundaries that represent erosion intervals.

5.3 Organic Horizons

O Decomposing organic materials accumulating at the soil surface with >30% organic matter. Horizon accumulates under wet conditions and

Fig. 14 The soil profile and its master horizons



is saturated with water for at least 30 consecutive days in most years.

Of O horizon consisting mainly of well preserved plant remains that are readily identifiable (botanically). Fibre content is at least 75% by volume.

Om O horizon that consists mainly of partially decomposed plant remains (semi-fibrous peat) and does not meet the requirements of either Of or Oh.

Oh O horizon that consists of strongly decomposed organic material (humified peat) with few or no identifiable plant remains. The fibre content is less than 15%.

5.4 Master Mineral Horizons

A Mineral horizon formed at the surface, or below an organic horizon that either:

- has humified organic matter that has been incorporated by biological activity or by mixing through cultivation, or
- has a morphology acquired by soil formation but doesn't have the properties of an E or B horizon.

Usually recognised by its dark colour.

E A subsurface mineral horizon underlying the O or A horizon that contains less organic matter, clay, iron, aluminium, and manganese compounds than the horizon immediately below. This is the result of downward movement of organic matter, clay, iron, aluminium, and manganese compounds. Usually recognised by pale colour, lower organic matter content, and coarser texture (often sandy).

B Subsurface mineral horizon without rock structure or sedimentary fabric of the parent material, these having been destroyed by soil forming processes. Underlies an A or E horizon and overlies a C or R horizon, and is usually redder or yellower in colour, or more clayey and strongly structured than the C horizon.

B horizons are characterised by one or more of the following:

- illuvial accumulation of clay, iron, aluminium, or organic matter, alone or in combination
- cementation and/or concretions
- mottled colour patterns
- coatings on ped surfaces.

There are many types of B horizons and their properties are one of the main features used in classifying soils. Each type of B horizon is distinguished by a letter suffix describing the main features.

C Unconsolidated or weakly consolidated mineral horizon with sedimentary or relict rock fabric that is little affected by soil forming processes and lacks properties of the overlying A, E, or B horizons. Usually partly chemically weathered but retains the fabric of the parent material.

R Hard consolidated bed rock that cannot be dug with a spade. The rock may contain a few small cracks but insignificant for root development. Usually underlies the B or C horizon.

Sometimes soil horizons have the features of two master horizons and this is indicated by letter combinations (e.g., AB, BC).

The following lower case letter suffixes are used to indicate the key characteristics of the master horizon:

c accumulation (>5% by volume) in concretionary form, usually used with another letter which indicates the nature of the concretionary material (e.g., Bcs for iron concretions in the B horizon) g gleyed horizon with mottled colour patterns reflecting variations in oxidation and reduction (e.g., Bg, Cg)

h accumulation of organic material in A or B horizons; not used where there is evidence of ploughing or tillage (see "p")

j straw-coloured jarosite present

k accumulation of secondary carbonate

m strongly cemented horizon which resists root penetration. Usually used in combination to indicate the cementing material (e.g., Cmk for a C horizon cemented by carbonate)

p horizon disturbed by ploughing or tillage, normally in the A horizon (e.g., Ap)

r dominantly greyish colours resulting from removal of iron due to prolonged water logging (e.g., Cr)

s accumulation of iron and/or aluminium, normally in B horizons, marked by bright yellow brown subsoil colours (e.g., Bms designates an iron pan)

t accumulation of clay (normally in the B horizon) washed down from horizons above and clay coatings on ped surfaces (e.g., Bt)

w B horizon that shows some alteration in place as reflected by clay content, colour, and structure (e.g., Bw)

y accumulation of gypsum (e.g., Cy)

The following lower case prefix:

b to denote a buried soil horizon (e.g., bAh for an A horizon buried by more recent sediment).

5.5 Soil Profile Description

Soil profile descriptions are a key part of the field data set collected during a soil survey. These data are collected in a standard format that can be entered into a computerised soil data base and used for soil correlation, soil classification and soil interpretation. The descriptions together with other field information form the basis of site characterisation, essential for evaluating land for specified purposes.

The soil description field record includes information associated with land-related features such as location, climate, other soil-forming factors, and other physical characteristics – all recorded systematically. Morphological and related properties, such as soil colour, texture, structure, consistence, root space and soil horizon boundaries are fully described as part of the field record.

The full soil profile description records the measurable morphological features for each horizon recognised within the profile. A typical description follows the format given in Table 2. Traditionally morphological data is presented in the following order for each horizon: depth (cm); colour (both in words and colour code); texture; consistence; structure (grade, class and type); mottles, concretions, coatings, etc. (if present); roots (abundance, size); and the nature of boundary to the next horizon.

Table 2 : Soil profile description of Matavelo clay (see Appendix 1)

Ap (0–20 cm)	Yellowish-brown (10YR 5/4) clay; friable, slightly sticky; weakly developed coarse blocky structure; many coarse reddish-yellow (7.5YR 6/8) mottles; common black (10YR 2/1) manganese nodules; many fine fibrous roots; diffuse boundary,
Ag (20–35 cm)	Dark brown (10YR 3/3) clay; firm, slightly sticky, weakly developed coarse nut structure; common fine reddish-yellow (7.5YR 5/6) mottles; few fine fibrous roots; diffuse boundary,
Bg1 (35–60 cm)	Very dark greyish brown (10YR 3/2) clay, very firm; slightly sticky; slightly plastic; strongly developed coarse blocky (tending prismatic when dry) structure; common small distinct reddish-yellow (7.5YR 6/8) mottles; few fine fibrous roots; diffuse boundary,
Bg2 (60–120 cm+)	Yellow (10YR 5/8) silty clay; very firm, very plastic; massive; common medium distinct grey (2.5YR 7/0) mottles.

6.1 Introduction

It is easy to classify a house, boat, chicken, or fish by placing it in a category of a classification system. These are distinct objects with well defined limits. Classifying soils is more difficult. While soil forms a near-continuous mantle (***continuum***) over the surface of the landscape with gradually changing soil properties, it cannot be studied as a single body. To classify a soil, one has to identify the ***individual soil unit*** that is to be classified. By defining the individual, we focus on a particular part of the continuum, and in doing this we recognise that particular properties of a soil individual can vary but within certain limits. Systematic subdivision of the soil continuum using soil classification systems enables soil surveyors to describe soils, suggest their potential for use and predict their response to management. In soil classification systems, soils are recognised by their properties and identified by names of *classes*. These names enable communication about soil properties and predictions about their behaviour when managed or used in particular ways. Thus, soil classification provides a tool for transferring land use experience and results of agricultural research.

6.2 Why Classify?

Classification is the grouping of things according to their similarities and differences. It summarises information and helps with communication between people. Soil classification is useful because it helps us to:

- ***Organise*** knowledge about soils and think more clearly and efficiently about them.
- ***Understand*** relationships between different soils, and between soils and the environment in which they have formed. Through understanding these relationships, we can see why certain soils are similar, and why others are different.
- ***Remember*** the main properties of the soils being classified.
- ***Learn*** new relationships between soils within the same class and between soils in different classes.
- ***Use*** classification to make interpretations for land use and establish groups of soils which we can use for practical applications, for example, estimating soil productivity.

6.3 Twyford and Wright (1965) Classification System

The comprehensive and well-used soil classification system developed by Twyford and Wright for ordering the Fijian soil assemblage is a ***genetic system***. In their scheme the main trends in soil development with climatic, vegetation and other environmental factors were considered and compared with the appearance and development of various morphological features of the soil profile. They emphasised the regular repetition of key soil features whenever a certain combination of environmental factors occurred. Twyford and Wright showed that the majority of soils had a ***zonal impress*** which could be correlated with environmental factors. The zonal arrangement is based on the ***'normal'*** site concept where factors such as relief and water table do not influence soil development, thus allowing differences in soil pattern due to other factors (climate, vegetation) to be clearly distinguished. This approach in effect attempted to classify soils keeping certain factors constant. The soils on such 'normal' sites were called zonal since they occurred in a clear zonal pattern.

Soils displaying no apparent change in profile appearance – little or no zonal impress – throughout the country's environmental range are restricted to the regularly flooded marine marshes and peat swamps.

The arrangement of soils used by Twyford and Wright has proven most valuable for demonstrating and helping to understand soil relationships. Their classification makes an initial separation between soils subjected to the very strong weathering environment of the hot, humid lowlands and foothills and the less strong weathering environment of the cooler and wetter uplands (land above about 600 m altitude).

Apart from very steep unstable soils, alluvial and gley soils, the soils of the uplands show the effects of a strong zonal impress. They are very acid, strongly leached and weathered. This is not always the situation with the soils of the lowlands and foothills, where some soils display only weak zonal impress.

Weakest zonal impress is shown in recent soils developed from coastal sand and river alluvium. These are 'young' soils where the time factor in soil development has been short. Gley soils where the water table influences development also show only weak zonal impress. Two other major groups of soils in the classification that show only a weak or moderate zonal impress are the black soils (***Nigrescent***) developed from parent materials rich in lime and magnesium, and a group of soils developed on 'young' volcanic materials (***Latosolic soils***). The remaining soils reflect strongly the impress of the local environment where they occur on land of easy relief, and less so where they occur as unstable soils on steep slopes. To clearly identify the site stability factor Twyford and Wright separated soils formed on steepland (slopes >0°) from those on hilly and flat land and gave them different names.

The classification further recognises and subdivides on the basis of the nature of the parent material, for example, in the case of coastal sand and alluvium, the division is between quartz-rich and quartz-poor parent materials; and for soils developed directly from volcanic and sedimentary rocks, it is the acidic or basic nature of the weathered products that is important.

Soils with strong zonal impress are classified mainly on the climatic regime under which they developed, as this is the primary factor, and only afterwards by their parent materials.

Gley soils are classified in relation to the zonal group from which their parent material was derived.

These are the broad principles on which Twyford and Wright classified the soils of Fiji.

The ***nomenclature*** (names) used in the classification of Fijian soils with some zonal impress reflects the American thinking on classification in the 1950s. Six of the names used (gley, recent, latosolic, humic latosols, red-yellow podzolic, ferruginous latosols) were established. However, Twyford and Wright created a seventh name – Nigrescent – to describe the predominantly black or very dark grey soils of high base status. These represent a unique soil group that are not normal under the strong weathering regimes in the humid tropics.

The classified list of Fijian soils after Twyford and Wright (1965) is presented in Appendix 5. Only soil series that have been retained in the modern soil survey of Leslie and Seru (1977) are listed.

Twyford and Wright's classification is a local one and is different from taxonomic systems that have been increasingly used since 1970. While this does not affect the utility of the local classification it does present certain limitations on the ability of Fiji agricultural scientists, foresters, and other users of soil information to fully assimilate and correlate with overseas literature that commonly classifies soils according to international soil classification systems, i.e., FAO/UNESCO, Soil Taxonomy.

6.4 Food and Agriculture Organisation (FAO) Classification

The soil classification used in the FAO/UNESCO system (FAO, 1974) is designed to produce soil maps at a scale of 1:5000 000. The classification has used many concepts of Soil Taxonomy. The 45 soils described in Appendix 1 are fully classified according to Twyford and Wright, FAO, and Soil Taxonomy.

The FAO/UNESCO system is a hybrid system incorporating certain aspects of genetic soil systems but also including certain features of 'key-out' systems. The system is hierarchal but it has only two category levels, and this imposes severe limitations in soil mapping at scales of less than 1:100 000.

6.5 Soil Map Units

Soil classification endeavours to group soils and diagnostic features of soils into logical groups such that general statements and predictions about these groups (classes) can be made.

Soil individuals can also be grouped on a landscape basis where soils that are similar (soil series, soil family) are included in a unit of land that can be delineated on the soil map. These are known as ***mapping units***. Mapping units and soil classes are not the same thing. ***Soil classes*** are taxonomic units whose definitions and limits are well defined using specific soil attributes. Mapping units delineate units of the landscape that ideally will contain a single taxonomic unit, or the map boundaries are located such that a soil contained within the delineation is as homogeneous as possible. In general the broader the scale of mapping, the more complex map units become, and several soil classes may be defined within the map unit.

6.6 Soil Series

The ***soil series*** is a group of soils having soil horizons similar in differentiating characteristics and arrangement in the soil profile, and developed from a particular type of parent material.

Soil series are differentiated mainly on the basis of significant variations in the morphological features of the soil profile. These features include mainly the kind, thickness, and arrangement of horizons, and their structure, colour, texture (except texture of the A horizon), reaction (pH value), consistence, content of carbonates and other salts, content of humus, and mineralogical composition.

The soil series consists of a group of soils that are essentially uniform below normal depth of ploughing (about 15 cm) in differentiating features and arrangement of diagnostic horizons or in the properties of defined zones in the soil profile. Greater variability is allowed in the nature of the surface horizons than in the deeper horizons because the former is in the plough zone and therefore readily subject to change.

The successful application of a soil survey depends upon the quality of the surveys including the accuracy and completeness of the soil series descriptions.

6.7 Soil Legends

In reading the soil map the names of soils are shown by symbols or numbers. The soil name and main characteristics are identified using the soil legends.

For the modern soil survey of Fiji there are two legends:

(i) A ***physiographic legend*** that gives the soil name, position of the soil in the landscape, the parent material from which the soil is formed, and the drainage class. For example,

SOILS OF THE PLATEAUX
– from rocks of basic and intermediate composition

(a) Plateaux surfaces
    Well drained
        Nasegai soils
        Namosau soils
        Bua soils
        Vunicibicibi soils
        Korokadi soils

(b) Slope margins of dissected plateaux
    Well drained
        Ba soils

– from rocks of acid composition
    Plateaux surfaces
        Imperfectly drained
            Koronivia soils
            Lovonivia soils

The physiographic legend makes a primary 'split' between soils of the lowlands and foothills (isohyperthermic soil temperature regime) and uplands (isothermic).

(ii) A ***taxonomic legend*** gives the classification of soils according to Soil Taxonomy where the taxonomic name summarises the main features of the soil.

6.8 Soil Taxonomic Unit Descriptions

Soil Taxonomic Unit Descriptions (STUDs) have been prepared for each taxonomic unit recognised and named in the national soil survey (Leslie and Seru, 1997) and are used as the primary document for soil correlation and reference. A list of headings used in each STUD is given in Appendix 6.

Chapter 7: Soil Taxonomy

7.1 Introduction

In 1981 the then Fiji Ministry of Primary Industries (MPI) decided to adopt Soil Taxonomy (Soil Survey Staff, 1975) as the national system for soil classification. This decision recognised the world-wide acceptance of Soil Taxonomy and the need to maintain effective communication between Fiji and the rest of the world on soil matters. The national soil survey conducted between 1981 and 1985 (Leslie and Seru, 1997) classified soils according to Soil Taxonomy as the primary system, with soil series also correlated to Twyford and Wright (1965) and FAO/UNESCO (FAO, 1974). Table 3 provides a broad correlation between the primary soil groups of Twyford and Wright and the orders, suborders and great groups of Soil Taxonomy.

Soil Taxonomy evolved from a series of earlier classifications with the primary objective of providing a soil classification system for the making and interpreting of soil surveys to guide land planners and managers. It aims to achieve this objective by bringing out known relationships between properties of the soils being classified, giving emphasis to properties of agricultural importance. Some of the soil features used for classification in Soil Taxonomy are given in Table 4.

7.2 Principles used in Developing Soil Taxonomy

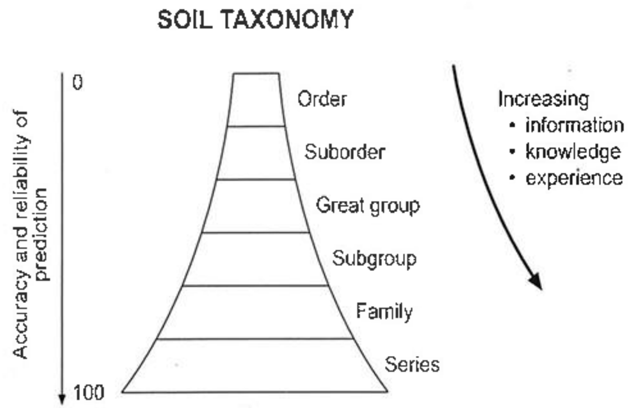
Several rules were used in developing Soil Taxonomy. These were:

- The definition of each class should carry as nearly as possible the same meaning to each user. The definitions are precise and, whenever possible, quantitative.

- The classification is multicategoric with the highest category having only a few classes, and with lower categories containing an increasing numbers of classes arranged in logical fashion. The highest category, the order, has only 10 classes while, at the lowest category, the family, there are several thousand. One need know only a few rules to understand the relationship of the lower categories to the higher. The multicategoric system enables more information to be included and more precise statements to be made at successively lower levels as soils become defined with increasing precision (Fig. 15).

- The classes are concepts of real soils that have been described and their properties analysed, rather than soils that might theoretically exist somewhere, but have never been described.

Fig. 15 Categories in Soil Taxonomy in relation to information, content and reliability of predictions of soil performance



Soil Taxonomy provides classes for all soils in the landscape. As noted previously soils occur as a continuum but we currently lack the knowledge to classify them as such. So we have to break the continuum into a realistic number of segments which have limited and defined ranges in properties. An example of this continuum is the gradational changes in soil drainage going away from the Toga waterway in the Rewa floodplain at Koronivia Research Station (Fig. 11). There are no sharp breaks in the drainage sequence, but to make general statements about the soils the continuum is divided into several *map units*. The main soil in each map unit has a specific *taxonomic name* because of different properties developed through differences in soil drainage.

Table 3 Broad correlation between Twyford & Wright and Soil Taxonomy classifications

Twyford & Wright: Primary Soil Groups	Soil Taxonomy: Order	Suborder	Possible Great Groups (Prefixes to Suborder)
Recent soils from coastal sands	Entisols Inceptisols	Psamment Tropept	Tropo Usti Quartzi Humi Eu
Recent soils from river alluvium	Entisols Inceptisols Mollisols	Aquent Tropept Aquept Udoll Aquoll Ustoll	Hydr Eu Dys Trop Hapl Hapl Hapl
Nigrescent soils	Inceptisols Mollisols Vertisols	Tropept Ustoll Udoll Ustert	Eu Us Hapl Hapl Argi Pale Hapl
Latosolic soils	Andisols Inceptisols	Udand Tropept	Melan Fulv Hapl Eu Humi
Humic latosols	Inceptisols Alfisols Ultisols	Tropept Udalf Humult	Eu Humi Trop Tropo Pale Kandi
Ferruginous latosols	Oxisols Inceptisols	Ustox Ustult Tropept	Acr Hapl Rhod Hapl Kandi Dys
Red-yellow podzolic soils	Ultisols Inceptisols	Humult Ustult Tropept	Tropo Hapl Kandi Dys
Gley soils	Inceptisols	Aquept Tropept	Trop Hydr Eu
Organic soils	Histosols	Fibrist	Tropo
Saline soils of the marine marsh	Entisols Inceptisols	Aquent Aquept	Sulf Trop Sulf

Table 4 Some soil features used for classification in Soil Taxonomy

1. **Soil Morphology**
   - Nature of soil boundaries
   - Soil structure
   - Depth to rock
   - Presence of pans
   - Presence of clay coatings
   - Seasonal cracking
   - Colour - matrix
     - mottles, etc.
   - Presence of Calcium Carbonate
   - Presence of rock structure
   - Presence of gypsum
   - Texture changes
   - Gilgai/slickensides
2. **Climate**
   - Moisture regime
   - Temperature regime
3. **Parent Material**
   - Volcanic ash
4. **Chemical Properties**
   - Base saturation
   - Exchange capacity of clay fraction
   - Organic matter content
   - Exchangeable sodium %
   - Extractable iron and aluminium
   - Salt content
5. **Physical Properties**
   - Particle size distribution
   - Bulk density
   - Shrink-swell potential

7.3 Diagnostic Horizons

One of the unique innovations in Soil Taxonomy is the diagnostic horizon where ***surface*** and ***subsurface*** diagnostic horizons were introduced. The surface horizons (or ***epipedons***) essentially represent the topsoil. The main criteria for separating epipedons are the ***organic matter content*** (often reflected in soil colour) and ***base saturation***, the latter being a measure of how leached the soil is. Soil Taxonomy identifies seven epipedons of which only six occur in Fiji (Table 5).

There are several diagnostic subsurface horizons defined in the classification but only four are widespread in Fiji. These are the argillic, cambic, kandic, and oxic horizons whose main properties are listed in Table 5.

7.4 Soil Moisture and Temperature Regimes

Climatic factors influence potential land uses and are important in understanding the environments in which Fiji soils have developed. The classification recognises soil moisture and soil temperature as key factors in differentiating soil classes.

(i) The ***soil moisture regime*** is important as it indicates the length of time that water is available to plants and, because water is involved in most of the chemical reactions in soils, the soil moisture regime indicates the leaching environment of the soil. Soil Taxonomy defines six soil moisture regimes and four of these are common in Fiji (Table 6). These are aquic, udic, perudic, and ustic. Fig. 16 shows soil moisture balances for contrasting areas of Viti Levu. Koronivia represents the perudic and Nadi Airport is typical of ustic areas, while Dobuilevu is typical of a site intermediate between these.

(ii) ***Soil temperature*** in part controls soil development because it determines rates of biological and chemical change in the soil, as well as influencing plant growth potential. There are ten soil temperature regimes defined in Soil Taxonomy covering soils from the equator to Antarctica. Two soil temperature regimes occur in Fiji. These are isothermic and isohyperthermic (Table 6).

Table 5 Diagnostic horizons used in Soil Taxonomy

Surface horizons (epipedons)	
Melanic	thick black; andic properties; >6% organic carbon
Mollic	thick dark coloured; base saturation >50%
Umbric	as for Mollic, but base saturation <50%
Histic	peaty, high organic matter
Anthropic	significantly modified by agricultural practices
Ochric	other surface horizons (light coloured, low organic matter)
Subsurface horizons	
Argillic	accumulation of clay due to illuviation
Cambic	altered from bedrock by changes in colour, texture, structure, presence of weatherable minerals
Kandic	clay content >horizon above, clays are of low acidity
Oxic	strongly weathered, low CEC, only iron and aluminium oxides, with kaolonitic mineralogy

Table 6 Soil moisture and temperature regimes of Soil Taxonomy

Moisture regimes	
Aquic	a reducing regime where the soil is saturated by ground water
Udic	humid climate where the soil is not dry (in any horizon) for as long as 90 days
Perudic	like Udic but rainfall >evapotranspiration in most years and water moves through the soil in all months
Ustic	limited moisture with a marked dry season (>3 months), some moisture available during growing season
Temperature regimes	
Isothermic	mean annual soil temperature range 15-22 °C, with the difference between winter and summer mean temperatures <5 °C
Isohyperthermic	Mean annual soil temperature range >22°C, with the difference between winter and summer mean temperatures <5 °C

7.5 Categories of Soil Taxonomy

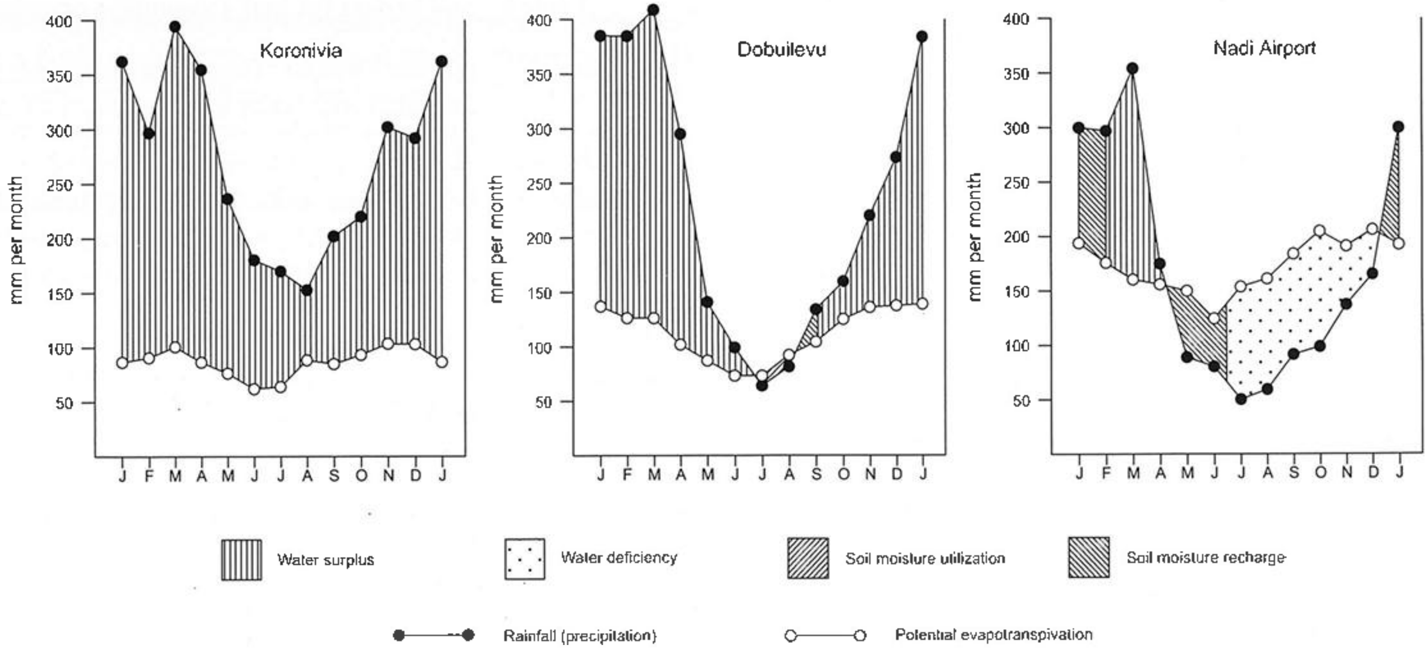
A group of soil individuals that form a class is called a ***taxon***. A taxon has the maximum number of properties or attributes in common. Because of these similarities we can make the greatest number of descriptive statements about a taxon. A category is a group of classes or ***taxa***, defined at about the same level of abstraction and including the whole population of soil individuals. Diagnostic surface and subsurface horizons, soil moisture and soil temperature regimes, and unique soil properties are all used to define categories and classes of Soil Taxonomy. There are six categories : order, suborder, great group, subgroup, family, series (Table 7). These categories serve specific purposes. The amount of detail that goes into the definition increases in the lower categories (Fig. 15).

(i) Eleven ***orders*** are described in Soil Taxonomy – nine are represented in Fiji (Table 8). These are the: Alfisols, Andisols, Entisols, Histosols, Inceptisols, Mollisols, Oxisols, Ultisols, and Vertisols. The order category provides a grouping of the soils based on common but important properties.

Alfisols have ***argillic*** (***translocated clay***) subsoil horizons that are moderate to high in bases and have an ***ochric*** surface horizon (see ***Tavua*** series). Base status is higher in Alfisols than in Ultisols. They are more weathered than Inceptisols and generally lower in organic matter than Mollisols. Alfisols occur in the udic and ustic soil moisture regimes of Fiji. They are less permeable than Inceptisols of comparable texture due to clay in the pores of the argillic subsurface horizon that restricts water movement.

Andisols are young soils that form from volcanic materials (ash, scoria, lava flows). Horizon development is poorly expressed. There is a high content of weatherable minerals throughout the profiles and generally Andisols have melanic or ochric surface horizons and a cambic subsurface horizon. Andisols have low bulk density with the exchange complex dominated by amorphous materials. The 'greasy' feel of these soils when moist relates to the allophane mineralogy. A feature important to soil fertility is that by definition Andisols must have phosphorous retention values >85%. As Andisols in Fiji are free draining, occur in the 'wet' zone, and have iso- soil temperature regimes (Table 6), they mostly classify as ***Udands*** at the suborder level. Those with very high organic carbon

Fig. 16 Soil moisture balances for contrasting areas of Viti Levu



values belong to Melanudands (see ***Vakawau*** series) and Fulvudands (see ***Manuka*** series). Those with lower organic carbon values are classified as Hapludands (see ***Waiqere*** series).

Entisols are the very young soils formed on recent coastal sands and alluvial deposits, unstable hill slopes, or soils whose rate of erosion is in equilibrium with soil development. They have little or no development of soil horizons.

Many Entisols in Fiji have an ochric diagnostic surface horizon; some are histic. They have a wide range of soil moisture and temperature regimes, texture, mineralogy, slope, vegetative cover, and landform. They may be excessively to very poorly drained. Little can be said about land use and management of Entisols at the order level. More can be said at lower categories; for example, ***Aquents*** are wet Entisols where periodic high water tables control use and management. ***Fluvents*** occur on floodplains and are associated with deposition of 'fresh' alluvium, while ***Psamments*** (see ***Yasawa*** series) develop in coastal sands and are highly permeable because of texture.

Histosols are organic or peaty soils (see ***Melimeli*** series) where little management of the water table is needed if used for water-tolerant crops such as rice. For water-sensitive crops, management of the water table is essential.

However, if the water table is lowered, too much subsidence may result, and if not lowered below the root zone, poor aeration will reduce crop growth.

Inceptisols have subsoils that are altered from the parent material by soil

Table 7 Categories of Soil Taxonomy

Orders	Presence or absence of diagnostic horizons or features : there are 10 orders.
Suborder	Properties that affect current processes of soil development, e.g., soil moisture and temperature regimes.
Great Groups	Dominant properties of the soil are defined. The whole soil is characterised, including the sequence of soil horizons.
Sub Groups	Used to indicate relationships between the central concepts (typic sub groups) of each great group and other, different great groups (intergrades). For example, Humoxic subgroups of Ultisols (e.g., Koronivia series) are intergrades to the suborder Humox.
Family	Groups of soils within a subgroup that have similar physical and chemical properties affecting their responses to use and management. Families are defined on the basis of: – particle size – mineralogy – soil temperature regime
Series	The lowest category. Values for separating properties of a series must be within the limits defined for the family. Series are given local names (e.g., Koronivia) indicating the geographical area in which they commonly occur.

Table 8 Soil orders (of Soil Taxonomy) present in Fiji

Histosols	(***Hist**os* - tissue). Organic or peaty soils that are saturated with water and contain >12% organic carbon.
Andisols	(***And**o* - dark soil). Young soils formed from volcanic parent materials, Andic properties (low bulk density, amorphous materials, high P retention).
Oxisols	(***Ox**ides* of iron and aluminium) strongly weathered, low CEC, dominated by oxides of iron and aluminium.
Vertisols	(***Vert**ical* cracks). Commonly clayey soils that swell when wet and shrink when dry, forming deep, wide vertical cracks. Clay fraction dominated by montmorillonite.
Ultisols	(***Ult**imate*). Strongly weathered and leached soils with an argillic (illuviated) horizon.
Mollisols	(***Mollis*** - soft). Dark coloured surface horizon, high in organic matter and bases. Weakly leached.
Alfisols	(Ped***alfer***- old soil name). Weak to moderately leached with an argillic (illuviated) horizon. Low organic matter in the topsoil.
Inceptisols	(In***cept***ion). Weakly altered from parent material by leaching and weathering.
Entisols	(Rec***ent***) Very young soils formed on recent alluvial deposits, unstable hill slopes, etc. They have little or no development of soil horizons.
Note:	Aridisols and Spodosols have not been identified in Fiji.

weathering. Change is indicated by chemical properties, colour, structure and texture, but is not significant and soils still have weatherable minerals. Inceptisols are roughly intermediate in weathering between Entisols and Alfisols. They cover a wide range of soil moisture and soil temperature regimes, landforms, and vegetation. They usually have loamy textures and mixed (see ***Saliadrau*** series), oxidic (see ***Lomaiviti*** series), and kaolinitic (see ***Sote*** series) mineralogies. The loamy textures and mineralogies enable them to be tilled quite easily. They respond well to N, P, K and may require applications of trace elements and lime in some areas. They usually have favourable available water capacities.

The key feature of ***Mollisols*** is the mollic surface horizon, which is dark coloured, high in organic matter and bases and friable. Mollisols occur in a wide range of soil moisture and soil temperature regimes, and vary widely in texture and mineralogy classes. They are well suited to rain-fed cropping (see ***Sigatoka*** series) but also often well suited to irrigated cropping. Mollisols are easy to manage because of deep and friable topsoils. Limitations to use can be physical properties of the subsurface horizon (see ***Samabula*** series) or moisture regime (see ***Narewa*** series).

Ultisols occur on older stable landscapes and are strongly weathered and leached soils with an argillic horizon. They usually have high extractable aluminium and are low in bases. They are more weathered and lower in bases than Alfisols, and less weathered and lower in bases than Oxisols. Soil moisture regimes may be aquic, udic, or ustic. Many Ultisols have slow permeability due to their high clay content and clay-filled pores in subsurface horizons (see ***Koronivia*** series).

Oxisols are very deeply weathered red or yellow soils where primary minerals have been totally transformed to kaolin, and iron and aluminium oxides. They lack distinct horizon boundaries, are well aggregated, and are more rapidly permeable than Alfisols, Mollisols, Ultisols and Vertisols. Oxisols have low productivity unless irrigated and both macro- and micro-nutrients are applied. Organic matter is critical in maintaining productivity in these soils (see ***Nadi, Namosau*** series).

Vertisols are clayey soils that swell when wet and shrink when dry; forming deep, wide, vertical cracks. They are high in organic matter and bases, but have slow permeability. The clay fraction is dominated by montmorillonite. Self-mulching and churning movement due to shrink-swell cycles are features of Vertisols and result in uneven ground surfaces (***gilgai***). Vertisols are difficult to till and have limited available moisture for some crops due to ***low porosity***. They respond well to application of the main plant nutrients but have severe limitations for engineering, urban or construction uses because of their high shrink-swell potential and low strength.

(ii) ***Suborders*** are generally defined on the basis of properties that affect the current processes of soil development. In most suborders, soil moisture and soil temperature regimes are the properties used.

(iii) ***Great groups*** identify a number of soil properties. The whole soil is characterised, including the arrangement of horizons and the number of any key accessory properties. Great groups contain sufficient information to allow some general statements about use of the soil.

(iv) The categories above the ***subgroup*** identify and focus on those processes that influence the direction and level of soil development. In addition, many soils have properties that are of lesser importance but are still important indicators of soil-forming processes.

Within any great group, a soil may show some indicators of soil processes that are dominant in other orders, suborders, or great groups. However, in the given great group these processes serve only to modify other, dominant processes.

By identifying these processes of lesser influence at the subgroup level we can show the relationships with other kinds of soils. Thus, there are three kinds of subgroups:

- the ***typic*** subgroup which defines the central concept of the great group;
- the ***intergrades***, which define the relationship to other orders,

suborders, or great groups. For example, Ultic subgroups are intergrades to the order of Ultisols;

- the ***extragrades***, which have properties not used in higher categories; for example, the lithic (hard bedrock with 50 cm of the soil surface) subgroup.

(v) In the ***family*** category, the intent has been to group within the subgroup, soils with similar physical and chemical properties that affect their responses to use and management.

(vi) The ***soil series*** is the lowest category. Properties that define the series cannot fall outside the limits established for the family.

7.6 Example of 'Keying Out' to Family Category

The ***Nadi series*** is used to demonstrate the sequence to follow when determining classification according to Soil Taxonomy from the order through categories to the soil family. In practice classification is done only when the results of laboratory analyses are available. Field soil profile features provide the guide to the specific analyses required.

Nadi series has an ***ochric epipedon*** and an ***oxic*** subsurface horizon and satisfies criteria for the ***oxisol order***. The soil occurs only within the ustic soil moisture regime and so classifies as an ***ustox*** at ***suborder*** level.

Base saturation is ≥35% in all horizons within 125 cm of the soil surface – this is a key attribute for ***Eutrustox great group***.

As Nadi series represents the central concept of the Eutrustox subgroup it classifies as ***Typic***.

At the ***family level*** three factors must be considered and are described. These are: particle size class, mineralogy, and soil temperature regime. The soil has a clayey particle-size class because there is ≥15% fine sand and between 18 and 35% clay. The mineralogy class is mixed. Formed in lowlands (i.e., <600 m altitude) Nadi series has an isohyperthermic soil temperature regime – the mean annual soil temperature is >22°C and the difference between mean summer and mean winter temperature values is <5°C (i.e., Iso-, see Table 6).

The complete classification for Nadi series to the family level thus reads as ***Typic Eutrustox, clayey, mixed, isohyperthermic***.

Chapter 8: Soil Surveys and Soil Maps

The Purpose of Soil Surveys

In general the purpose of ***soil surveys*** is to ***examine, classify, describe*** and ***map*** soils so that predictions can be made about their behaviour for different land uses and their response to various management practices. A soil survey is conducted for a defined area. This may be a nation, an island, a province, a research station, or a farmer's field. The kinds of soil in the survey area and their distribution (extent) is shown on a map(s) which is commonly accompanied by a report.

The Soil Survey Report contains information about the soil-forming factors; a description of methods used to conduct the soil survey; a detailed description of soil morphological, chemical, physical and mineralogical properties; descriptions of where each soil occurs in the landscape; descriptions of other relevant environmental features of profiles (e.g., landform position, drainage class, vegetation, etc.); and analytical data. Information on land use is often included. Thus, the Soil Survey Report provides a comprehensive description of soils shown on the soil map.

Soil surveys may be general purpose (multi purpose) or special purpose. The modern national soil survey of Fiji (Leslie and Seru, 1997) is a general purpose soil survey that mapped natural soil units in the landscape at a scale of 1 : 50 000. Soil mapping units were digitised and entered into a geographic information system (GIS) from which soil maps can be printed. The GIS also includes ***non-spatial*** soil, climate, and crop data bases that enables quantitative interpretations for crop suitabilities, and various land uses, to be made.

Special purpose soil surveys have specific targets and therefore a limited number of morphological properties are collected. Examples of special purpose surveys are – drainage of soil with high water tables (i.e., Navua floodplain) or suitability for irrigation for growing export crops (i.e., adjacent to Nadi airport) or evaluating soil type with tree growth performance (i.e., Lololo, Nadi, Nabou forests).

Soil survey involves the following steps:

- deciding which properties of the soil are important for the particular purpose;
- selecting categories for each soil morphological property relevant to the purpose of the survey;
- classifying soils into map units so that soil variation within map units is less than between units;
- locating and plotting the boundaries of these units on maps; and
- preparing maps and reports for publication.

Whatever the type of survey undertaken, the aim is make the classification and mapping units relevant to the purpose of the soil survey. A vast amount of information is gathered in a soil survey, but to be useful the survey should be able to predict at least some of the properties of soil at a site without having to visit it. The most useful classification systems are those with the ability to predict.

Chapter 9: General Soil Pattern of Fiji

Information about the soils of Fiji is available from the Land Use Section of Ministry of Agriculture, Forestry, and Fisheries (MAFF) at Koronivia Research Station. Maps showing the soil pattern can be reproduced through a geographic information system (GIS) at various map scales. The field mapping however, was conducted to produce a national soil map at the 1:50 000 scale. Detailed information for the specific soil series is found in the soil taxonomic unit description sheets (STUDs) (Leslie and Seru, 1997).

The soil pattern shows 65% of soil develops on steep slopes (>21°), 20% on rolling and hilly land (4–21°) and 15% on flat land (<4°).

Soils of the uplands (>600 m altitude) are separated from those of the lowlands to reflect the different soil temperature regimes above (isothermic) and below (isohyperthermic) 600 m altitude. Soil temperature has a major influence on plant growth. Similarly soil moisture regimes further influence land use and crop options and are used as primary criteria for differentiating soils between the dry (ustic), wet (udic), and very wet (perudic) moisture zones.

Soils are further subdivided by the general type of genetic process which produced them and their resultant soil profile. They are generally called by the name in the soil legend (Table 9).

Young very sandy soils from various coastal deposits are found on or near the shores of the islands (***Soils of the beach sands***).

Soils of the regularly inundated coastal flats, at or near the mean tide level, fringe significant areas of the main islands (***Soils of the marine marshes***) and for the most part support mangrove forest marsh.

Free-draining soils derived from river deposits occupy valley floors. These are generally fertile, deep, and agriculturally valuable (***Recent well drained alluvial soils***). They are subdivided into those soils developed from non-acidic rocks and those from acid rocks.

Soils with high water tables and impeded internal drainage occupy low-lying depressions in valleys and on terraces and peneplains (***Poorly drained alluvial soils***). They are subdivided in those soils developed from non-acidic rocks and those from acid rocks. The latter are generally less fertile and have lower pH. In shallow depressions where the water table lies at the surface during much of the year peats formed from rush and fern develop (***Organic soil***).

Often some of the most developed soil profiles are found on near flat, stable remnants of old peneplain surfaces and very old river terraces (***Soils of the high terraces and peneplains***). Those from non-acidic rocks have deep red profiles often with subsoil mottling and iron oxide concretions in the upper horizons. These represent the most advanced stage of soil development from non-acidic parent materials. Profiles from acid rocks are commonly in high rainfall areas and tend to be yellow mottled red, clayey, and not well drained.

The other soils not included in the foregoing groups occur on sloping land (***Soils of the rolling and hilly terrain***).

- Soils from ***young volcanic materials*** have silty deep profiles with unweathered parent material still present but are fertile and excellent cropping soils.

- Soils from ***volcanic ash over reef limestone*** have silty thin profiles with good physical properties on rock but, due to shallowness, have limitations of rooting volume and droughtiness.

- Soils developed on ***calcareous tuffs and marls*** have shallow black profiles, are nutrient rich and mainly used for pasture because of shallowness. This group can be subdivided into those that occur in the wet zone and those found in the dry zone.

- Soils from older ***weathered volcanic rocks*** occur mainly in the dry zones and are typified by deep friable bouldery clays from basalt. They are generally fertile with a high base status.

Table 9: Legend for simple soil groups

(a) *Soils of the Lowlands with Isohyperthermic STR*

Soils of the beach sands
Yasawa, Dawasamu, Volivoli series

Soils of the marine marshes
Soso, Dreketi series

Recent well drained alluvial soils
(i) from non-acidic rocks
- wet zone Rewa, Wainibuka series
- dry zone Sigatoka series

(ii) from acid rocks
- wet zone Saliadrau series
- dry zone Lagilagi series

Poorly drained alluvial soils
(i) from non-acidic rocks
- wet zone Tokotoko series
- dry zone Narewa, Nika, Matavelo, Saunaka series

(ii) from acid rocks
- wet zone Deuba, Toguru series

Organic soils
Melimeli soils

Soils of high terraces and peneplains
(i) from non-acidic rocks
- Nadi, Namosau series

(ii) from acid rocks
- Koronivia series

Soils of the rolling and hilly terrain
(i) from young volcanic materials
- Waiqere, Vakawau, Taveuni series

(ii) from volcanic ash over reef limestone
- Cikobia series

(iii) from calcareous tuffs and marls
- wet zone Samabula series
- dry zone Dobuilevu, Momi, Emuri series

(iv) from older weathered volcanic rocks
- Tavua, Yaqara series

(v) from basic and intermediate rocks
- wet zone Sote, Wainunu, Lomaiviti, Nasou series
- dry zone Raviravi, Tuva, Bua series

(vi) from acid rocks
- wet zone Lutu series
- dry zone Dogotuki, Nukudamu series

(b) *Soils of the Uplands with an Isothermic STR*

Recent well drained alluvial soils
Navai series

Recent poorly drained alluvial soils
Nadrau series

Soils of the rolling and hilly terrain
(i) from raw volcanic materials
- Manuka series

(ii) from basic rocks
- Wailulu series

Table 10: Twyford and Wright (1965) classification of the 45 selected soil series

The 45 soil series described in this volume are placed into the appropriate category of the Twyford and Wright classification.

Soils of the hot, humid to subhumid lowlands

Recent Soils
from coastal sands
(Yasawa, Dawasamu, Volivoli)
from alluvium (including closely related young soils)
(Rewa, Wainibuka, Sigatoka, Saliadrau, Lagilagi)

Nigrescent Soils (including soils of high base status)
(Samabula, Dobuilevu, Momi, Emuri, Tavua, Yaqara)

Latosolic Soils (from young basic ash, scoria and flows, and from limestone)
(Waiqere, Vakawau, Taveuni, Cikobia)

Humic Latosols (from parent materials of basic and intermediate composition)
with weak or no dry season
(Sote, Wainunu, Lomaiviti, Nasou)

with moderate and strong dry season
(Nadi)

Ferruginous latosols ([Talasiga soils] from parent materials of basic and intermediate composition)
(Namosau, Raviravi, Tuva, Bua)

Red Yellow Podzolic Soils (from parent materials of acidic composition)
(Koronivia, Lutu, Dogotuki, Nukudamu)

Gley Soils
(Tokotoko, Narewa, Nika, Matavelo, Saunaka, Deuba. Toguru)

Organic Soils
(Melimeli)

Saline Soils of the Marine Marsh
(Soso, Drekiti)

Soils of the Warm, Super Humid to Humid Uplands

Recent Soils (from alluvium)
(Navai)

Latosolic Soils
(Manuka)

Humic Latosols
(Wailulu)

Ferruginous Latosols
(not described)

Gley Soils
(Nadrau)

Organic Soils
(not described)

- Soils from ***basic and intermediate rocks*** comprise deep weathered clays, are rather acid and of low nutrient status. However they are good agricultural soils when properly treated with fertilisers. They can be subdivided with those that occur in the wet zone and those found in the dry zone.

- Soils from ***acid rocks*** tend to have deep, sandy profiles in which clay content increases into the subsoil. They are very strongly weathered and usually strongly leached and of rather low but still some agricultural value for pastures and certain tree crops.

9.1 Key to the Identification of the 45 Soil Series

Leslie and Seru (1997) recognised 228 soil series in their national soil survey. The range of variation in soil properties across Fiji is very large indeed, and cannot be described or understood easily, and certainly not in an introductory soils book such as this. It was therefore decided to recognise a subset of key soil profile forms (45) and organise them in a manner that represents the main landscape/physiographic, climatic and parent material types described for the national soil survey. These selected soils are described in Appendix 1. For readers familiar with Twyford and Wright (1965) these 45 soils have been placed into the appropriate category of their classification (Table 10).

The key to the identification of the 45 selected soil series (Table 11) is based on the following criteria listed in the logical order of the questions asked in the key:

(i) Altitude zone
(ii) Soil temperature regime
(iii) Landscape type
(iv) Broad parent material type
(v) Mineral or organic soil
(vi) Drainage class
(vii) Parent rock
(viii) Moisture zone
(ix) Dominant soil characteristic
(x) Soil series.

Often a soil can be keyed out (Table 11) without having to utilise all of (i) – (x) above; for example, to find the Dreketi soil series requires only: (i) box 1; (ii) box 2; (iii) box 3; (iv) box 4; (ix); and (x) while the Emuri soil series requires: (i) box 1; (ii) box 2; (iii) boxes 3, 6, 22, 25; (iv) boxes 26, 27, 28; (viii) box 29; (viii) boxes 30, 31; (ix); and (x).

9.2 Formation

(i) Environment and soil formation

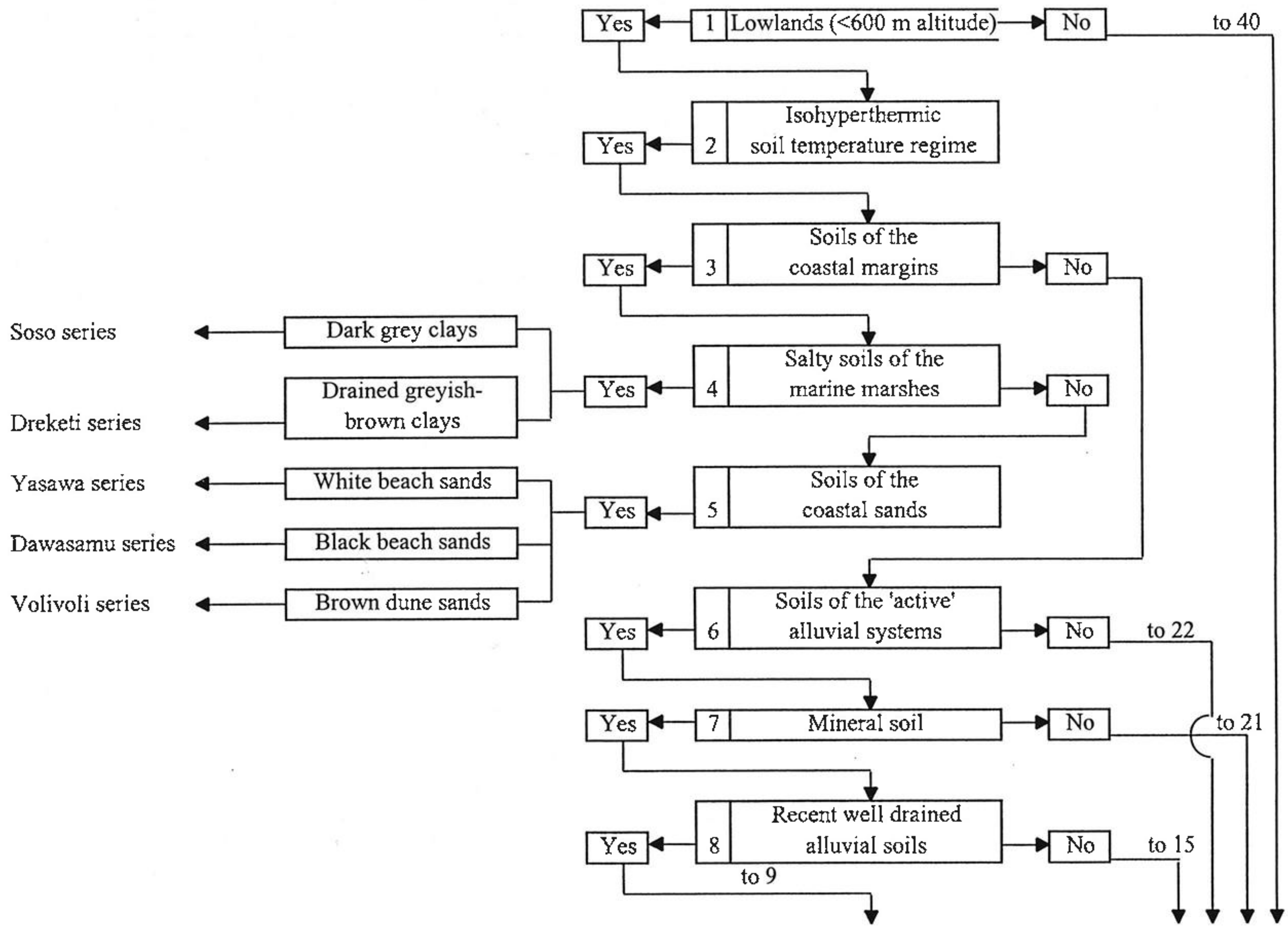
Soil formation is essentially a process of change in which decay plays an important role. It is the soil-forming parent materials that decay and the nature of the parent material is one of the key factors in soil formation. More specifically this relates to the relative amounts of ferromagnesium minerals to the more resistant quartz and feldspars.

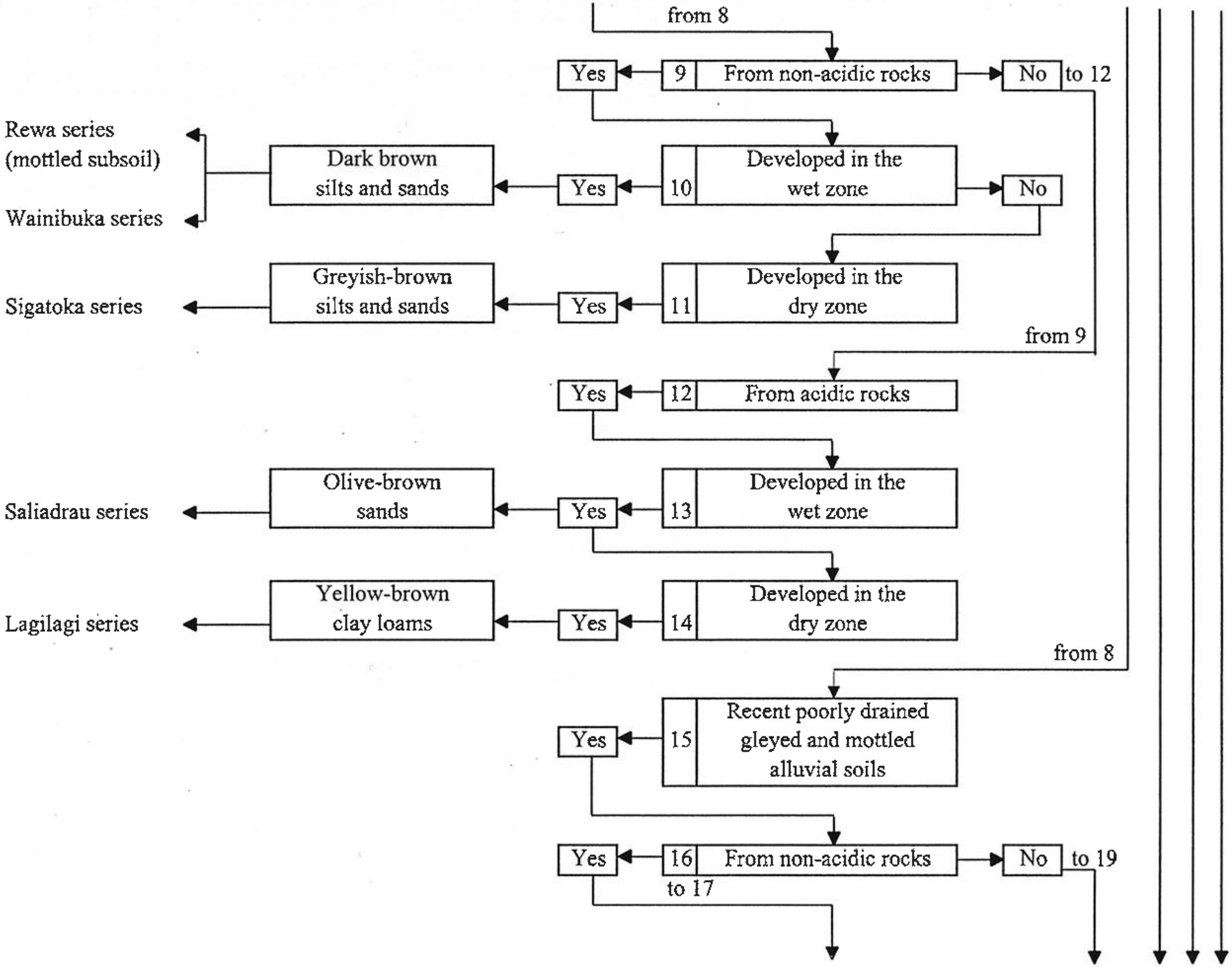
The rate of decay (soil weathering) of the mineral soil parent material is rapid in the hot and humid climate of Fiji because chemical change is faster. This process is of importance during the initial stages of rock decay when primary minerals are attacked and broken down to form clay minerals.

The difference in soils formed from acidic and basic parent materials is not obvious nor are the stages of progressive leaching. It is the relative porosity of basic parent materials and coarse quartz content of the acidic parent materials, both of which influence the movement of water and air through the soil system, combined with intensity and frequency of strong drying conditions that seem to have had the greatest influence in the formation of Fiji soils. Thus, it is the free movement of air and water which is important. The movement of air and water tends to be channelled through structural cracks, leaving a significant volume of soil material in which there can be a tendency for reducing conditions to develop.

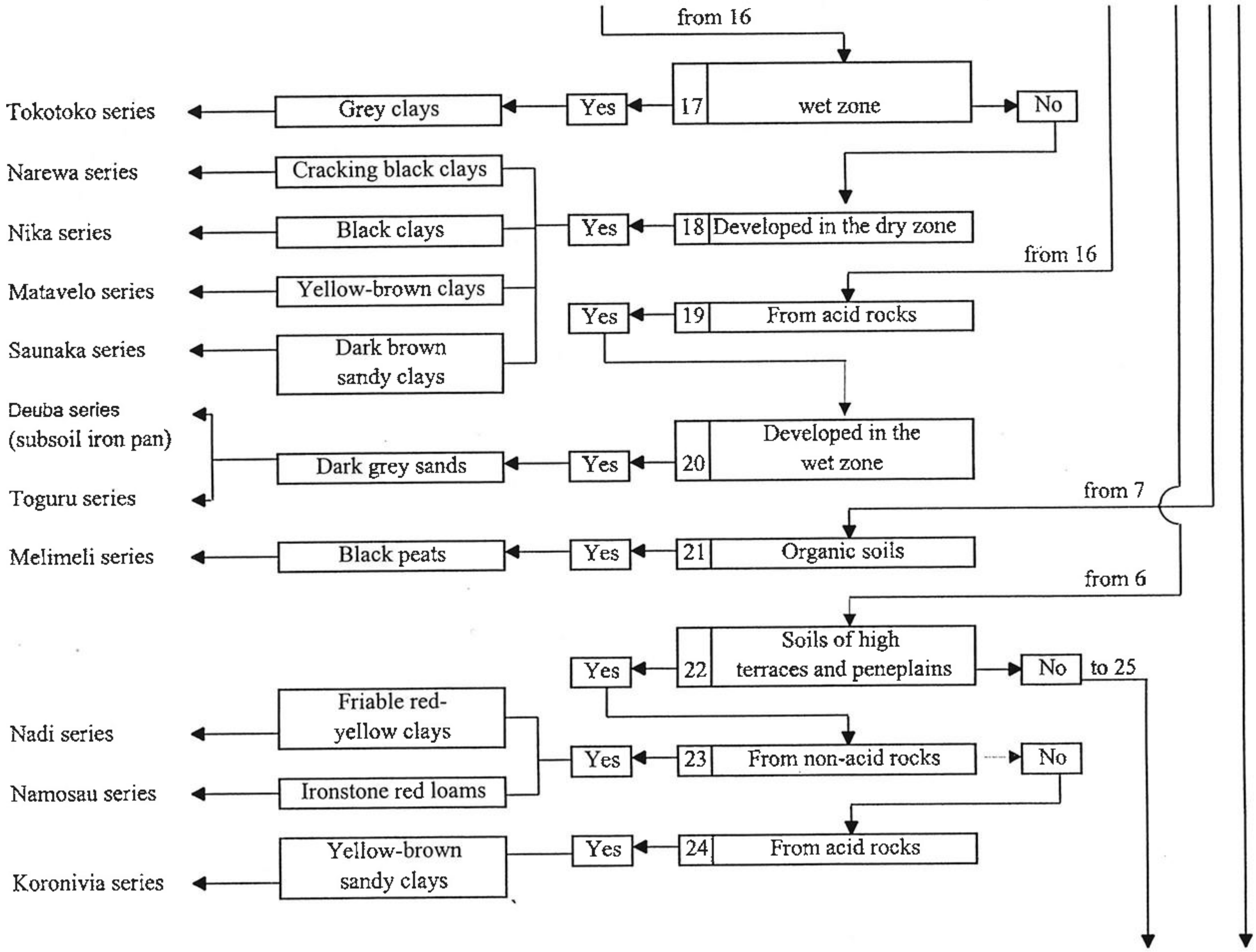
The organic cycle is very efficient in most soils because of the greater metabolic rate under hot humid conditions. Most material is retained within the cycle with little lost in solution.

Table 11: Key to the identification of the selected 45 soil series

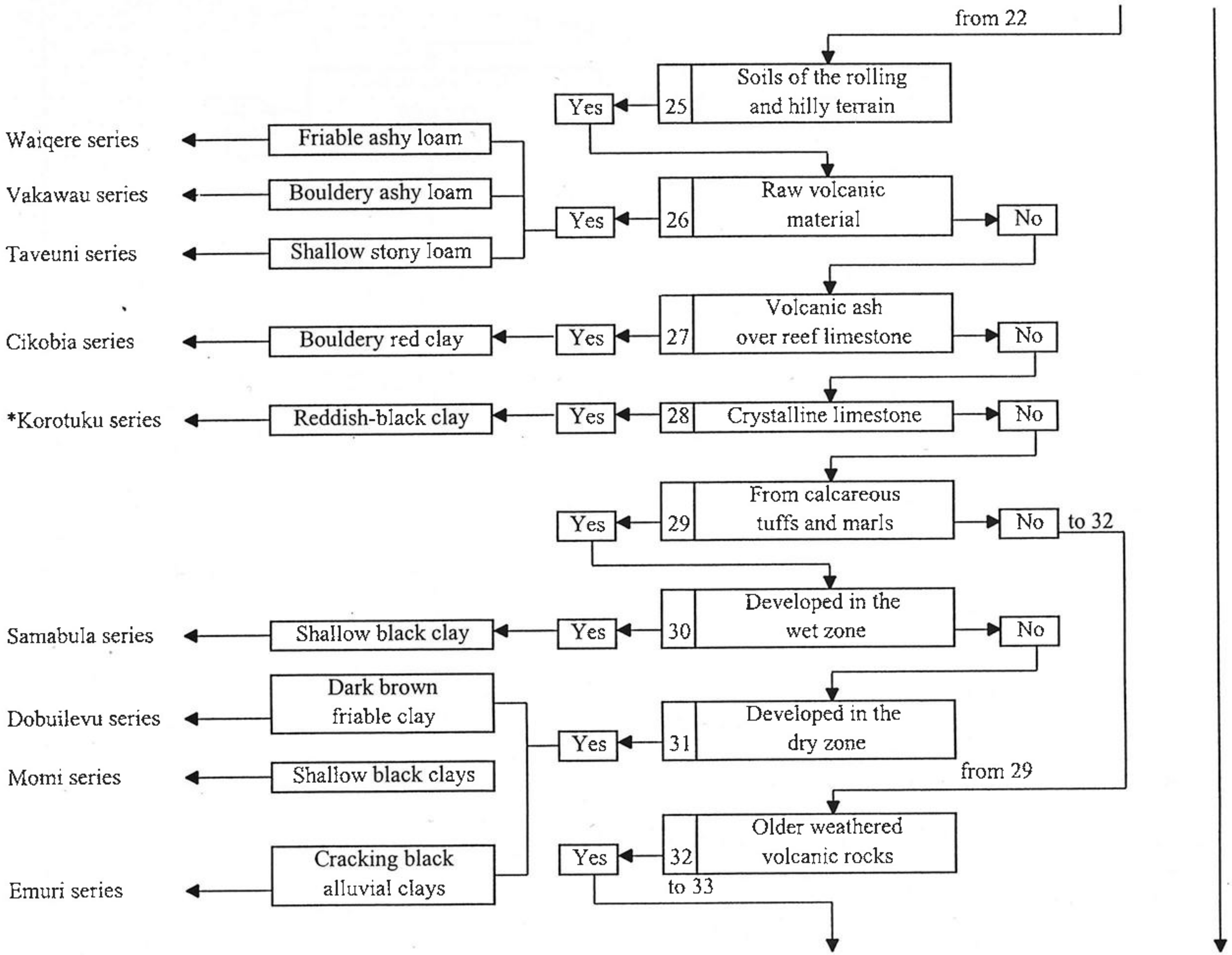


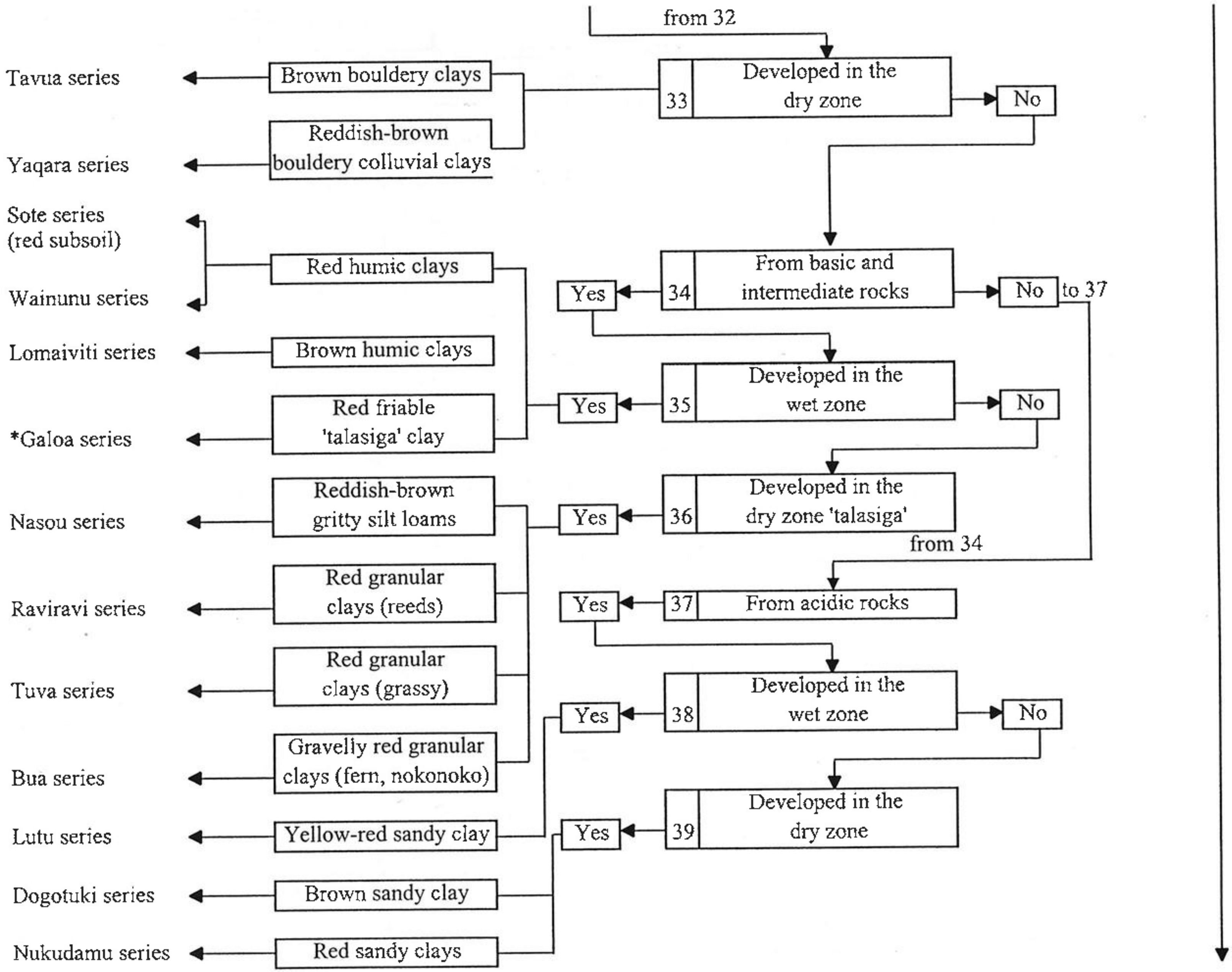


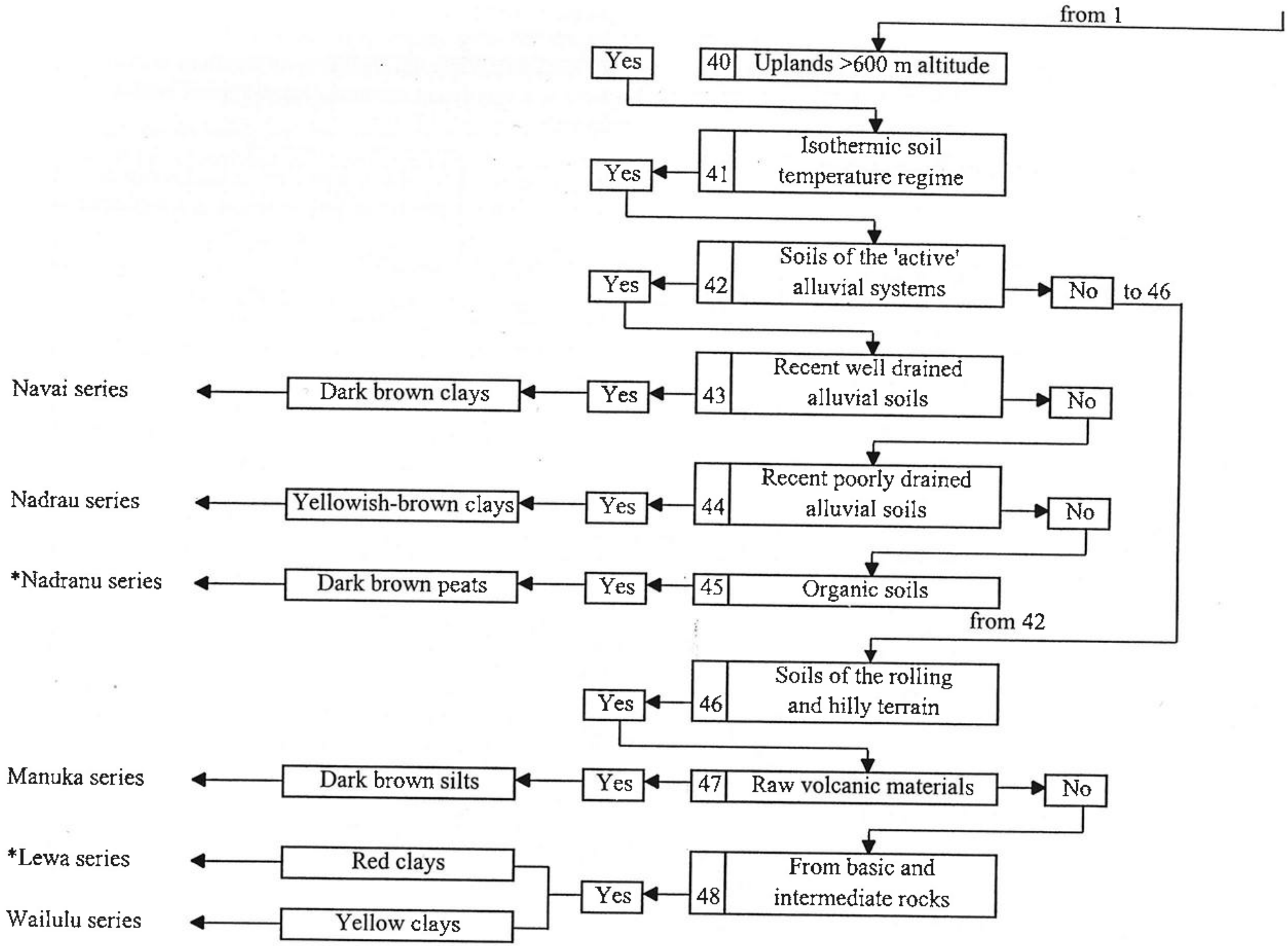
from 8
Yes
9
From non-acidic rocks
No
to 12
Rewa series
(mottled subsoil)
Wainibuka series
Dark brown
silts and sands
Yes
10
Developed in the
wet zone
No
Sigatoka series
Greyish-brown
silts and sands
Yes
11
Developed in the
dry zone
from 9
Yes
12
From acidic rocks
Saliadrau series
Olive-brown
sands
Yes
13
Developed in the
wet zone
Lagilagi series
Yellow-brown
clay loams
Yes
14
Developed in the
dry zone
from 8
Yes
15
Recent poorly drained
gleyed and mottled
alluvial soils
Yes
16
From non-acidic rocks
No
to 19
to 17



from 16
17
wet zone
Yes
No
Grey clays
Tokotoko series
Narewa series
Cracking black clays
Nika series
Black clays
Yes
18
Developed in the dry zone
from 16
Matavelo series
Yellow-brown clays
Yes
19
From acid rocks
Saunaka series
Dark brown sandy clays
Deuba series (subsoil iron pan)
Developed in the wet zone
Dark grey sands
Yes
20
Toguru series
from 7
Melimeli series
Black peats
Yes
21
Organic soils
from 6
Soils of high terraces and peneplains
Yes
22
No
to 25
Nadi series
Friable red-yellow clays
Yes
23
From non-acid rocks
No
Namosau series
Ironstone red loams
Yellow-brown sandy clays
Yes
24
From acid rocks
Koronivia series


from 22
25
Soils of the rolling and hilly terrain
Yes
Waiqere series
Friable ashy loam
Vakawau series
Bouldery ashy loam
Taveuni series
Shallow stony loam
26
Raw volcanic material
Yes
No
27
Volcanic ash over reef limestone
Yes
No
Cikobia series
Bouldery red clay
28
Crystalline limestone
Yes
No
*Korotuku series
Reddish-black clay
29
From calcareous tuffs and marls
Yes
No
to 32
30
Developed in the wet zone
Yes
No
Samabula series
Shallow black clay
31
Developed in the dry zone
Yes
Dobuilevu series
Dark brown friable clay
Momi series
Shallow black clays
Emuri series
Cracking black alluvial clays
from 29
32
Older weathered volcanic rocks
Yes
to 33


from 32
33 Developed in the dry zone
No
Brown bouldery clays
Reddish-brown bouldery colluvial clays
Tavua series
Yaqara series
34 From basic and intermediate rocks
Yes
No
to 37
Red humic clays
Sote series (red subsoil)
Wainunu series
Brown humic clays
Lomaiviti series
35 Developed in the wet zone
Yes
No
Red friable 'talasiga' clay
*Galoa series
36 Developed in the dry zone 'talasiga'
Yes
Reddish-brown gritty silt loams
Nasou series
from 34
37 From acidic rocks
Yes
Red granular clays (reeds)
Raviravi series
Red granular clays (grassy)
Tuva series
38 Developed in the wet zone
Yes
No
Gravelly red granular clays (fern, nokonoko)
Bua series
Yellow-red sandy clay
Lutu series
39 Developed in the dry zone
Yes
Brown sandy clay
Dogotuki series
Red sandy clays
Nukudamu series



***Not included in the 45 soil series described in Appendix 1**

(ii) Features of soil formation

While soil weathering is an active and widespread process, the depth of soil seen on stable sites varies greatly. The depth of soil (mantle) to unweathered rock can be related to:

- ease of access of water and air into the parent rock,
- type of rock minerals present and the nature of the rock matrix, and
- presence of carbonates (e.g., calcium and magnesium) which are easily dissolved.

The weathering process contributes to soil formation by forming new clay minerals (e.g., halloysite, kaolinite, montmorillonite), oxides (e.g., haematite, geothite), hydroxides (e.g., gibbsite) and secondary silica. These mineral names are classification descriptors used with particle size and temperature regime in the Soil Taxonomy classification at the family level.

The process of leaching whereby water moves through a soil often transporting solutes with it, operates in all Fijian soils except those that are waterlogged for most of the time. While an important process in soil formation, leaching can lead to losses in soil materials and of applied fertilisers. It is a near constant process in the isothermic soil temperature regime (>600 m in altitude) and lowlands with udic and perudic soil moisture regimes (wet zones). In the ustic areas, leaching can be suspended for up to 5 months during the winter months (dry season). Commonly, alkaline materials are totally removed from soils, even in the ustic zones, although minor amounts of calcium carbonate can be seen in fissures of weathering rock. Other features of accumulation such as clay pans, and iron, alumina, and manganese deposits are uncommon in the solum.

Dense subsoil horizons formed as a result of clay illuviation (argillic horizons) are rarely well developed, although evidence of clay movement and accumulation (cutans) is seen, particularly in soils from acidic parent materials (see ***Koronivia*** series).

The organic cycle can have a significant impact on soil formation. This includes the processes of mixing (by earthworms), overturning of trees, incorporation of organic residues by soil organisms living near the soil surface, etc. While the organic cycle functions uniformly in the lowlands there is a significant accumulation of topsoil humus under forest in the uplands.

As previously described, steeply sloping land is extensive throughout the country. Thus, transport of soil on slopes is a predominant soil process. While the present landscape may appear stable, redistribution of soil material within the landscape is a continuous process. Landscapes are dynamic systems experiencing periods of stability during which soil formation occurs, alternating with periods of instability when erosion truncates soils on the upper part of slopes and then progressively deposits soil material towards and at the foot of the slope.

Accelerated erosion can be seen in a number of situations. Mass movement (soil creep, earth flows, debris avalanches) often associated with high intensity rain storms is triggered on steep slopes where vegetative cover has experienced excessive burning over time. Soil loss is increasingly common on the intensively cultivated cane farms that have been developed on rolling land, particularly those with slopes >11°.

The inorganic cycle is therefore a very active element in soil formation in Fiji, particularly on the floodplains and valley floors that are subject to significant discontinuous flooding and alluvial deposition. Current accumulation of wind-blown material is restricted to a narrow zone around the beaches. Deposition of volcanic ash (tephra) has not occurred in Fiji since the late Pleistocene.

10.1 Introduction

Soil fertility and soil survey (including soil classification) are two distinct aspects in the study of soils. While classifying soils according to Soil Taxonomy uses the whole profile, in soil fertility (as it relates to farmer interests), the main concern is with the plough layer. The following discussion considers the whole profile and the broad nutrient characteristics of the main soil groups.

The key properties of the soil that govern its ability to grow plants are those which determine its suitability as a rooting medium ('root room'): ***water, air,*** and ***heat*** economy and the supply of ***nutrients***. Together they determine ***soil fertility***.

A reason for establishing fertility status of soils is to help farmers estimate productivity/yields for their crops. The economic margins for the farmer can be measured by deducting the real costs of the inputs (such as fertiliser, irrigation, drainage, etc.) from gross income.

The capability of a soil to produce quality crops sustainably over time constitutes ***fertility***. A distinction should be made between ***soil fertility***, which directly belongs to the soil itself, and ***site fertility***, which includes the inputs of climate, location, and management.

10.2 Rooting Volume

On rock the volume of soil penetrated by roots is generally controlled by the depth of the ***solum***, while on soft soil materials roots commonly penetrate deeper than the solum. Soil structure and soil consistence influence the ease of root penetration. A number of crops require a soil depth >1 m, for adequate support, so this figure can be taken as a minimum for high soil fertility. Impermeable horizons (pans, high water tables or impeded drainage, etc.) can confine roots to only part of the solum.

10.3 Water

A plant's water needs are governed by the available water content of the rooting zone and by permeability. Soil depth, texture, nature of the clay fraction, and organic matter are key attributes. Low available water capacity makes plants more dependent on the amount and frequency of rainfall. Thus, in the wet zones (udic soil moisture regime [SMR] – see Table 6) with near continual rainfall, the soil's role in supplying water is not critical, rather its ability to quit water other than to the plant is more important. However, in the dry zones (ustic SMR) the water holding and supply capacity is critical for soil fertility and outweighs even nutrient status. The rainfall distribution for Viti Levu is given in Fig. 17 and for Vanua Levu in Fig. 18.

Fig. 17 Distribution of rainfall: Vitu Levu

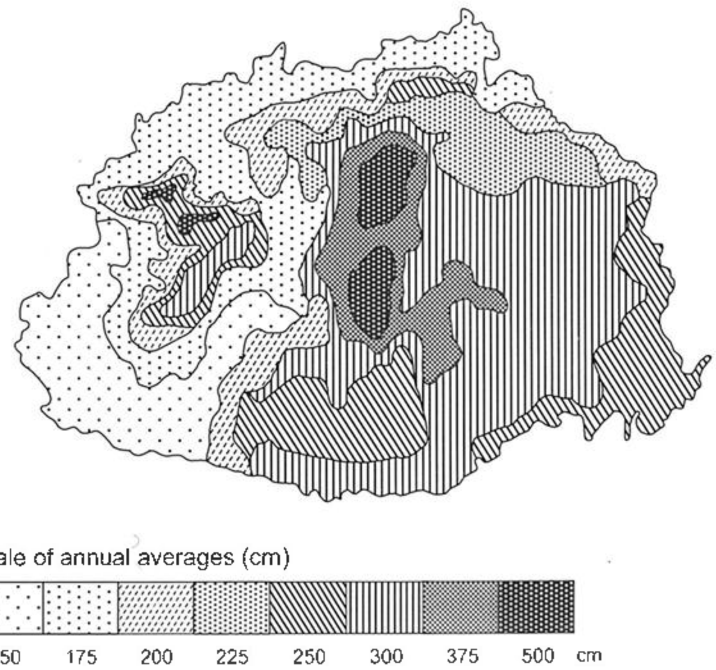
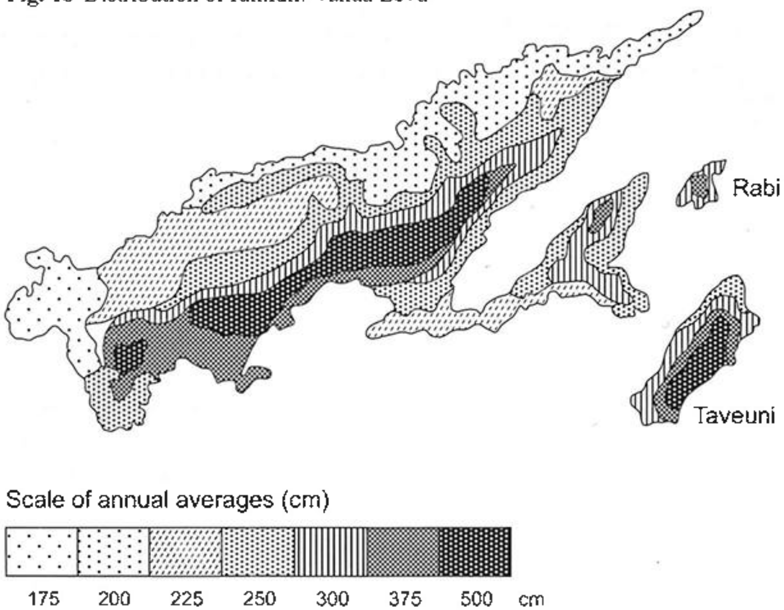


Fig. 18 Distribution of rainfall: Vanua Levu



10.4 Aeration

Availability of soil air (aeration) is closely connected with water content. Air content of a soil is zero when the soil is waterlogged (all pores filled with water) while in a totally dry soil all pores are filled with air. Most plants require a well aerated soil and therefore free internal drainage of water is a prerequisite for soil fertility. On the valley floors, lack of soil aeration can be a serious problem. Here seasonally waterlogged soils, peats, and gleyed soils must generally be drained to become fertile. In the udic and perudic SMR's rainfall can be intense and frequent and soils therefore must have the ability to contend with significant volumes of water quickly.

10.5 Heat

Soil temperature is important for germination, respiration, and nutrient uptake by higher plants and for the activity of soil organisms. Temperature is adequate throughout Fiji, there being an isohyperthermic temperature regime in the lowlands below 600 m (mean annual temperature >22°C and the difference between winter and summer <5°C) and an isothermic regime in the uplands (mean annual temperature >15°C).

10.6 Nutrient Supply

Given that root volume, water content, and aeration are adequate, soil fertility finally depends on nutrient supply. To grow successfully, plants require a mix of different nutrients and of these, most come from the soil (in solution) through the roots to the plant proper.

Contrasts in the nutrient status of soils commonly relate to the nature of the parent material, degree of weathering and soil leaching, and variable management practices. Plants contain on average 45 elements but, apart from carbon, oxygen, and hydrogen only 19 of these have proved to be essential for plant growth.

Nutrients are separated into a few key macronutrients, e.g., N, P, K, Ca, Mg, S, and micronutrients (trace elements), such as Fe, Mn, Cu, Zn, Mo, B, Cl. Both groups are equally essential.

If any one of these essential nutrients is not present in the soil then plant growth will be retarded.

The processes of soil weathering and soil leaching which are paramount in soil formation normally work in concert; a strongly weathered soil is usually strongly leached. However, in considering nutrient supply, the weathering and leaching processes must be viewed separately as weathering releases the nutrients, and leaching takes them away.

Given appropriate moisture status, weathering will convert rock to clay (and sands and silts) thereby releasing macro- and micronutrients. The quantities of nutrients available through the weathering process are dependent on the composition of the parent rock.

Water moving through the soil profile can potentially remove nutrients that were released and made available through the weathering process. Thus nutrient balance is governed by the rate of nutrient release and removal. In the high rainfall zones of Fiji, soils tend to have a lower average nutrient status than those in the dry (ustic) zones.

10.7 Nutrient Status

The nutrient status of a soil may be evaluated in a number of ways. Some of these are:

- Field plot fertility trials
- Greenhouse pot experiments
- Visual examination of plant tissue material
- Plant foliar analysis
- Rapid chemical analysis of the soil

Laboratory analyses alone cannot accurately predict productivity; although this is what farmers want from analysis of their soil samples. There are many variables other than nutrient status of the soil that influence productivity. Some of these are:

- Climate variables
- Crop varieties
- Husbandry related to such items as
  - – timeliness of on-farm operations
  - – application of best practices
  - – pest and disease control

10.8 Ratings of Chemical Properties

General information on the interpretation of analyses for soil pH, phosphorus, organic matter, cations and, where relevant, soil salinity is given for each of the 45 soil series (Appendix 1). However, the relationship between the qualitative values and the numerical range for each of these factors requires explanation with some comment as to why these parameters have significance for soil fertility.

The ratings given in the following tables (12–15) provide a guide to the interpretation of the results of chemical analyses and show the ranges of values encountered in the analyses of Fiji soils.

Table 12 Soil pH

Rating	pH	Description
very high	>9.0	extremely alkaline
	8.5–9.0	strongly alkaline
	7.9–8.4	moderately alkaline
high	7.3–7.8	slightly alkaline
	6.7–7.2	near neutral
medium	6.1–6.6	slightly acid
	5.6–6.0	moderately acid
low	4.4–5.5	strongly acid
very low	<4.4	extremely acid

Most soils are in the pH range 5.0–6.5, with values greater than 7 occurring in soils derived from limestone or coral, and values less than 5 occurring in strongly leached soils under high rainfall or in soils with oxidisable sulfides (such as reclaimed mangrove soils).

pH is an important soil property and has a significant effect on the availability of many nutrients, with high or low pH causing reduced availability, particularly for micronutrients. Also pH controls the occurrence of exchangeable aluminium, which is toxic to most plants and can restrict root development.

Table 13 Available phosphorus

Rating	OlsenP (mg/kg)	Mod. Truog-P (mg/kg)	Bray-2 P (mg/kg)
very high	>50		
high	30–50	>60	>40
medium	20–30	20–60	20–40
low	10–20	10–20	10–20
very low	<10	<10	<10

For most crops the ideal level for phosphorus is represented by the medium range. Soils with high levels of available phosphorus are unlikely to show plant growth responses to added phosphorus, while soils with low levels will give responses.

Of the different P-extractant methods, Olsen-P and Bray-2 available P are widely used in a number of countries and provide acceptable correlations with plant uptake, while the modified Truog method is used by the Fiji Sugar Corporation for sugar cane soils.

Organic matter is important as it maintains soil structure and water holding capacity in soils. The mineralisation of organic matter provides a vital source of nutrients particularly in low-input farming systems, but to be sustainable the level of organic matter must be maintained.

Ratings for carbon and nitrogen indicate the total organic matter level in soil, while the ratio between the two indicates the state of decomposition. Well decomposed, relatively stable organic matter has a C/N ratio of about 10–12,

Table 14 Organic matter (carbon and nitrogen)

Rating	Carbon (%)	Nitrogen (%)
very high	>20	>1.0
high	10–20	0.6–1.0
medium	4–10	0.3–0.6
low	2–4	0.1–0.3
very low	<2	<0.1

Table 15 Cation exchange properties

Rating	CEC	TEB	BS	Exchangeable Ca	Mg	K	Na
	---me / 100g---		%	---	---	---me / 100g---	--- ---
very high	>40	>30	80–100	>20	>7	>1.2	>2
high	25–40	15–30	60–80	10–20	3–7	0.6–1.2	0.7–2
medium	15–25	4–15	30–60	2–10	1–3	0.3–0.6	0.3–0.7
low	10–15	2–4	20–30	1–2	0.5–1	0.1–0.3	0.1–0.3
very low	<10	<2	<20	<1	<0.5	<0.1	<0.1

while recently added organic matter or organic matter in peats have C/N ratios of 20 or more.

Cations (Ca, Mg, K, Na, and Al) are held on the ***exchange complex***, are not dissolved in the soil solution, are resistant to leaching, but are exchangeable with other cations from the soil solution, fertilisers, or plant roots.

Cation Exchange Capacity (CEC) reflects the total number of sites available for cation exchange. The CEC of a soil comprises a fixed component that increases in value with increasing pH.

Total exchangeable bases (TEB) is the sum of the exchangeable cations including the oxides (Ca, Mg, K and Na) but excluding aluminium.

Base saturation is the sum of TEB expressed as a percentage of CEC. % BS is a useful indicator of leaching, with low or very low % BS indicating strong leaching.

In general, exchangeable Ca is the abundant exchangeable base and therefore dominates both %BS and pH. Deficiency of Ca as a nutrient is uncommon.

Key levels of exchangeable Mg and K for plant growth vary with each crop. The critical Mg level is about 0.3–0.5 me / 100 g, while for K critical levels vary from about 0.5 me / 100 g for vegetables and other high K-demand crops, to 0.2–0.3 me / 100 g for other crops.

Exchangeable Na levels indicate possible salt effects in soils, i.e., coastal or saline areas.

11.1 Arable Land – Our Most Important Soil Resource

Traditional shifting cultivation commonly occurs on sloping land often on steep slopes. Continuous more intensive cultivation is discouraged by the Fiji government on slopes greater than 11°, and the land area below this limit – that is, potential arable land – represents 305 600 ha (16.5% of the total land area). However, these potentially arable soils are not all of equal value for food production. Some are stony and difficult to plough, subject to repeated and damaging floods (e.g., low terraces), droughty (e.g., sandy coastal flats, shallow soils in the ustic soil moisture regimes), and poorly drained (soils that experience severe wetness, are difficult to drain, such as peats, mangrove areas). Because of these limitations only 137 300 ha (or 7.5%) of Fiji's land area is regarded as having high value for food production.

11.2 Soil Versatility

A priority of sound land use planning is to protect versatile soils for agricultural purposes. A highly versatile soil is one that has the capacity to grow a wide range of crops suited to its particular climate sustainably (see box below.)
The soil survey of Fiji has put emphasis on determining the versatility and crop-specific sustainability of the soils.

11.3 Soil and Climate Factors in Land Use

Within this broad category of high-value soils there are very different potentials for the growth of a range of crops. Some crops need specific soil conditions, and the influence of climate is very important. In general, equitable temperature (crop-specific), well-distributed rainfall, plus a soil which is capable of storing this rainfall (or irrigation water), are the key factors. It is the storage property that makes soil such a valuable medium for plant growth for it can act as a 'heat sink', a 'water sponge' and a 'nutrient bank'. It is the combination of these three factors that makes soil an extraordinary natural product.

As a ***heat sink,*** soils store up the heat from the sun. While air temperatures can fluctuate between day and night and between fine and bad weather, soil temperatures are much more stable. Fiji is subdivided into two soil temperature regimes (STR) – isothermic >600 m altitude and isohyperthermic <600 m – the definitions for these are given in Section 7.4. The significance of the isothermic zone lies in the opportunity to grow temperate zone fruits and vegetables. There are 1782 ha of potential arable land with an isothermic STR, mainly in the uplands of Viti Levu.
Soil also acts as a ***water sponge,*** retaining much of the moisture received from rainfall or irrigation. This capacity depends on a number of factors: soil depth; chemical and physical properties; the amount of water that has percolated into the soil; and the amount of water taken up by plants or evaporates from the soil surface. The weather essentially controls how much moisture will be in the soil. However, in low rainfall areas the moisture-retaining properties of the soil assume greater importance.

Definitions and the land use implications for the three soil moisture regimes recognised for Fiji – ustic, udic and perudic – are described in Section 7.4.

Soil is a ***nutrient bank,*** holding nutrients until they are required by plants. Generally the greater the depth of soil capable of penetration by roots the greater the availability of moisture and nutrients to the plant. The roots of sugar cane will exploit the entire upper 2 m of friable, well-drained soils (see ***Nadi*** series). This accounts for much of their drought tolerance. Tree roots from ***Pinus carribaea*** can be seen at depths >4 m. However, impediments (for example, pans, water table, compacted layers, stony subsoils, gleyed layers) can restrict root penetration, and so limit the plant's access to both nutrients and water.

Soil Versatility

In terms of its physical characteristics a highly versatile soil is one which:
- occurs on flat land or on slopes <5°;
- has a potential rooting depth of at least 0.75 m;
- offers little resistance to root penetration;
- experiences few days of soil-water deficit;
- experiences few days of waterlogging;
- has good internal drainage and soil aeration;
- has a low content of stones;
- can be cultivated by machines at most times;
- has high structural stability;
- and is unlikely to suffer from erosion, flooding and salt contamination.

12.1 Land Use Capability (LUC)

Land use capability (LUC) classification can be described as the systematic arrangement of different kinds of land according to those properties that determine its capacity for sustained production, where ***capability*** is used in the sense of suitability for productive use.

The Land Use Division of MAFF assesses land use capability based on its ***LUC Land Inventory System.*** This was developed in 1977 and is based on the USDA Land Use Capability (Klingebiel and Montgomery, 1961) and has been adapted to the Fiji environment.

Soil is a key element in determining land capability as most forms of land utilisation ultimately depend on soil as the medium for plant growth.

The capacity for sustained production depends largely on the physical qualities of the soil and related environmental factors. These factors are regarded as limitations when they are not ideal in some way. The limitations affect the productivity, the types of corrective measures required, and the intensity and type of land use. The degree of the limitation is assessed and the following factors are evaluated:

- susceptibility to erosion;
- steepness of slope;
- susceptibility to flooding;
- liability to wetness or drought;
- salinity;
- depth of soil;
- soil characteristics (texture, structure, fertility, etc.); and
- climate.

As a basis for this assessment an inventory is undertaken in the field. This ***land inventory*** phase maps rock type, soil type, slope, erosion, vegetation and current land use. Land inventory units describing these factors are delineated on the final land inventory map.

Based on the land inventory, the land use capability classification is conducted. It groups the land inventory units into one of eight land use capability classes. A description of the eight Fiji LUC classes is given in Table 16.

There are dangers in adopting unchanged/modifying a system like the US LUC that was developed for a temperate zone farming system (viz., extensive mechanised arable production of cereals) to, for example, the Fijian humid tropical system in which subsistence agriculture involving complex multiple cropping is an important component. The results can be irrelevant to the type of agricultural development taking place in the country – adopting or modifying the system.

Over the last 20 years FAO has endeavoured to find a solution to this problem by developing a framework for land evaluation whose principles, if followed, produce outcomes that are appropriate in all farming systems and all soil environments. The underlying philosophy is matching land utilisation types with soil and climate characteristics to determine soil suitability classes on a specific crop basis.

12.2 Land Evaluation

As more demands are made on the use of the land for specified purposes, land use planning becomes, more than ever, an important function. One of the processes in determining the suitability of land in land use planning is land evaluation. FAO defines land evaluation as "the process of assessment of land performance when used for specified purposes, involving the execution and interpretation of surveys and studies of land forms, soils, vegetation, climate, and other aspects of land in order to identify and make a comparison of promising kinds of land use in terms applicable to the objectives of the valuation".

Table 16: Fiji land capability classes

Class I	Versatile multiple-use land. It is flat (0–3°); has deep, easily worked, fertile soils; no erosion risk; well drained but not seriously affected by drought, and the climate is favourable for the growth of a wide range of crops. No special soil conservation measures required.
Class II	Good arable land with slight limitations which make it more difficult to manage than Class I. The land may be flat to gently undulating (0–7°); well drained to moderately drained, deep to slightly shallow, and fertile to moderately fertile soils. Simple management and conservation practices to overcome soil limitations are easy to apply.
Class III	Fair arable land with moderate limitations which restrict the choice of plants and/or require intensive soil conservation measures. The land may be flat or gently sloping (0–11°); slightly unstable; of moderate to severe wetness; subject to frequent damaging floods; and have shallow, moderately stony and/or infertile soils.
Class IV	Marginal arable land with severe limitations which restrict the choice of crops grown, or require intensive soil conservation measures and very careful management. Limitations may affect land use in both of these ways. Class IV land may be flat to rolling (0–15°) and may comprise one or more of the following – poor to very poorly drained; stony or bouldery soils; very shallow soils; infertility; coarse textured soils with very low moisture retention capacity; or mangrove or peats that can be drained and reclaimed for cropping.
Class V	Land is unsuitable for arable cropping but suitable for pastoral or forestry use. Steepness (slopes 16–20°) or stoniness are the main limitations. Only slight erosion risk under pasture or forest trees.
Class VI	Marginal pastoral land with moderate to severe limitations. Land is too steep (21–25°) for pastoral use; or has a high susceptibility to erosion, or there is evidence of severe past erosion. Soil limitations include shallowness, low moisture retention, and low fertility. Production or commercial forestry is the preferred land use.
Class VII	Unsuitable land for pastoral use and marginal for commercial forestry land is either very steep (26–35°); highly susceptible to erosion; there is evidence of severe past or present erosion; or soils are either very shallow, very bouldery, or with very low fertility.
Class VII	Land is generally unsuitable for productive use in both agriculture and forestry. This is primarily very steep mountain land mostly above an altitude of 800 m. It also includes lowland areas in unfavourable situations, such as extreme erosion or high susceptibility to erosion (particular mass movement), or extreme stoniness, shallowness or infertility. Class VIII land is best protected and/or reserved for watershed and environmental purposes.

To reflect limitations or hazards, subclasses can be recognised for some of the above major land use capability classes. The four general kinds of limitations recognised are: erodibility (E); wetness (W); soil limitation within the rooting zone (S); and climate (C).

Commonly there is more than one subclass type recognised and an Arabic numeral is added to the subclass symbol (for example, III E 1; III E 2).

Some of the objectives in land evaluation are to determine:

- how the land is currently used and how its management can be improved;
- what the alternative land use options are;
- what the socio-economic benefits related to sustained production from each land use option are; and
- what inputs are necessary for each land use option and what outputs will result.

Certain principles are recognised in land evaluation. These are:

- ***Land suitability is assessed and classified with respect to specified kinds of uses:*** This recognises that a given land use has specific requirements and that land suitability is related to the characteristics or qualities of the land. For example, parts of the Navua alluvial floodplain with impeded drainage are correctly cited as being highly suitable for rice cultivation but not suitable for many other kinds of agriculture.
- ***Evaluation requires a comparison of the benefits obtained and the inputs needed on different types of land:*** Suitability for a specific use requires comparison between the inputs and the outputs in terms of yield and benefits. For example, in comparing the different types of land, the highest crop yield may not necessarily represent the best suitability because high input costs may be responsible for the high yield.
- ***A multidisciplinary approach is required:*** Land evaluation must include consideration of socio-economic factors. Therefore, a land use evaluation team should not only include the soil scientist or agronomist, but also a resource economist and a rural sociologist.
- ***Evaluation is made in terms relevant to the physical, economic, and social context of the area concerned:*** In addition to biophysical information, other factors such as financial resources, availability and cost of labour, standard of living, proximity and access to markets must be considered. Experience shows extensive non-mechanised rice cultivation which requires much low-cost labour is unrealistic in a country with high labour costs.
- ***Suitability refers to use on a sustained basis:*** This relates to land use and its impact on the environment. Immediate benefits of land use should be assessed carefully against long-term land degradation such as that caused by soil erosion.
- ***Evaluation involves comparison of more than a single kind of use:*** A comparison of the alternative uses of the land, farming systems, or crops is undertaken to determine suitability. Such a comparison is necessary to identify the land's most suitable sustainable use.

Thus, the basic concept in land evaluation is to match the requirements of land use with land qualities. Land evaluation is a study of the land use system which, in turn, is a study of two components : the kinds of land use in relation to the land mapping unit.

Land use can be described in either a major or a detailed way. Major kinds of land use descriptions are associated with reconnaissance land evaluation studies (for example, "rainfed agriculture"), while the detailed kinds, called land utilisation types (for example, "irrigation field maize"), are those associated with quantitative studies. In the latter example, there would be moderate financial resources, with moderate to high labour intensity, using small mechanical machinery, applying 'best' technology and maintaining near optimum management of fertilisation, irrigation, and control of weeds, pests, and disease.

The major kind of land use is only a generalised description, while the land utilisation type is a precise definition with specific requirements (capital, labour, technology used, scale of operation, and so on) of land use.

The second component of the land use system is the land mapping unit, and associated with this unit are land characteristics and land qualities. Here, the basic unit under evaluation is the land and its soils, climate, vegetation, topography, and other land-related factors.

Land characteristics include the soil properties and other features such as slope angle and biomass vegetation, while land qualities are the result of the interactions of two or more land characteristics. Some examples of land qualities that relate to crop productivity include moisture availability, nutrient availability (e.g., phosphorus), oxygen availability in the rooting zone, and workability of the land. For phosphorus availability, examples of interacting characteristics are soil pH, amount and kind of soil minerals, levels of primary phosphorus, etc.

Thus, the land evaluation method relates the specified types of land use, or the land utilisation type, to the land mapping units. The use requirements of the land utilisation types are matched with the land characteristics and qualities of the land mapping units. The land suitability classification is then derived to show the assessment of a given parcel of land for a defined use based on current condition or after improvements.

12.3 Land Use Implications of Soil Taxonomy

What role does Soil Taxonomy have in better understanding soil agronomy and land use? Soil Taxonomy makes it easier to map, describe and interpret soils and greatly assists the transition from soil survey to land use, development, and management. The hierarchic structure of the classification, definitions of the categories and the key diagnostic horizons makes Soil Taxonomy a powerful tool for making and interpreting soil surveys and conducting land use planning.

The ***diagnostic horizons*** can (through these definitions) say much about soil properties, fertility, and limitations. For example, the mollic and umbric surface horizons (epipedons) can be described as follows:

The ***mollic epipedon*** (see ***Wainibuka*** series) is a mineral surface horizon that is dark coloured, friable, high in bases and high in organic matter. It is very fertile; while the ***umbric epipedon*** (see ***Vakawau*** series) is like the mollic epipedon in all aspects, except it is low in bases. It responds well to applications of plant nutrients.

Similarly descriptions influencing land use are given in the diagnostic subsurface horizons; for example, the ***oxic horizon*** (see ***Nadi*** series). The oxic horizon represents the most advanced stage of weathering. The clays are totally weathered and sesquioxides have accumulated. It is very low in bases and differs from the cambic horizon in this respect. The oxic horizon differs from the argillic horizon by lacking clay coatings and by lacking an increase in clay with increasing depth.

Pans (see ***Namosau*** series) are subsurface horizons that are cemented by a variety of materials including iron, aluminium, calcium carbonates, etc. They restrict the downward movement of both roots and water.

An outline of Entisols and Oxisols – two of the nine soil orders – which represent each end of the weathering spectrum – is given to show how their properties relate to agronomic and other land use decisions.

The ***Entisols*** are essentially the very young soils formed on recent alluvial fans, or flood plains; unstable soils on mountain slopes or soils whose geologic erosion is in equilibrium with soil development. Some Entisols are so young or so 'raw' it is difficult even to call them soil. Entisols have a very wide range of soil moisture and temperature regimes, texture, mineralogy, slope, vegetative cover, and landform. They are deposited by wind, water, or gravity; are nearly level to extremely steep; and are excessively drained to very poorly drained and ponded.

Since about the only characteristic the Entisols have in common is their lack of genetic soil horizons, it is extremely difficult to make generalisations about their potential for use and management – at the order level at least. Much more can be said about Entisols at the suborder or lower category levels. For instance, the Aquents are wet Entisols whose use and management are limited by a periodically high water table. Fluvents are Entisols on flood plains whose use and management is limited by periodic flooding with its associated scouring and deposition of new materials. Psamments (see ***Yasawa*** series) are the sandy

Entisols with low available water capacity and nutrient retention capacities, high soil blowing hazard, low bearing capacity when dry, and rapid permeability.

Probably less is known about the ***Oxisols*** (see ***Cikobia*** series) than any of the other orders. The Oxisols represent the extreme or ultimate in weathering. They are typically weathered to great depths, and have weakly expressed soil horizonation. They are more rapidly permeable for a given clay content, than other orders, such as the Alfisols, Mollisols, Ultisols, and Vertisols. The Oxisols are generally formed under tropical forests on ancient stable landscapes. Most Oxisols are clayey and are dominated by sesquioxides. Typical mineralogy is ferritic, oxidic, or gibbsitic.

Oxisols typically have low productivity for cultivated crops unless large amounts of both major and minor nutrients are applied. Applications of organic matter are also important in maintaining the productive capacity of these soils. Many areas of Oxisols are bare and may never produce vegetation without help from humans. As a result they are source areas of sediments because of the severe erosion problem. In some instances the soils have been subjected to sufficient sheet erosion that concretions have been concentrated and now completely cover the soil surface. The Oxisols have unique engineering properties that are not fully understood. They are, however, generally fairly well suited to most engineering and urban use.

By using ***Soil Taxonomy*** we can take any soil map and prepare a specified area plan giving the best locally adapted uses for that area. A knowledge of locally adapted crops, community needs, the chemical and physical limitations of the soils (through the classification), will help achieve a better result in land use planning. This is done by matching crops and land uses to soil suitability as much as possible.

13.1 Introduction

Land use conflicts are inevitable where the demands for competing uses – cropping, grazing, forestry, urban development, environmental protection, tourism – out-strip the land resources available. These demands will increase as population increases. Constraints of land tenure, scarcity of versatile soils, a high proportion of hill and steepland relative to arable land, and large tracts of degraded land (e.g., talasiga soils) are some of the factors which heighten the pressure (and conflicts) on limited land resources in Fiji.

Land use planning is the logical process for resolving these problems, evaluating land, determining the land use options available, and providing planners and decision-makers with the information on which plans for sustainable land use should be based.

Principles developed by FAO to promote sustainability include:

- managing the land in order to maintain or improve its productive capacity through erosion control, manuring, irrigation;
- assessing and preparing for predictable natural hazards such as drought, floods, cyclones, tsunamis, mass movement, etc.; and
- minimising the loss of productive land, for example, protecting versatile arable soils for food production, siting urban development on land that is not critical for other desirable uses.

Broadly, land use planning aims to enhance the use of limited resources by:

- assessing current and future needs and evaluating the land's capacity to meet them;
- resolving conflicts between competing uses;
- identifying sustainable optional uses and indicating those that best meet the needs;
- planning to achieve the needed changes; and
- learning from past development mistakes.

13.2 Urban Soils and Land Use

The engineering properties of soils rather than their capacity to grow plants dominate any soil evaluation in areas zoned urban or being considered for urban use. The main purpose of urban soil surveys is to identify those areas that may present soil-related hazards for urban development.

The soil properties to be measured and understood in an urban soil survey include: depth and rockiness; soil erodibility and dispersibility; soil drainage and permeability; suitability for foundation material; fertility; and proneness to land sliding and related phenomena. Compared to rural surveys an emphasis is placed on subsoil characteristics.

13.3 Planning at Different Scales

For Fiji, land use planning can be applied at three scales: national, divisional, and village. At each level there needs to be a broad planning strategy, policies that show planning priorities, indicative projects to address the priorities, and operational mechanisms to implement the work. At each successive level the participatory planning with the community and amount of detail required increases.

13.4 Land use Planning Activities

While land use planning is non-sectoral, a land use plan has to be implemented, not by planners but by sectoral agencies, for example, Ministries of Agriculture, Forestry, Fisheries and ALTA (MAFFA), Fijian Affairs, Lands and Survey; water authorities; extension services.

13.5 People in Planning

Land use planning involves getting many different people to work together towards common goals. Three groups of people are involved – land users, decision-makers and the land use planning team. Fig. 19 shows a likely model for the different roles people have in the planning process and the inter-relationships between these groups, including government (legislation, policy, resources) and sectoral agencies who are responsible for implementation.

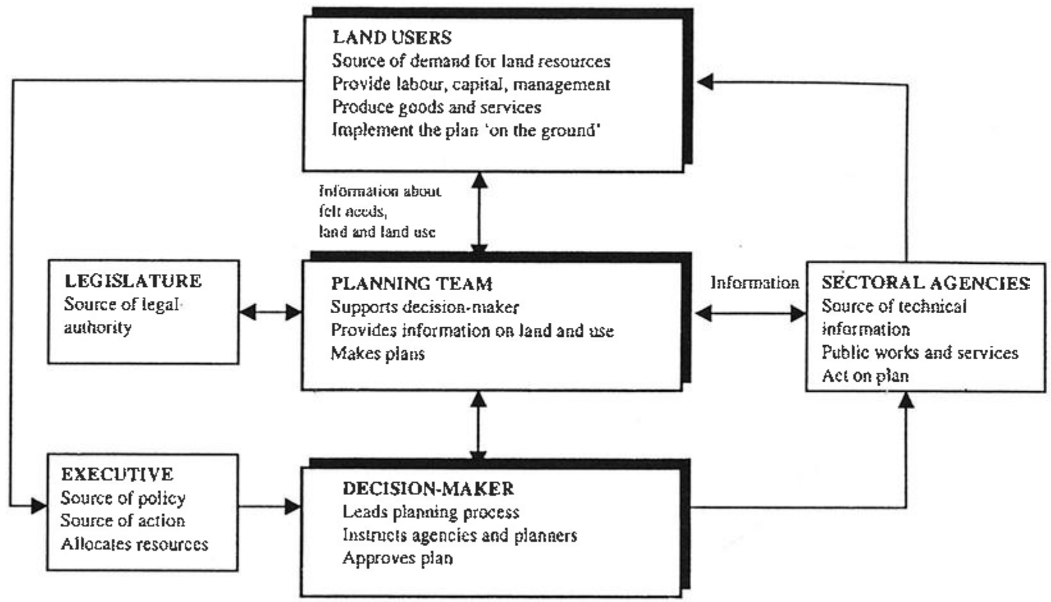
13.6 Role of Soil and Land Resource Specialists

Each planning project is different, because local conditions are unique, but the sequence of steps in land use planning is the same whether the project is a village-based land use plan, a national land use strategy, or something in between. FAO has identified ten steps in the planning process. Each step represents an activity or set of activities, and their outputs provide information for subsequent steps. The ten steps, in order, are:

(a) Establish goals and terms of reference
(b) Organise the work
(c) Analyse the problems
(d) Identify opportunities for change
(e) Evaluate land suitability
(f) Appraise alternatives
(g) Choose the best option
(h) Prepare the land use plan
(i) Implement the plan
(j) Monitor and revise the plan

Soil and land resource specialists have major input into steps 'd' and 'e'. Step 'd' evaluates promising land uses by way of identifying and drafting a design for a range of land use types that might achieve the goals of the plan These options are then presented to stakeholders for public discussion. Step 'e' involves evaluating land suitability – this process starts with the specific land resource

Figure 19: People in planning



surveys, of which soil surveys are fundamental. Based on these, a physical land evaluation is conducted. Various land uses – for example, crop-specific suitabilities – are then modelled, using appropriate software in a land information system (GIS) of the type established at Koronivia Research Station. The main output for step 'e' is land suitability maps, which are then analysed with farming system, socio-economic and environmental data in step 'f', from which viable land use options are developed.

For managed and sustainable development, protection of fragile ecosystems, conservation of biodiversity, and socio-economic well-being it is of some urgency that sound land use planning is introduced at all levels in Fiji's administration.

The typifying soil series presents a graphical representation of the soil profile features (colour, structure, roots and other features such as mottles, concretions, stones, etc.), horizonation with designations and the key profile features. On the opposing page is descriptive information about the soil in four parts:

(i) **General reference data**

The soil series is classified to three ***soil classification*** systems:

- Soil Taxonomy (Soil Survey Staff, 1975)
- The legend of the World Soil Map (FAO, 1974) and
- The Soil Resources of the Fiji Islands (Twyford and Wright, 1965)

Parent material is the weathered unconsolidated material from which the soil has been formed (Chapter 2.2).

Landscape position describes the facet or element of the landscape in which the soil most commonly occurs.

Soil moisture regime gives the regime under which the soil occurs, according to Soil Taxonomy. The alternatives are aquic, udic/perudic, or ustic. These are defined in Chapter 7.4.

Drainage class refers to natural drainage conditions prevailing at sites at which the soil occurs. They are very poorly drained; poorly drained; imperfectly drained; moderately well drained; well drained; somewhat excessively drained; and excessively drained.

(ii) **Profile description**

This gives the detailed description for the typifying profile for the soil series and follows definitions for profile features described in Chapter 4. The graphical presentation of the profile follows this description.

(iii) **Fertility data**

Only the chemical features that relate to soil fertility are considered. These are - soil pH, phosphorous, organic matter, potassium and, where relevant, soil salinity. The ratings on which the assessments are based are described in Chapter 10.

(iv) **General limitations and potential for land use**

Here the main soil limitations which affect land use are listed. These include such factors as rooting volume, available nutrients, water-holding capacity, internal drainage, slope, erosion potential, etc.

Potential land use recommendations are given for unimproved land and for land suitable for amelioration and the different types of improvements are indicated.

For permanent agriculture on unimproved land, pasture is the predominant recommendation and, for shifting cultivation, the crops most commonly grown by Fijians.

For improved land first, second, and third choices are given. Abbreviations are given for the type of amelioration required. These are as follows:

C	= contour planting	i	= minor irrigation
d	= local drainage	I	= irrigation a prerequisite
D	= major drainage	S	= planted shade
f	= small fertiliser inputs	T	= terracing
F	= major fertiliser input needed	W	= livestock water system
g	= improved grass species		

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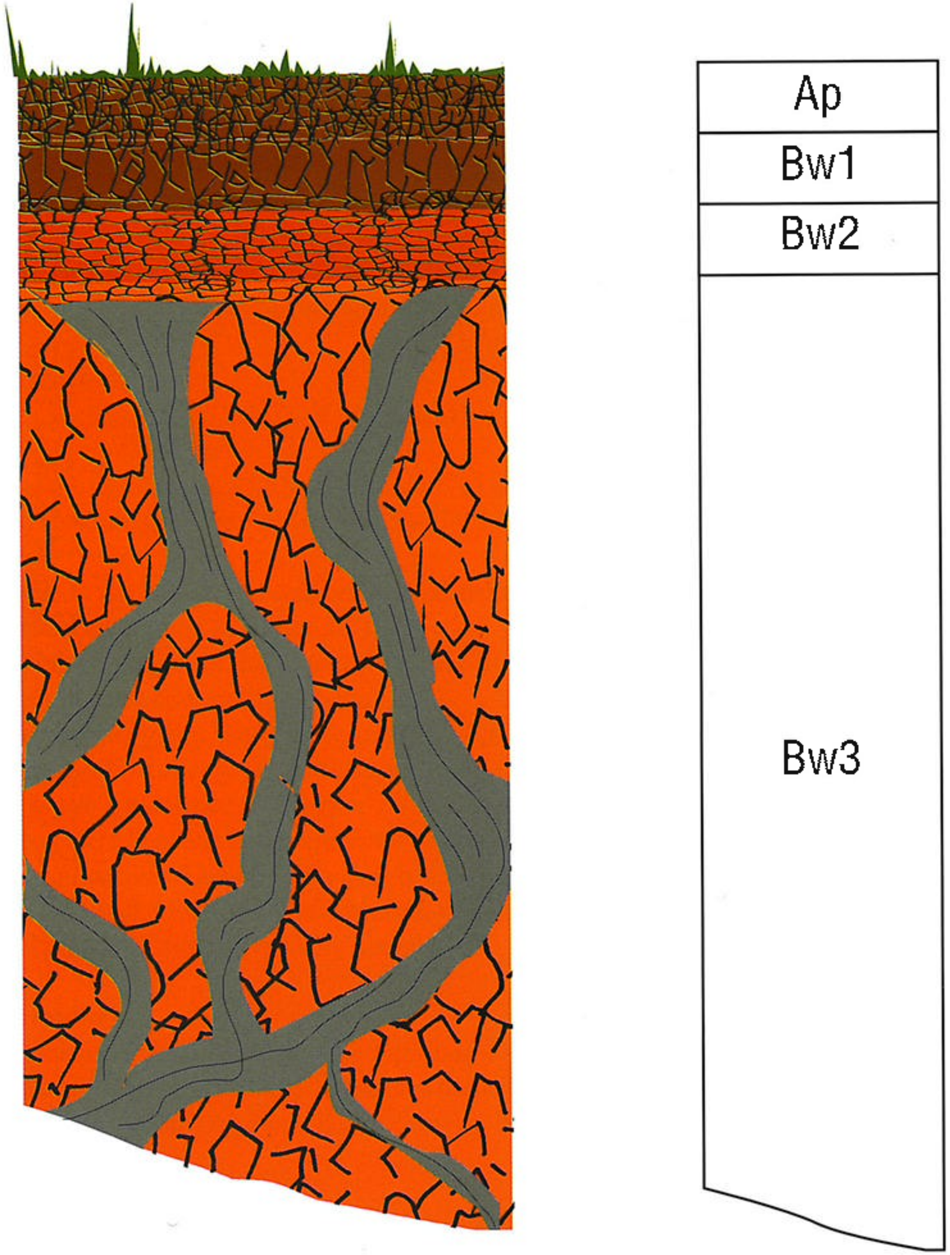
Bua



- Reddish brown and very friable Ap and Bw1 horizons
- Weathered dark red *in situ* basalt, streaked yellow and black at 28 cm
- Clayey textures
- Ironstone gravels in Ap horizon

BUA

Classification:

Soil Taxonomy: Typic Kanhaplustalf, very fine, ferruginous, isohyperthermic
FAO: Eutric Planosol
Twyford and Wright: Ferruginous latosol with strong dry season

Parent Material: Strongly weathered ***in situ*** rock of basic composition
Landscape Position: Planar surfaces on undulating to rolling slopes of hilly land
Moisture Regime: Ustic **Drainage Class:** Well drained

Horizon	Depth (cm)	REPRESENTATIVE PROFILE DESCRIPTION	Diagnostic Horizons
Ap	0–8 cm	reddish-brown clay; moderate fine granular structure; very friable; few ironstone gravels; many roots; indistinct boundary,	Ochric
Bt1	8–18 cm	reddish-brown clay; weak medium blocky structure; very friable; few roots; few weathered stones; distinct boundary,	
Bt2	18–28 cm	dark red clay; moderate fine nut structure; friable; distinct boundary,	Argillic
Bt3	28–110+ cm	dark grey loam; weak coarse blocky structure; sticky; abundant shell fragments; few stones; many coral fragments; high organic matter.	

FERTILITY DATA

pH: strongly acid	Phosphorous: very low	Organic Matter: very low
Potassium: high		

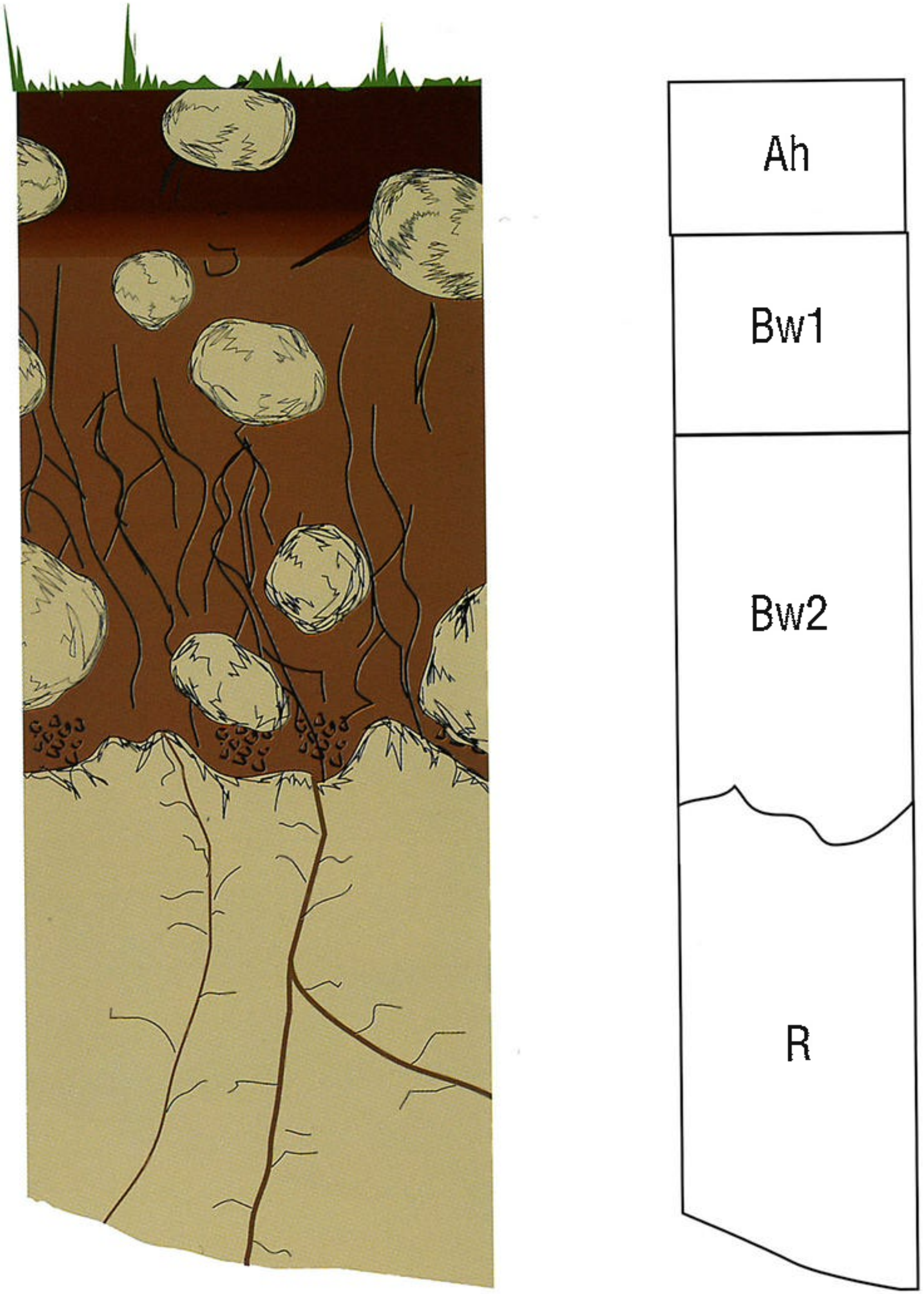
GENERAL LIMITATIONS AND POTENTIAL FOR LAND USE

Soil limitations
Moisture stress (dry season); Al. toxicity; anion fixation; rapid permeability; soil acidity; nutrient deficiencies; erosion risk (slopes >3°)

Land use options for unimproved land
(a) Shifting cultivation: tavioka, pineapples; slopes >11° – tavioka
(b) Permanent use: inferior pasture on all slopes

Land use options for improved land (with ameliorations)
(a) Preferred use: pineapples (F, C), pulses (F, C); slopes >11° – pasture (f)
(b) 1st alternative: cane (F. C, i), mango (F, i), pawpaw (F, i), macadamia nuts (F, i)
(c) 2nd alternative: pasture (F, i, w)

Cikobia



- Strong nut structure in Ah horizon
- Reddish hues
- Friable, weak Bw horizon structures
- Coralline boulders
- *In situ* limestone rock at 95 cm

CIKOBIA

Classification:

Soil Taxonomy: Tropeptic Eutrustox, clayey, gibbsitic, isohyperthermic
FAO: Rhodic Ferralsol
Twyford and Wright: Latosolic soil with moderate to strong dry season

Parent Material: *In situ* limestone materials
Landscape Position: Flat to sloping surfaces in the centre of large areas of raised coralline limestone
Moisture Regime: Ustic **Drainage Class:** Well drained

Horizon	Depth (cm)	REPRESENTATIVE PROFILE DESCRIPTION	Diagnostic Horizons
Ah	0–22 cm	dark reddish brown clay loam; very friable; strong fine nut structure; abundant coarse and medium roots; many coral boulders (515 cm); indistinct boundary,	Ochric
Bw1	22–50 cm	dusky red clay; friable; weak, fine and medium nut structure; abundant coarse roots; few large coral boulders; indistinct boundary,	Oxic
Bw2	50–95 cm	dusky red clay; very friable; massive, breaking to weak medium crumb structure; few to many fine roots; few to many coral boulders (5–10 cm); distinct boundary,	
R	at 95 cm	hard white (stained red) coralline limestone..	

FERTILITY DATA

pH: slightly alkaline Phosphorous: medium Organic Matter: medium
Potassium: low

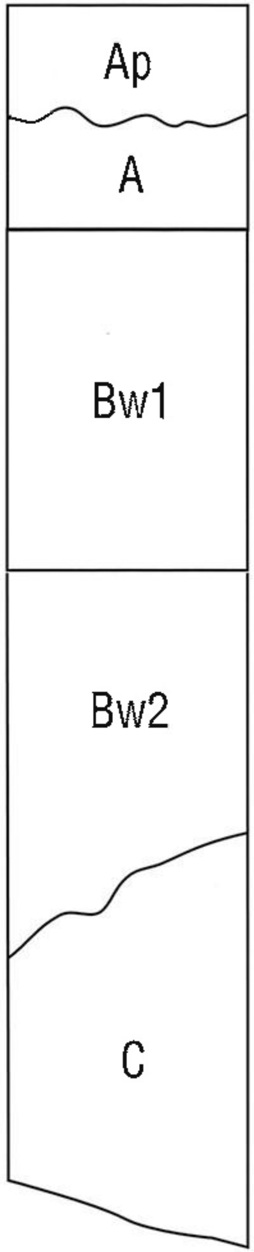
GENERAL LIMITATIONS AND POTENTIAL FOR LAND USE

Soil limitations
Moisture stress (dry season); rapid permeability; anion fixation; trace element deficiency (due high pH); rock outcrops; profile boulders

Land use options for unimproved land
(a) Shifting cultivation: kumala, dalo, yams, banana
(b) Permanent use: pasture

Land use options for improved land (with ameliorations)
(a) Preferred use: pasture (g, i, W)
(b) 1st alternative: pulses, maize (C, T, i, f)
(c) 2nd alternative: cane, market gardening (C, T, I, F), peanuts

Dawasamu



- Dark profile colours
- Sandy textures
- Single grain and loose consistence below 15 cm
- Concretions in most horizons

DAWASAMU

Classification:

Soil Taxonomy: Typic Quartzipsamment, ferritic, isohyperthermic
FAO: Arenosol
Twyford and Wright: Recent soil from coastal sands with a weak dry season

Parent Material: Non-calcareous black sands of low quartz content
Landscape Position: Low coastal dunes and beach margins
Moisture Regime: Udic **Drainage Class:** Somewhat excessively drained

Horizon	Depth (cm)	REPRESENTATIVE PROFILE DESCRIPTION	Diagnostic Horizons
Ap1	0–15 cm	very dark grey loamy sand; moderate fine granular structure; abundant fine roots; distinct boundary,	Ochric
Ap2	15–30 cm	black medium sand; single grain; loose; few large concretions; common fine roots; indistinct boundary,	
Bw1	30–75 cm	black medium sand; single grain; loose; few small concretions; few fine roots; indistinct boundary,	Cambic
Bw2	75–95 cm	black to very dark grey sand; single grain; loose; few concretions; few fine roots; distinct boundary,	
C	95–120+ cm	dark brown sandy loam; single grain; loose.	

FERTILITY DATA

pH: slightly alkaline	Phosphorous: very low	Organic Matter: very low
Potassium: very low	Salinity: low	

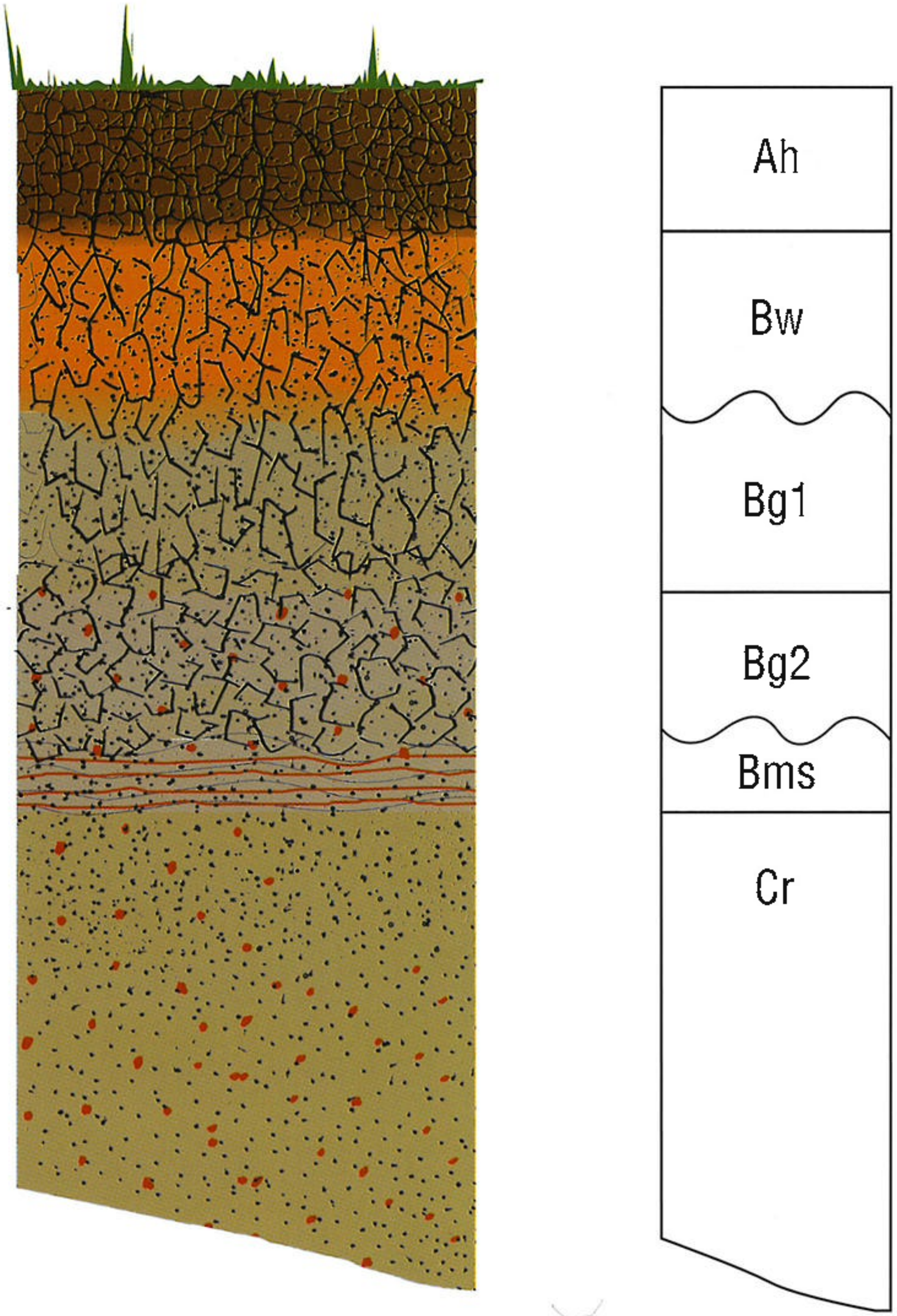
GENERAL LIMITATIONS AND POTENTIAL FOR LAND USE

Soil limitations
Excessively drained; moisture stress; nutrient deficiencies; erosion risk

Land use options for unimproved land
(a) Shifting cultivation: most food crops
(b) Permanent use: coconuts, pasture

Land use options for improved land (with ameliorations)
(a) Preferred use: market gardening (F)
(b) 1st alternative: maize, peanuts, cane, kumala, potatoes, pulses
(c) 2nd alternative: coconuts

Deuba



- Medium to coarse sand textures below 18 cm
- Strongly red mottled Bg horizons
- Cemented iron stained bedding in Bms horizon
- Water table at 73 cm

DEUBA

Classification:

Soil Taxonomy: Typic Tropaquept, sandy, mixed, isohyperthermic

FAO: Dystric Gleysol

Twyford and Wright: Gley soil related to red yellow podzolic soil with weak or no dry season

Parent Material: Estuarine alluvial sands of high quartz content derived from acidic rocks

Landscape Position: Coastal dunes with indistinct ridge and swale topography

Moisture Regime: Aquic **Drainage Class:** Poorly drained

Horizon	Depth (cm)	REPRESENTATIVE PROFILE DESCRIPTION	Diagnostic Horizons
Ah	0–18 cm	very dark greyish brown fine sandy loam; strong fine nut structure; friable; abundant fine roots; distinct boundary,	Ochric
Bw	18–46 cm	strong brown with patches of grey medium sand; weak coarse blocky structure; very friable; many fine roots; distinct wavy boundary,	Cambic
Bg1	46–69 cm	greyish brown coarse sand; many coarse red mottles; very weak coarse blocky structure; firm; slightly cemented; few fine roots; diffuse boundary,	
Bg2	68–89 cm	grey coarse sand; few coarse red mottles; weak coarse blocky structure; few fine roots; distinct wavy boundary,	
Bms	89–99 cm	dark grey to grey coarse sand; weak coarse blocky structure; extremely firm; cemented; strong bedding; iron staining in patches and bands; distinct boundary,	
Cr	99–115+ cm	grey coarse sand; few coarse red mottles; single grain.	

FERTILITY DATA

pH: strongly acid	Phosphorous: very low	Organic Matter: high
Potassium: low	Salinity: high	

GENERAL LIMITATIONS AND POTENTIAL FOR LAND USE

Soil limitations

Floods; high water table; reducing conditions; soil acidity; nutrient deficiencies

Land use options for unimproved land

(a) Shifting cultivation: dalo, tavioka

(b) Permanent use: rice, inferior pasture

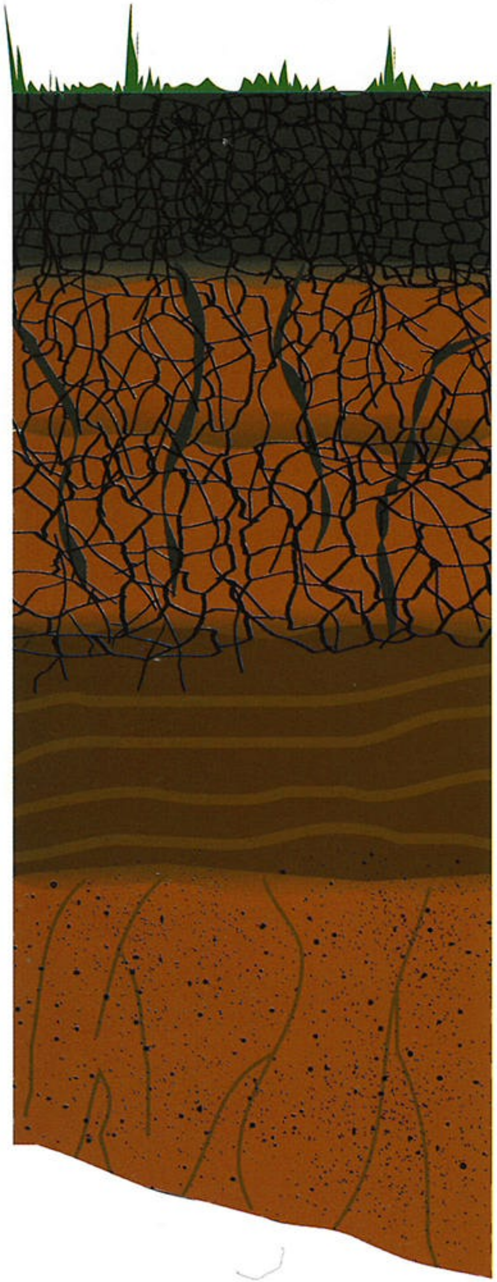
Land use options for improved land (with ameliorations)

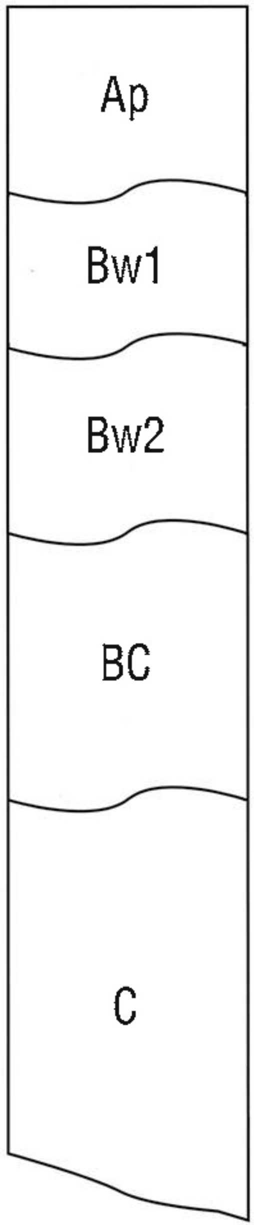
(a) Preferred use: rice (i, F)

(b) 1st alternative: pasture (d, f)

(c) 2nd alternative: –

Dobuilevu





- Massive and layered BC horizon encountered at 70 cm
- Well structured, friable Ap and Bw horizons
- Humus coatings to peds in Bw horizons
- Sandy C horizon with many black crystals

DOBUILEVU

Classification:

Soil Taxonomy: Typic Hapludoll, fine, smectitic, isohyperthermic
FAO: Haplic Phaeozem
Twyford and Wright: Nigrescent soil with weak to moderate dry season

Parent Material: Weathered ***in situ*** tuffaceous rock of basic composition
Landscape Position: Ridges, sideslopes, and slumped areas in hilly land
Moisture Regime: Udic **Drainage Class:** Well drained

Horizon	Depth (cm)	REPRESENTATIVE PROFILE DESCRIPTION	Diagnostic Horizons
Ap	0–23 cm	very dark grey clay; friable; plastic; strong fine nut structure; abundant fine roots; distinct wavy boundary,	Mollic
Bw1	23–46 cm	dark brown clay; many dark grey humus coatings; friable; strong medium blocky structure; few thin clay coats; many fine roots; indistinct wavy boundary,	Cambic
Bw2	46–71 cm	dark brown sandy clay loam; dark grey humus coatings on peds; friable; moderate coarse blocky structure; many fine roots; distinct wavy boundary,	
BC	71–103 cm	dark brown sandy clay loam; horizontal layers of clay (up to 1 cm thick); friable; massive; few fine roots; distinct wavy boundary	
C	103–130 cm	dark brown loamy sand; many black crystals; thin dark greyish brown veins; firm; massive.	

FERTILITY DATA

pH: strongly acid Phosphorous: very low Organic Matter: low
Potassium: medium

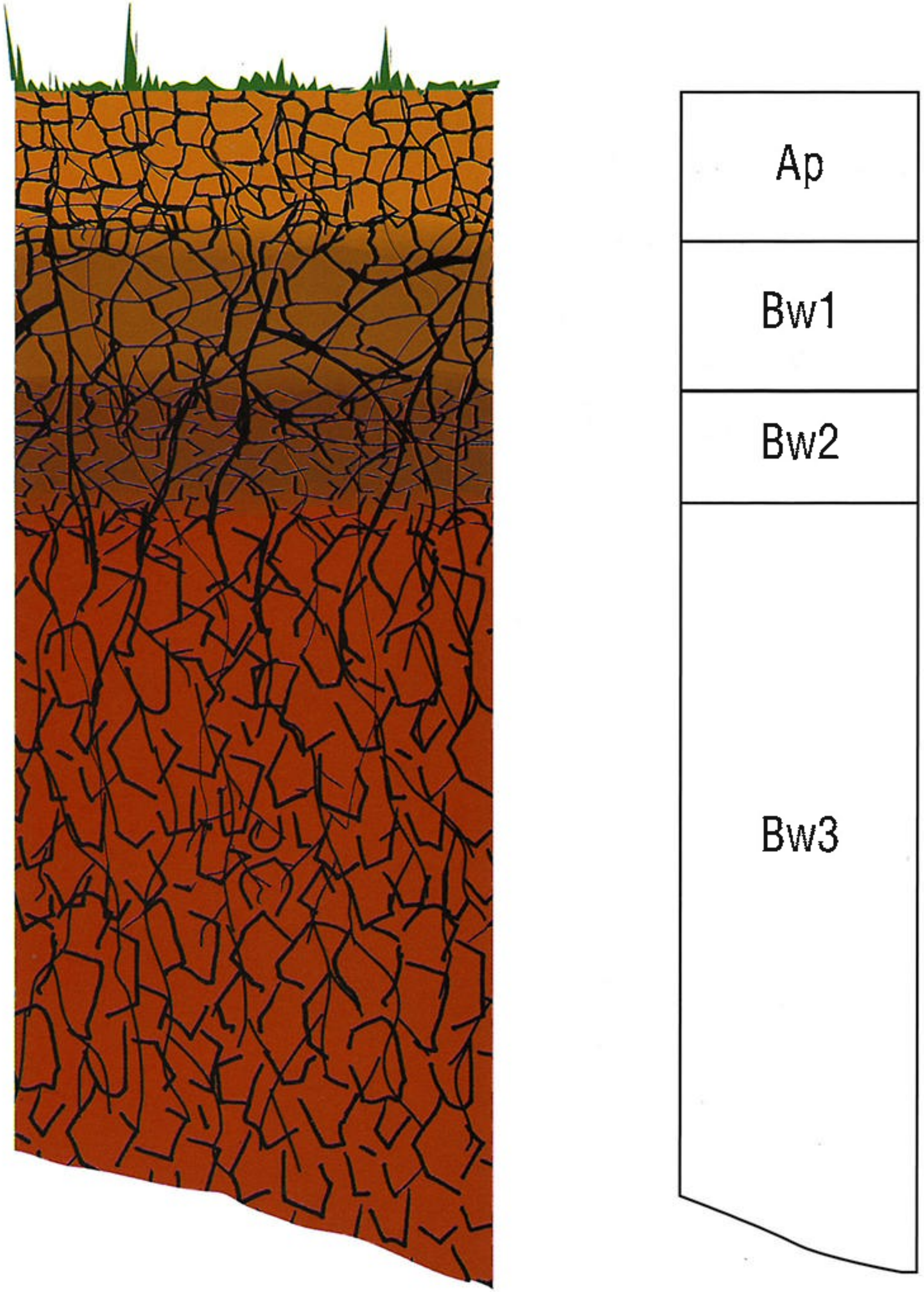
GENERAL LIMITATIONS AND POTENTIAL FOR LAND USE

Soil limitations
Moisture stress (dry season); slope; erosion risk on slopes >12°; nutrient deficiencies

Land use options for unimproved land
(a) Shifting cultivation: most food crops; slopes >11° – yams, kumala, tavioka
(b) Permanent use: pasture, coconuts; slopes >11° – pasture

Land use options for improved land (with ameliorations)
(a) Preferred use: cane (f, C), coffee (s), yaqona (f), cocoa (S), coconuts (f), bananas (f, i); slopes >11° – pasture
(b) 1st alternative: market gardening, peanuts, pulses, ginger (f, C), potatoes; slopes >11°– maize, pulses (f, C, T), yaqona (f), coconuts (f, C), cocoa (f, s)
(c) 2nd alternative: –

Dogotuki



- Bw horizons have firm, clay loam textures and blocky structures
- Strong brown well structured clayey Ap horizon
- Reddish brown to red Bw horizons

DOGOTUKI

Classification:

Soil Taxonomy: Ustic Humitropept, fine, kaolinitic, isohyperthermic
FAO: Humic Cambisol
Twyford and Wright: Red yellow podzolic soil with a moderate dry season

Parent Material: Weathered ***in situ*** rocks of acidic composition
Landscape Position: All slope positions in rolling hilly land
Moisture Regime: Ustic **Drainage Class:** Well drained

Horizon	Depth (cm)	REPRESENTATIVE PROFILE DESCRIPTION	Diagnostic Horizons
Ap	0–20 cm	strong brown clay; strong medium nut structure; firm; plastic; many fine roots; diffuse boundary,	Ochric
Bw1	20–39 cm	reddish brown clay loam; moderate nut and blocky structure; firm; sticky; common medium roots; diffuse boundary,	Cambic
Bw2	39–54 cm	reddish brown clay loam; weak medium blocky structure; firm; common medium roots; diffuse boundary,	
Bw3	54–100 cm	red clay loam; weak blocky structure; firm; few fine roots	

FERTILITY DATA

pH: moderately acid
Potassium: low
Phosphorous: very low
Organic Matter: low

GENERAL LIMITATIONS AND POTENTIAL FOR LAND USE

Soil limitations

Moisture stress (dry season); high Al.; soil acidity; nutrient deficiencies; erosion risk

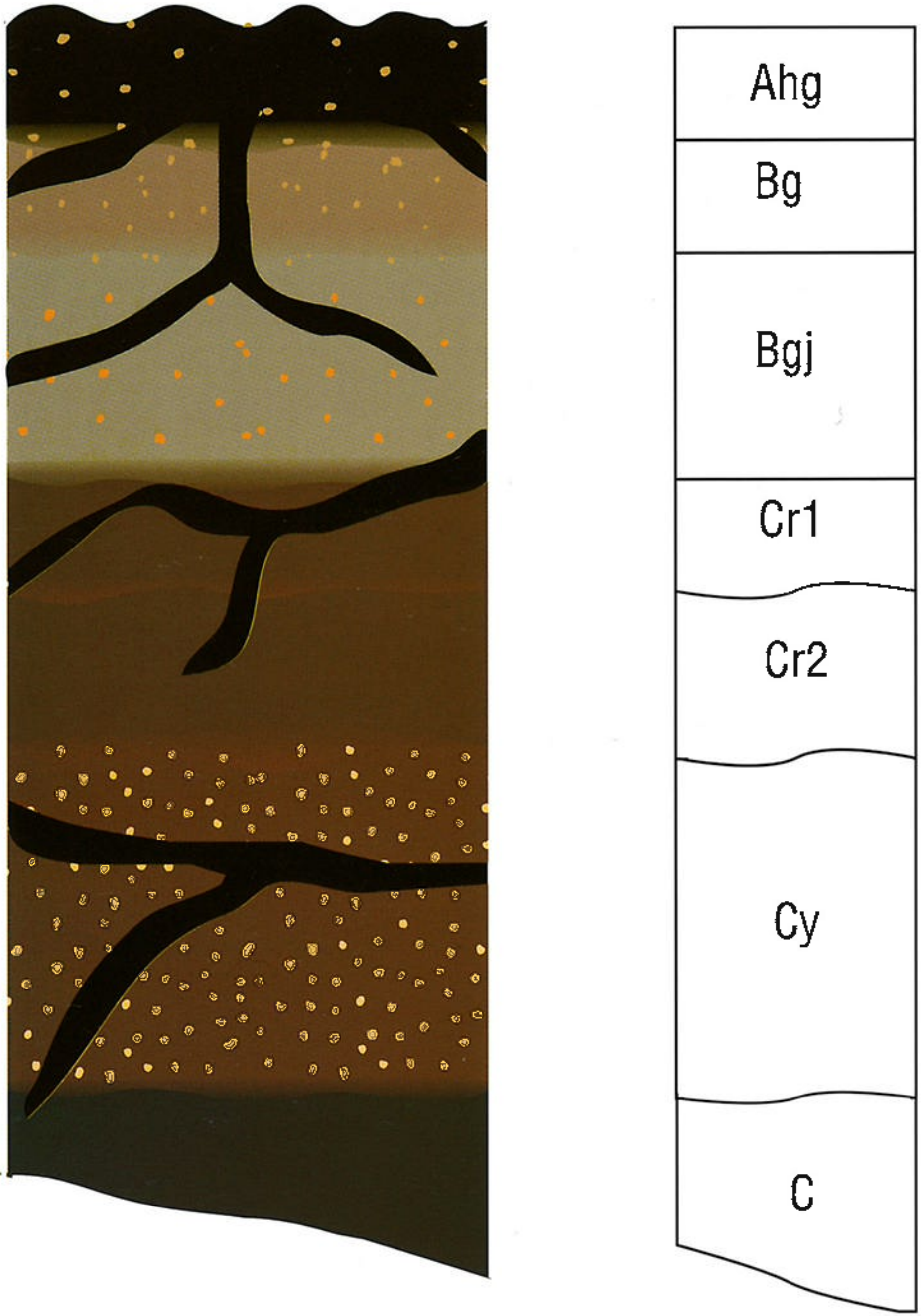
Land use options for unimproved land

(a) Shifting cultivation: tavioka, kumala
(b) Permanent use: inferior pasture

Land use options for improved land (with ameliorations)

(a) Preferred use: pasture (F, g)
(b) 1st alternative: cane (F, C); slopes >11° – citrus (T, F, C)
(c) 2nd alternative: pineapples, tavioka, citrus (f); slopes >11° – forestry

Dreketi



- Dark-coloured humus rich Ahg horizon
- Clayey, massive and plastic Bg horizons
- Yellow jarosite mottles below 60 cm
- Water table at about 65 cm
- Dead mangrove roots in all horizons
- Shell fragments and gypsum crystals in Cy horizon
- Sandy textures below 140 cm

DREKETI

Classification:

Soil Taxonomy: Sulfic Tropaquept, clayey, mixed, isohyperthermic
FAO: Thionic Fluvisol
Twyford and Wright: Saline soil of the marine marsh

Parent Material: Alluvia from marine and river sources
Landscape Position: Deltas where artificial drainage has occurred (often behind sea walls)
Moisture Regime: Aquic **Drainage Class:** Very poorly drained

Horizon	Depth (cm)	REPRESENTATIVE PROFILE DESCRIPTION	Diagnostic Horizons
Ahg	0–14 cm	black peaty silty clay; few yellowish brown mottles; moderate medium crumb structure; friable; abundant fine dead roots; distinct boundary,	Umbric
Bg	14–32 cm	greyish brown clay; many yellowish brown mottles; massive; very plastic; very firm; many fine dead roots; distinct boundary,	Cambic
Bgj	32–58 cm	greyish brown clay; profuse yellow mottles; massive; firm; plastic; many fine dead roots; sharp boundary,	Sulfuric
Cr1	58–72 cm	dark brown clay; massive; firm; plastic; common fine dead roots; distinct wavy boundary	
Cr2	72–95 cm	dark grey silty clay; massive; friable; many medium dead roots; distinct wavy boundary,	
Cy	95–141 cm	dark brown silty clay loam; many very pale brown mottles; many medium dead roots; distinct wavy boundary,	
C	141–170+ cm	dark grey loamy fine sand; single grain; loose; few fine dead roots.	

FERTILITY DATA

pH: strongly acid	Phosphorous: low	Organic Matter: high
Potassium: medium	Salinity: high	

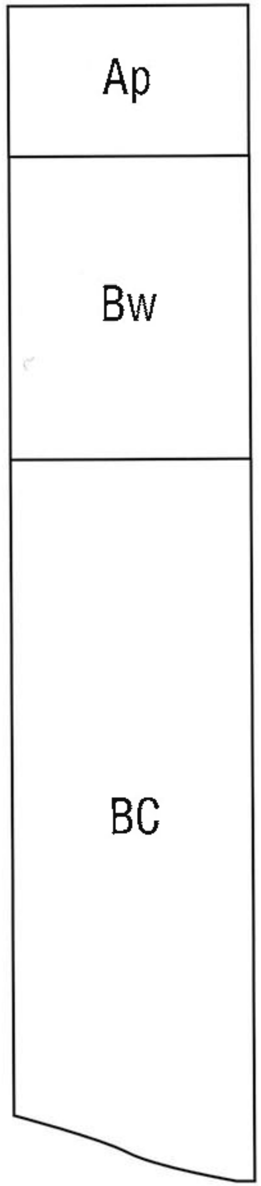
GENERAL LIMITATIONS AND POTENTIAL FOR LAND USE

Soil limitations
Drainage; water table fluctuations (with tides); reducing conditions; soil acidity; high Na

Land use options for unimproved land
(a) Shifting cultivation: dalo, rice
(b) Permanent use: pasture, cane, rice

Land use options for improved land (with ameliorations)
(a) Preferred use: market gardening (d, F)
(b) 1st alternative: rice (d), cane (D)
(c) 2nd alternative: coconuts, pasture (D)

Emuri



- Black horizon colours and clayey textures
- Firm, sticky and plastic consistence
- Strongly developed very coarse blocky structures
- Polished ped surfaces and slickensides
- Parent material grits and fine gravels

EMURI

Classification:

Soil Taxonomy: Udic Haplustert, fine, smectitic, isohyperthermic
FAO: Pellic Vertisol
Twyford and Wright: Nigrescent soil with a strong dry season

Parent Material: Strongly weathered colluvium from basic rocks
Landscape Position: Toeslopes and valley floors in hilly land
Moisture Regime: Ustic **Drainage Class:** Poorly drained

Horizon	Depth (cm)	REPRESENTATIVE PROFILE DESCRIPTION	Diagnostic Horizons
Ap	0–20 cm	black clay; strong very coarse blocky structure; firm; sticky; plastic; common slickensides to peds; common fine and medium roots; common weakly weathered grits; indistinct boundary,	Ochric
Bw	20–60 cm	black clay; strong very coarse blocky structure; very firm; sticky; plastic; black slickensides and polished surfaces; few fine and medium roots; common weakly weathered very fine gravels; indistinct boundary,	Cambic
BC	60–110+ cm	black clay; few fine yellowish red mottles; massive to weak coarse columnar structure; firm; sticky; plastic slickensides and polished surfaces; common weakly weathered very fine gravels.	

FERTILITY DATA

pH: moderately acid Phosphorous: high Organic Matter: medium
Potassium: medium

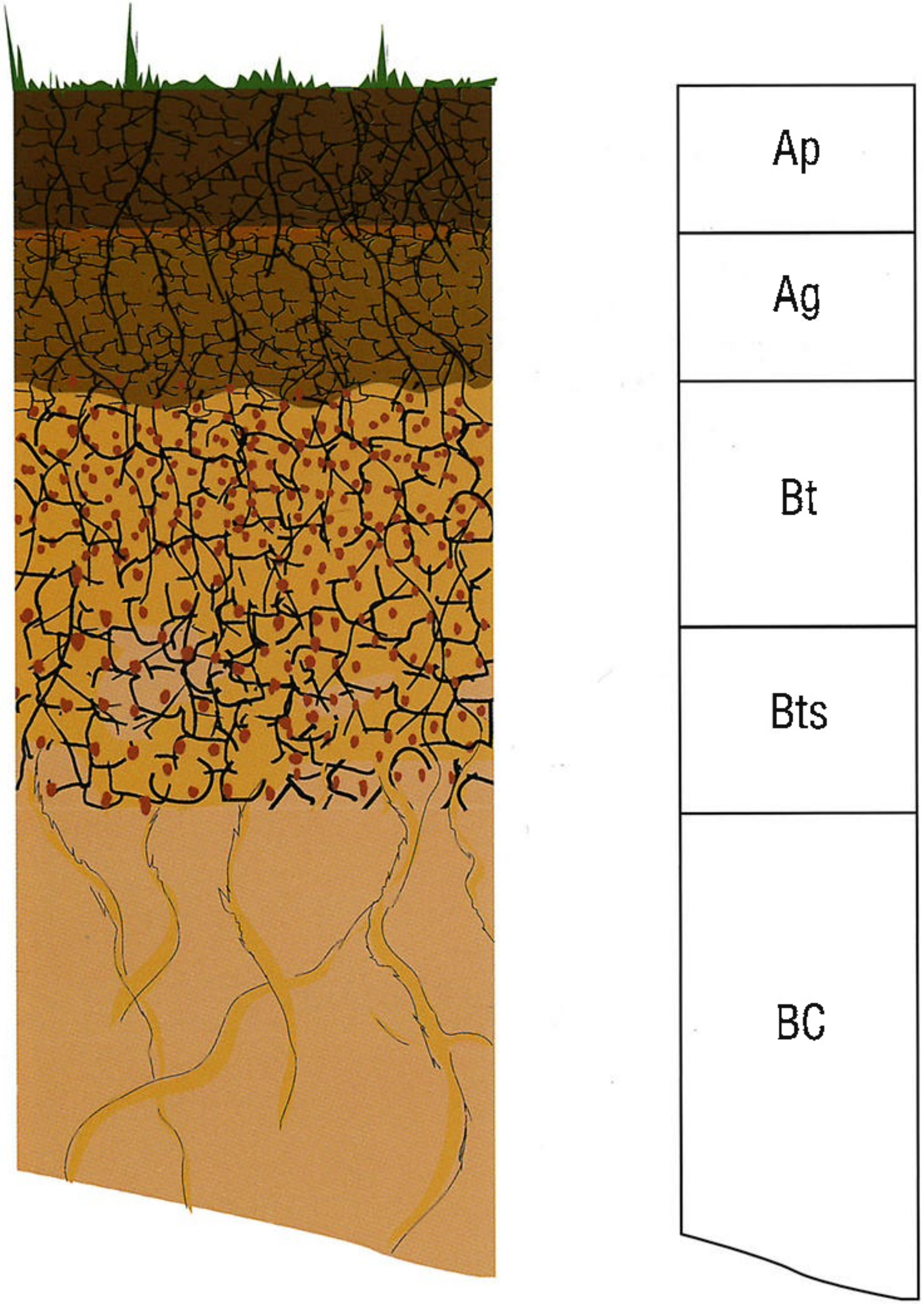
GENERAL LIMITATIONS AND POTENTIAL FOR LAND USE

Soil limitations
Moisture stress (dry season); subsoil waterlogging (wet season); vertic properties; clayey; nutrient deficiencies

Land use options for unimproved land
(a) Shifting cultivation: dalo, rice
(b) Permanent use: pasture, cane, rice

Land use options for improved land (with ameliorations)
(a) Preferred use: market gardening (d, F)
(b) 1st alternative: rice (d), cane (D)
(c) 2nd alternative: coconuts, pasture (D)

Koronivia



- Humus rich and fine structured Ap horizon
- Distinctly mottled Ag and B horizons
- Clayey firm and sticky B horizons with coarse nut structures
- Clay coatings to peds in B horizons
- Strongly weathered *in situ* parent material at 100 cm

KORONIVIA

Classification:

Soil Taxonomy: Typic Kandihumult, clayey, kaolinitic, isohyperthermic
FAO: Humic Nitosol
Twyford and Wright: Red yellow podzolic soil with no dry season

Parent Material: Weathered outwash from acidic rocks, deposited and marine planated
Landscape Position: Flattish surfaces of dissected plateaux remnants
Moisture Regime: Perudic **Drainage Class:** Imperfectly drained

Horizon	Depth (cm)	REPRESENTATIVE PROFILE DESCRIPTION	Diagnostic Horizons
Ap	0–18 cm	dark brown silt loam; humic staining along root channels; weak nut with granular structure; friable to firm; many fine roots; indistinct boundary	Ochric
Ag	18–41 cm	olive brown silt loam; common yellowish red mottles; weak fine nut and granular structure; friable; common fine roots; sharp wavy boundary,	
Bt	41–73 cm	yellowish brown clay loam; few dark red mottles; weak coarse nut structure; firm; sticky; few yellowish brown clay coats; few very fine roots; indistinct boundary,	Argillic
Bts	73–100 cm	yellowish brown with very pale brown clay loam; abundant coarse dark red mottles; weak coarse nut structure; firm; sticky; common strong brown clay coats; indistinct boundary,	
BC	100–130+ cm	very pale brown silty clay loam; massive; firm; few, yellowish brown clay coats; *in situ* strongly weathered rock.	

FERTILITY DATA

pH: strongly acid Phosphorous: very low Organic Matter: low
Potassium: low

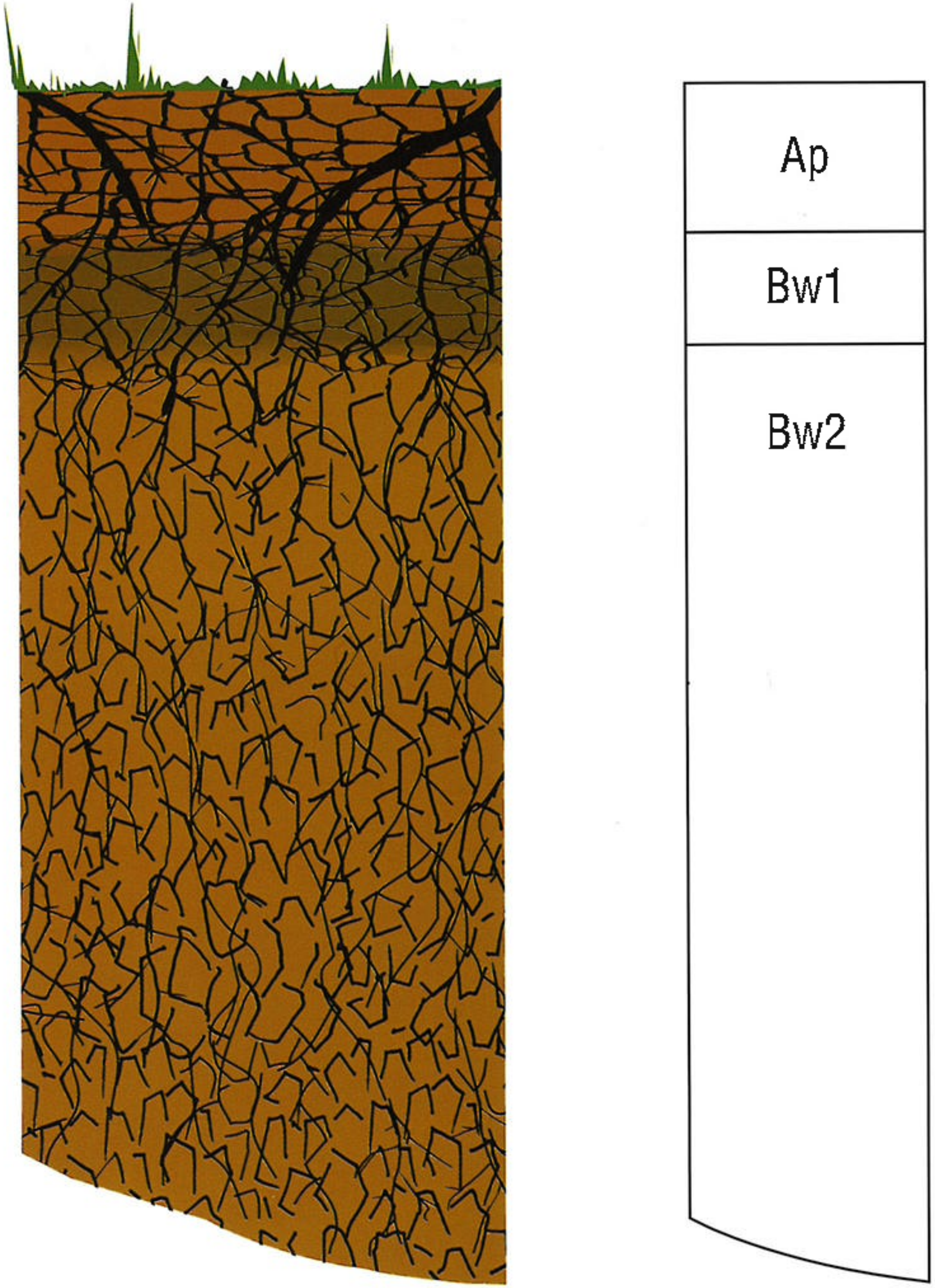
GENERAL LIMITATIONS AND POTENTIAL FOR LAND USE

Soil limitations
Imperfect drainage; slow permeability; high Al.; soil acidity; nutrient deficiencies

Land use options for unimproved land
(a) Shifting cultivation: tavioka
(b) Permanent use: inferior pasture

Land use options for improved land(with ameliorations)
(a) Preferred use: pasture
(b) 1st alternative: coffee, citrus (d, f)
(c) 2nd alternative: tea (d, F)

Lagilagi



- Sandy clay loam Ap horizon with strong nut structure
- Firm consistence
- Bw horizons have coarse blocky structures

LAGILAGI

Classification:

Soil Taxonomy: Ustoxic Dystropept, fine, kaolinitic, isohyperthermic
FAO: Dystric Cambisol
Twyford and Wright: Recent soil with moderate to strong dry season

Parent Material: Alluvium of high quartz content (from acidic rocks)
Landscape Position: Flood plains and low terraces
Moisture Regime: Ustic **Drainage Class:** Well drained

Horizon	Depth (cm)	REPRESENTATIVE PROFILE DESCRIPTION	Diagnostic Horizons
Ap	0–20 cm	dark brown sandy clay loam, strong nut structure; firm; many fine roots; diffuse boundary,	Ochric
Bw1	20–36 cm	brown clay loam; moderate coarse blocky structure; firm; slightly sticky; plastic; many fine roots; diffuse boundary,	Cambic
Bw2	36–100 cm	dark yellowish-brown clay loam; weak coarse blocky structure; firm; slightly sticky; many fine roots.	

FERTILITY DATA

pH: moderately acid
Potassium: very low
Phosphorous: very low
Organic Matter: low

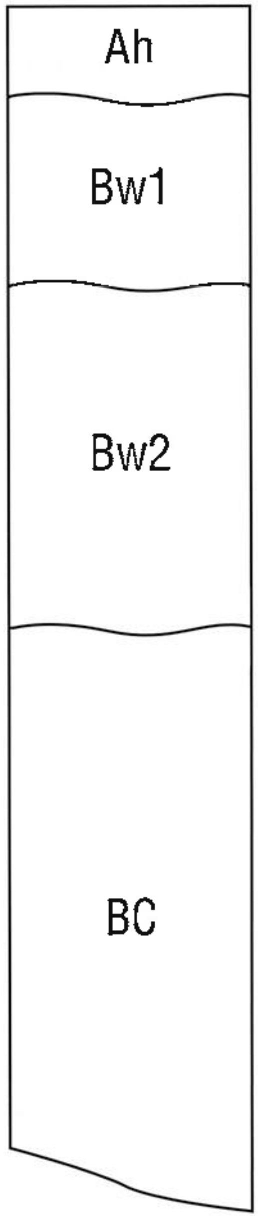
GENERAL LIMITATIONS AND POTENTIAL FOR LAND USE

Soil limitations
Moisture stress (dry season); high Al.; nutrient deficiencies

Land use options for unimproved land
(a) Shifting cultivation: most food crops
(b) Permanent use: pasture, cane, bananas

Land use options for improved land (with ameliorations)
(a) Preferred use: cane, maize, pulses, potatoes, ginger, dalo, gardening (f, i)
(b) 1st alternative: coffee, cocoa, bananas (s, f)
(c) 2nd alternative: peanuts (f), coconuts (f), pasture (i, f)

Lomaiviti



- Dark reddish brown Ah horizons
- Red Bw horizons
- Clay coatings to peds in Bw horizons
- Firm, sticky and plastic consistence
- Weathered in situ rock at 85 cm

LOMAIVITI

Classification:

Soil Taxonomy: Typic Eutropept, fine, mixed, isohyperthermic
FAO: Eutric Cambisol
Twyford and Wright: Humic latosol with a weak dry season

Parent Material: Weathered ***in situ*** from basalt and rocks of basic composition
Landscape Position: In all slope positions in hilly land
Moisture Regime: Perudic **Drainage Class:** Well drained

Horizon	Depth (cm)	REPRESENTATIVE PROFILE DESCRIPTION	Diagnostic Horizons
Ah	0–12 cm	dark reddish brown clay; friable to firm; sticky; plastic; moderate fine nut structure; many fine and medium roots; indistinct wavy boundary,	Ochric
Bw1	12–39 cm	red clay; firm; sticky; plastic; strong fine and medium blocky structure; common distinct red clay coats; many fine and medium roots; indistinct wavy boundary,	Cambic
Bw2	38–85 cm	red clay; firm; sticky; plastic; moderate fine and medium blocky structure; common distinct red clay coats; common fine roots; few strongly weathered stones; indistinct wavy boundary,	
BC	85–120+ cm	weathered ***in situ*** rock; yellowish red coarse sandy clay loam; firm to very firm; massive common red clay coats along fissures; few very fine roots.	

FERTILITY DATA

pH: moderately acid
Phosphorous: very low
Organic Matter: medium
Potassium: high

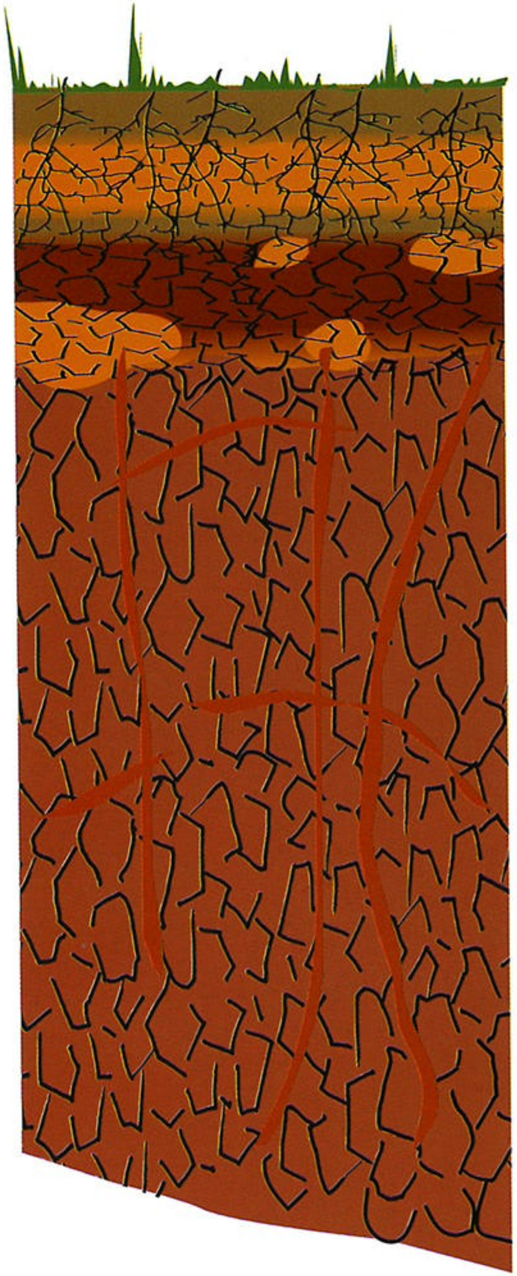
GENERAL LIMITATIONS AND POTENTIAL FOR LAND USE

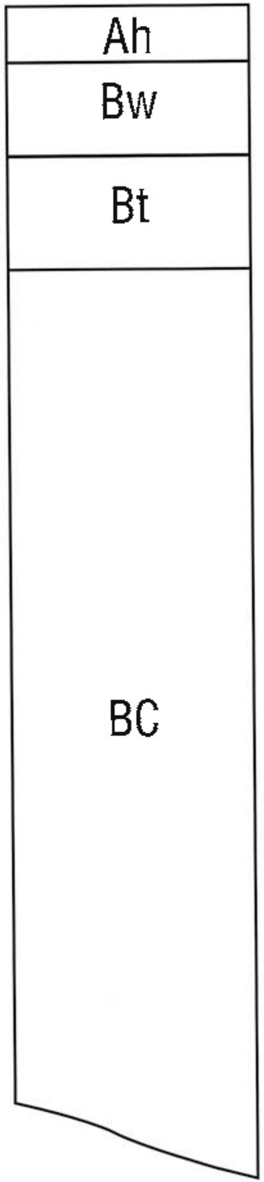
Soil limitations
Soil acidity; nutrient deficiencies; erosion risk; slope

Land use options for unimproved land
(a) Shifting cultivation: most food crops
(b) Permanent use: coconuts, pasture; slopes >11°– cocoa

Land use options for improved land (with ameliorations)
(a) Preferred use: cocoa (f), bananas (f), yaqona (f); slopes >11° – pasture (f)
(b) 1st alternative: pasture (f), coconuts, coffee; slopes >11° – cocoa, bananas (f, T), yaqona
(c) 2nd alternative: maize, cane (C, T, f); slopes >11° – market gardening (T, C, f), coconuts (f)

Lutu





- Thin Ah horizon
- Quartz grits and gravels in upper 20 cm
- Clay coatings to peds in Bt, BC horizons
- Increasing reddish hue with depth

LUTU

Classification:

Soil Taxonomy: Typic Kandihumult, clayey, kaolinitic, isohyperthermic
FAO: Humic Nitosol
Twyford and Wright: Red yellow podzolic soil with little or no dry season

Parent Material: Strongly weathered ***in situ*** acidic rocks
Landscape Position: Rolling ridges, convex backslopes and midslopes in hilly land
Moisture Regime: Udic (Perudic) **Drainage Class:** Moderately well drained

Horizon	Depth (cm)	REPRESENTATIVE PROFILE DESCRIPTION	Diagnostic Horizons
Ah	0–7 cm	brown gritty clay loam; moderate medium nut structure; friable; sticky; many fine roots; few unweathered rounded quartz gravels and grits; distinct boundary,	Ochric
Bw	7–20 cm	strong brown and brown clay loam; weak fine nut structure; friable; plastic; common dark brown humus coats; few fine roots; many quartz grits; distinct boundary,	Cambic
Bt	20–55 cm	yellowish red and strong brown clay; weak medium blocky structure; friable to firm; very sticky; few yellowish red clay coats; distinct boundary,	Argillic
BC	55–150+ cm	dark red and red silty clay loam; massive breaking to weak coarse blocky structure; friable to firm; plastic; few red clay coats.	

FERTILITY DATA

pH: strongly acid Phosphorous: very low Organic Matter: low
Potassium: very low

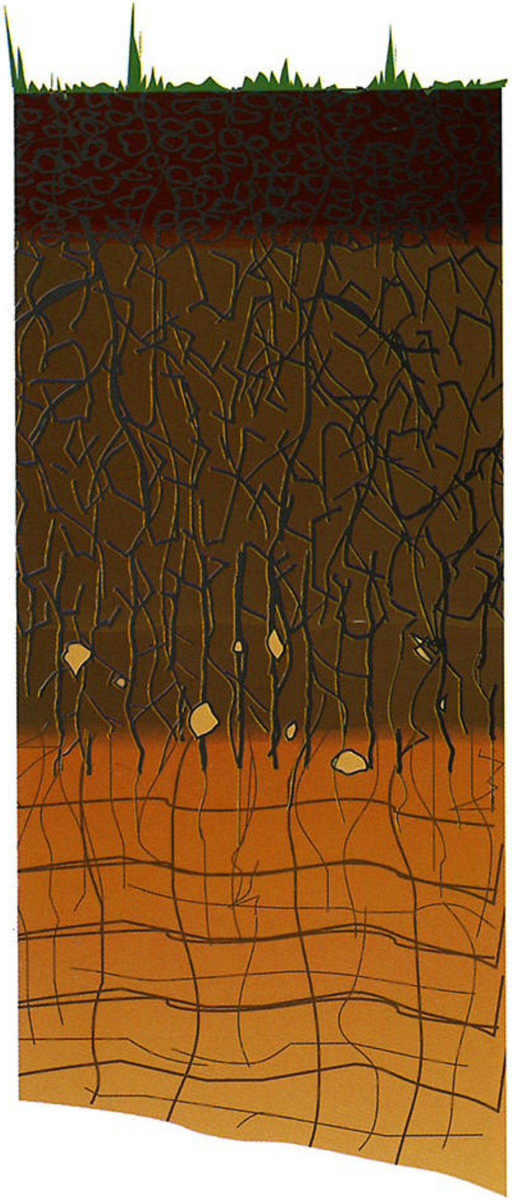
GENERAL LIMITATIONS AND POTENTIAL FOR LAND USE

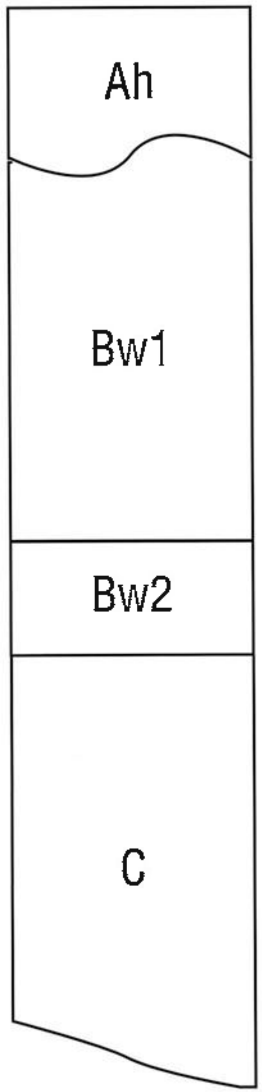
Soil limitations
Soil acidity; high Al.; nutrient deficiencies; erosion risk

Land use options for unimproved land
(a) Shifting cultivation: tavioka
(b) Permanent use: inferior pasture

Land use options for improved land (with ameliorations)
(a) Preferred use: pasture
(b) 1st alternative: coffee, citrus (d, f) on slopes <11°; slopes >11° – forestry
(c) 2nd alternative: pineapple, tea (d, F)

Manuka





- Stony and friable Ah horizon
- Firm, plastic Bw horizons
- Dark brown weakly developed coarse structures in Bw horizons
- Varicoloured laminated weathered in situ rock below 85 cm

MANUKA

Classification:

Soil Taxonomy: Acrudoxic Hydric Fulvudand, medial, isothermic
FAO: Humic Andosol
Twyford and Wright: Upland latosolic soil with no dry season

Parent Material: ***In situ*** moderately weathered basaltic rock
Landscape Position: Broken and uneven rolling terrain in the Taveuni uplands
Moisture Regime: Perudic **Drainage Class:** Well drained

Horizon	Depth (cm)	REPRESENTATIVE PROFILE DESCRIPTION	Diagnostic Horizons
Ah	0–20 cm	very dark brown stony silt loam; moderate medium granular structure; friable; plastic; many fine and medium roots; distinct wavy boundary,	Umbic
Bw1	20–70 cm	dark brown silt loam; weak coarse blocky structure; very firm; plastic; few fine and medium roots; distinct boundary,	Cambic
Bw2	70–85 cm	dark brown sandy loam; weak medium prismatic structure; firm; plastic; many grits and fragments of weathered basalt; few fine roots; diffuse boundary,	
C	85–120+ cm	varicoloured yellowish dark brown and yellowish brown ***in situ*** weathered basalt.	

FERTILITY DATA

pH: strongly acid Phosphorous: very low Organic Matter: very high
Potassium: medium

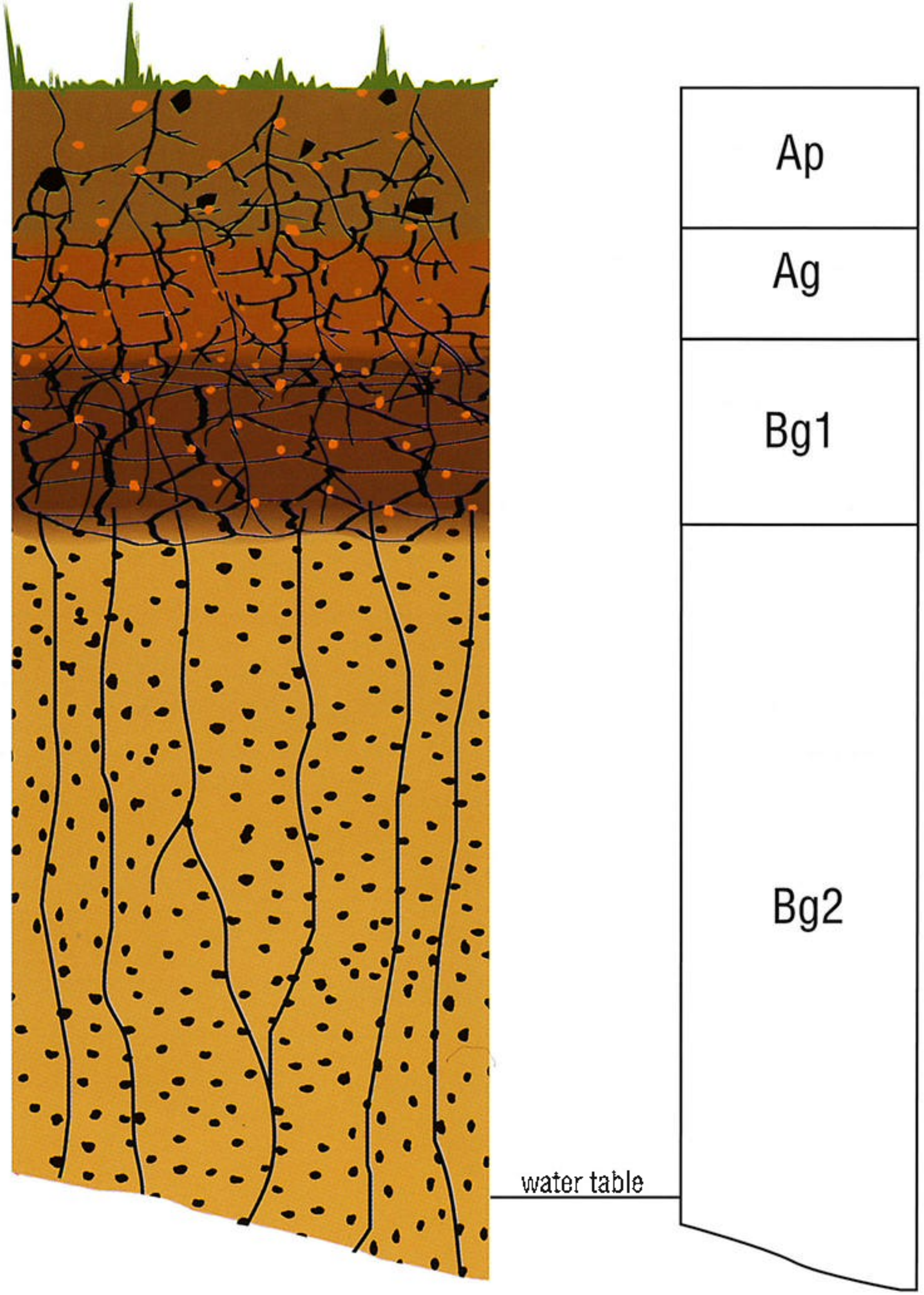
GENERAL LIMITATIONS AND POTENTIAL FOR LAND USE

Soil limitations
Rapid permeability; soil acidity; anion fixation; low mineral content; rock outcrops/surface boulders; nutrient deficiencies

Land use options for unimproved land
(a) Shifting cultivation: tavioka
(b) Permanent use: inferior pasture

Land use options for improved land (with ameliorations)
(a) Preferred use: pasture (F, g); slopes >11° – tea, coffee, citrus (T, C, F)
(b) 1st alternative: tea, coffee, citrus (d, F); slopes >11° – pasture
(c) 2nd alternative: forestry on all slopes

Matavelo



- Yellow-brown mottled reddish yellow Ap horizon
- Black manganese nodules in Ap horizon
- Clayey textures
- Coarse structures, tending prismatic in Bg1 horizon
- Water table at 150 cm
- Yellow, massive, very firm, plastic and mottled grey Bg2 horizon

MATAVELO

Classification:

Soil Taxonomy: Aeric Tropaquept, fine, kaolinitic, isohyperthermic

FAO: Dystric Gleysol

Twyford and Wright: Gley soil related to latosols with strong dry season

Parent Material: Strongly weathered alluvium from basic and intermediate rocks

Landscape Position: Valley floors and depressions on broad surfaces

Moisture Regime: Aquic **Drainage Class:** Poorly drained

Horizon	Depth (cm)	REPRESENTATIVE PROFILE DESCRIPTION	Diagnostic Horizons
Ap	0–20 cm	yellowish brown mottled reddish yellow clay; common black manganese nodules; weak coarse blocky structure; friable; many fine roots; diffuse boundary,	Ochric
Ag	20–35 cm	dark brown clay; common fine reddish yellow mottles; weak coarse nut structure; firm; few fine roots; diffuse boundary,	
Bg1	35–60 cm	very dark greyish brown clay; common reddish yellow mottles; strong very coarse blocky (tending prismatic when dry) structure; very firm; diffuse boundary,	Cambic
Bg2	60–120+ cm	yellow silty clay; common grey mottles; massive; very firm; very plastic.	

FERTILITY DATA

pH: strongly acid — Phosphorous: low — Organic Matter: low

Potassium: low

GENERAL LIMITATIONS AND POTENTIAL FOR LAND USE

Soil limitations

Poor drainage; reducing conditions; high water table (wet season); nutrient deficiencies

Land use options for unimproved land

(a) Shifting cultivation: rice, dalo

(b) Permanent use: inferior pasture, cane, rice

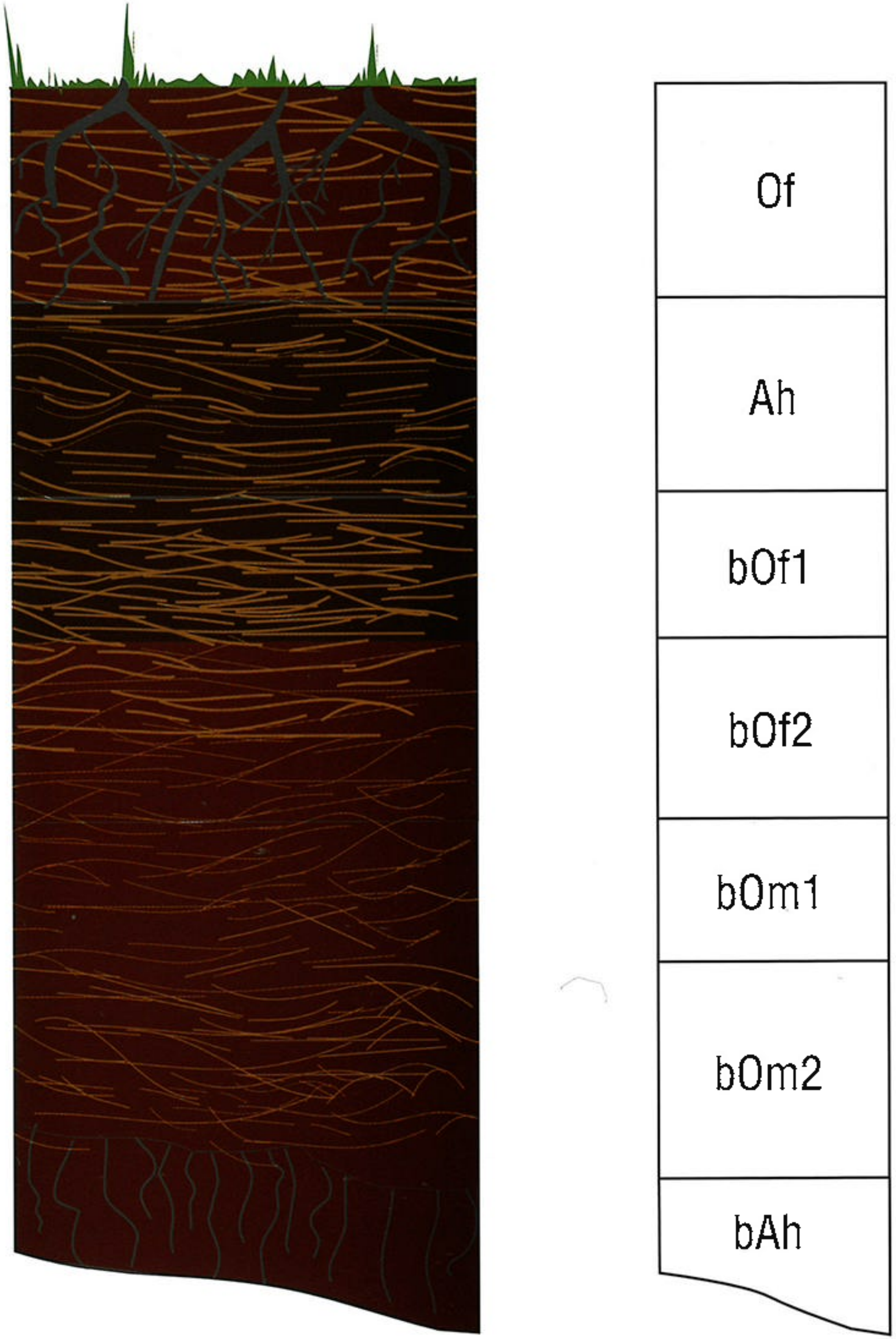
Land use options for improved land (with ameliorations)

(a) Preferred use: cane (D, F)

(b) 1st alternative: rice (d, F), pasture (d, F)

(c) 2nd alternative: tavioka, peanuts (D, F)

Melimeli



- Fibrous peat to 100 cm
- Humus rich muck below 100 cm
- Water table at 30 cm

MELIMELI

Classification:

Soil Taxonomy: Hydric Tropofibrist, dysic, isohyperthermic
FAO: Dystric Histosol
Twyford and Wright: Organic soil

Parent Material: Poorly decomposed rushes and ferns with layers of alluvium
Landscape Position: Peat bogs on major flood plains
Moisture Regime: Aquic **Drainage Class:** Very poorly drained

Horizon	Depth (cm)	REPRESENTATIVE PROFILE DESCRIPTION	Diagnostic Horizons
Of	0–30 cm	black fibrous peat; fibres comprise 60% of mass; many woody roots; indistinct smooth boundary,	Histic
Ah	30–53 cm	brown fibrous peat; fibres comprise 80% of mass; distinct smooth boundary,	Umbric
bOf1	53–76 cm	brown fibrous peat; distinct smooth boundary,	
bOf2	76–99 cm	very dark brown mucky fibrous peat; fibres comprise 80% of mass; indistinct boundary,	
bOm1	99–122 cm	very dark brown muck; fibres less than 30% of mass; indistinct boundary,	
bOm2	122–154 cm	black muck; fibres less than 10%; indistinct boundary,	
bAh	154–168 cm	black clayey muck; slightly sticky; slightly plastic.	

FERTILITY DATA

pH: strongly acid Phosphorous: very low Organic Matter: high
Potassium: high

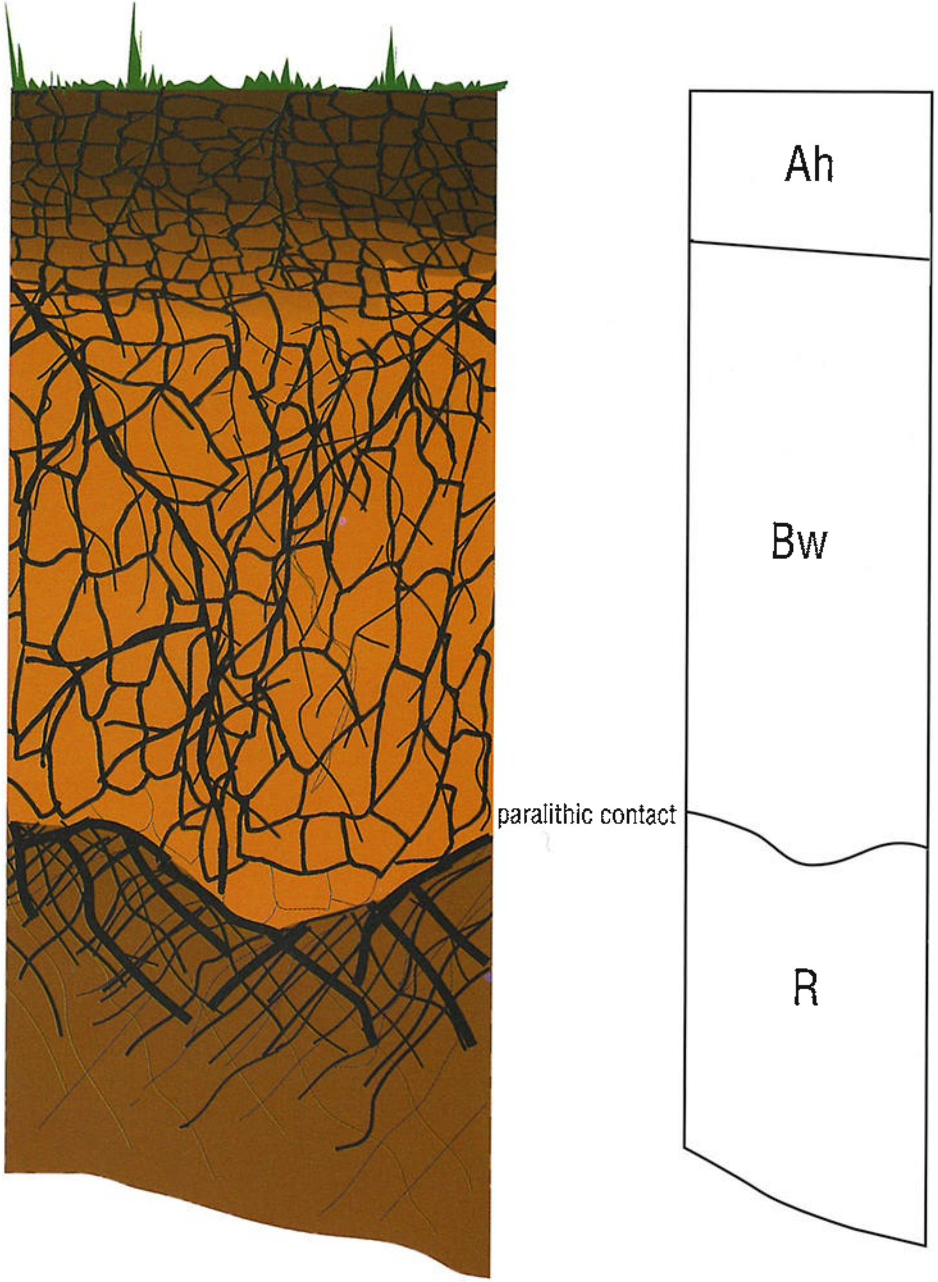
GENERAL LIMITATIONS AND POTENTIAL FOR LAND USE

Soil limitations
Permanent high water table; difficult to drain; soil acidity; nutrient deficiencies

Land use options for unimproved land
(a) Shifting cultivation: –
(b) Permanent use: sago

Land use options for improved land (with ameliorations)
(a) Preferred use: sago (f), inferior pasture
(b) 1st alternative: market gardening (D, F)
(c) 2nd alternative: –

Momi



- Strong structures
- Clayey textures
- Firm, sticky and plastic consistence
- Thick reddish yellow Bw horizon
- Paralithic contact at 1m

MOMI

Classification:

Soil Taxonomy: Typic Ustropept, fine, smectitic, isohyperthermic
FAO: Eutric Cambisol
Twyford and Wright: Nigrescent soil with strong dry season

Parent Material: Weathered *in situ* marls and calcerous tuffs
Landscape Position: Crests, backslopes, and midslopes in strongly rolling hilly land
Moisture Regime: Ustic **Drainage Class:** Well drained

Horizon	Depth (cm)	REPRESENTATIVE PROFILE DESCRIPTION	Diagnostic Horizons
Ah	0–20 cm	very dark greyish brown clay; strong medium nut structure; very firm; sticky; plastic; common fine roots; diffuse boundary,	Ochric
Bw	20–100 cm	reddish yellow clay; strong coarse blocky structure; firm; sticky; plastic; sharp boundary,	Cambic
R	*on*	reddish brown weathered tuff.	

FERTILITY DATA

pH: slightly acid
Potassium: high
Phosphorous: very low
Organic Matter: low

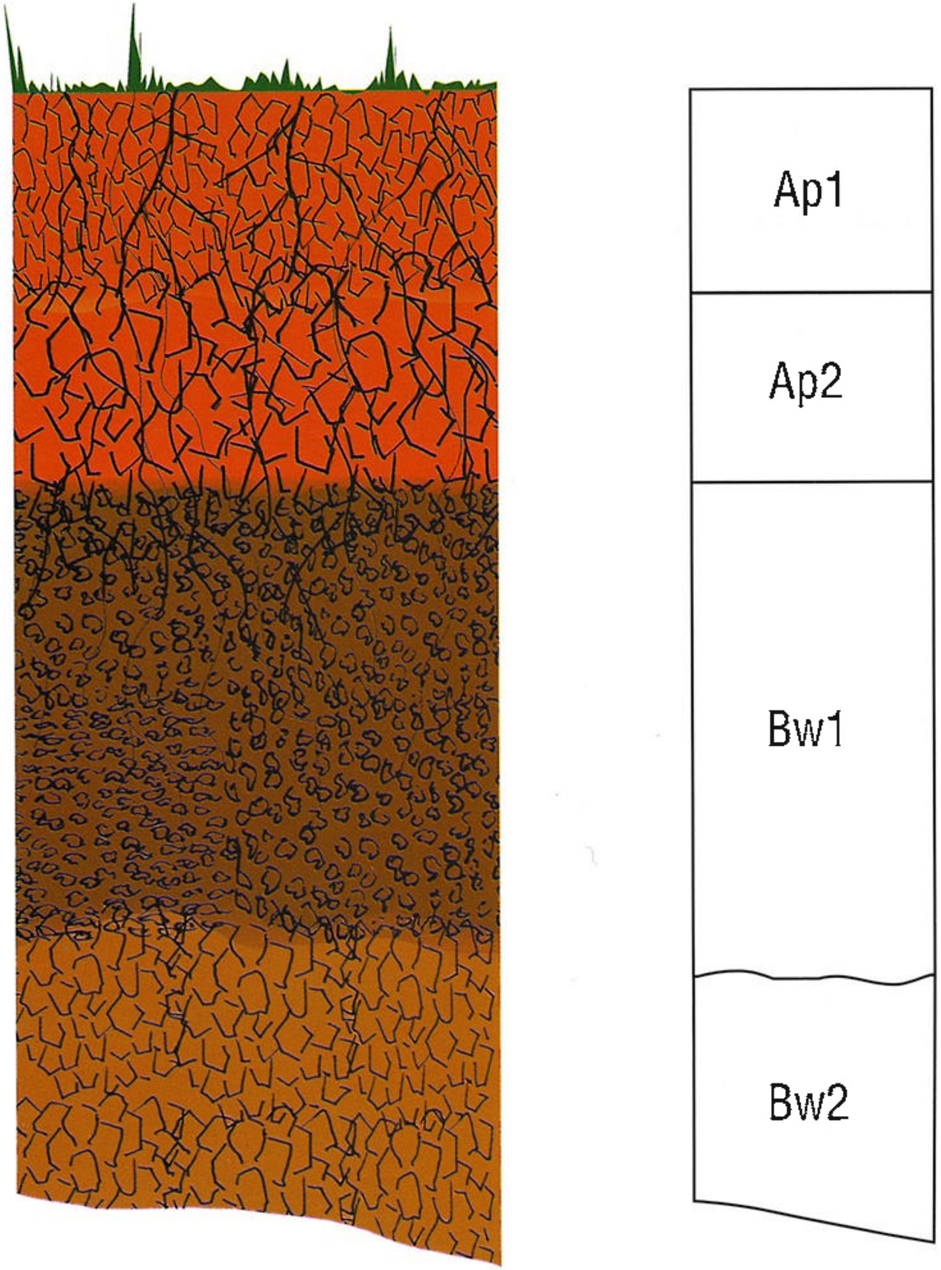
GENERAL LIMITATIONS AND POTENTIAL FOR LAND USE

Soil limitations
Moisture stress (dry season); clayey; nutrient deficiencies; erosion risk

Land use options for unimproved land
(a) Shifting cultivation: tavioka, yams, kumala; slopes >11° – tavioka
(b) Permanent use: inferior pasture

Land use options for improved land (with ameliorations)
(a) Preferred use: pasture (g, i, w, f); slopes >11° – pasture (g, F)
(b) 1st alternative: cane (C, T, i, f); slopes >11° – forestry
(c) 2nd alternative: pulses, tavioka on slopes <11°

Nadi



- Very friable, weakly structured sandy clay loam Ap horizons
- Reddish brown colours to 1m depth
- Massive Bw horizons breaking easily to finer structures

NADI

Classification:

Soil Taxonomy: Typic Eutrustox, clayey, mixed, isohyperthermic
FAO: Orthic Ferralsol
Twyford and Wright: Humic latosol with a strong dry season

Parent Material: Strongly weathered alluvium from basic rocks
Landscape Position: Crests and backslopes of weakly dissected 'old' terraces
Moisture Regime: Ustic **Drainage Class:** Well drained

Horizon	Depth (cm)	REPRESENTATIVE PROFILE DESCRIPTION	Diagnostic Horizons
Ap1	0–28 cm	dark reddish brown sandy clay loam; very friable; weak very fine blocky structure breaking to fine crumb structure; few fine roots; diffuse boundary,	Mollic
Ap2	28–54 cm	dark reddish brown sandy clay loam; very friable; weak medium blocky structure breaking to fine crumb structure; few fine roots; diffuse smooth boundary,	
Bw1	54–109 cm	reddish brown sandy loam; very friable; massive breaking to fine crumb structure; distinct wavy boundary,	Oxic
Bw2	109–141+ cm	strong brown sandy clay loam; friable; massive breaking to fine blocky structure.	

FERTILITY DATA

pH: strongly acid Phosphorous: very low Organic Matter: very low
Potassium: low

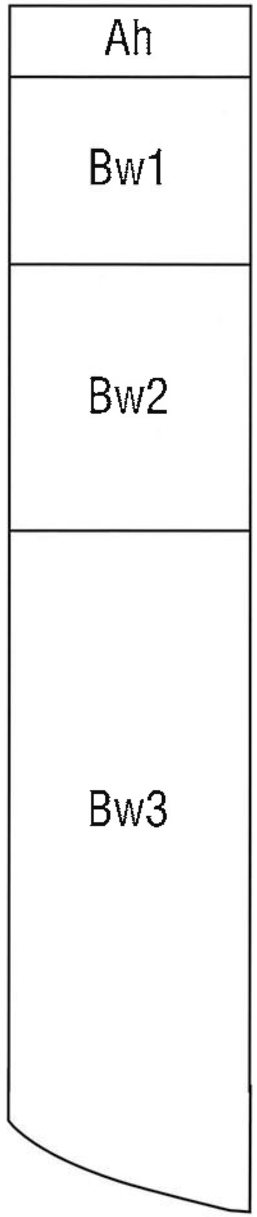
GENERAL LIMITATIONS AND POTENTIAL FOR LAND USE

Soil limitations
Moisture stress (dry season); Al. toxicity; anion fixation; low mineral content; nutrient deficiencies

Land use options for unimproved land
(a) Shifting cultivation: tavioka, pineapples
(b) Permanent use: inferior pasture

Land use options for improved land (with ameliorations)
(a) Preferred use: pineapples (F, C), pulses (F, C)
(b) 1st alternative: cane (F, C, i), mango (F, i), pawpaw (F, i), macadamia nuts (F, i)
(c) 2nd alternative: pasture F, i, w)

Nadrau



- Thin (10 cm) dark greyish brown Ah horizon
- Bw horizons mottled with firm and plastic consistence
- Coarse prismatic structures in Bw horizons

NADRAU

Classification:

Soil Taxonomy: Oxyaquic Humitropept, fine, mixed, isothermic

FAO: Gleyic Cambisol

Twyford and Wright: Upland gley soil related to humic latosols

Parent Material: Alluvium derived from various parent rocks

Landscape Position: Valley floor and levees in small river systems

Moisture Regime: Aquic **Drainage Class:** Imperfectly drained

Horizon	Depth (cm)	REPRESENTATIVE PROFILE DESCRIPTION	Diagnostic Horizons
A	0–10 cm	very dark greyish brown clay loam; moderate medium nut structure; firm; abundant very fine roots; distinct boundary,	Ochric
Bw1	10–35 cm	very dark brown and dark yellowish brown mottled clay; strong coarse blocky structure; firm; plastic; discontinuous clay pan; common fine roots; diffuse boundary,	Cambic
Bw2	35–65 cm	dark yellowish brown and olive brown mottled clay; weak coarse prismatic structure; very firm plastic; abundant very fine roots; distinct boundary,	
Bw3	65–120 cm	dark yellowish brown and dark brown mottled silty clay; weak, very coarse prismatic structure; very firm sticky; many prominent organic iron and manganese coats; few medium live roots.	

FERTILITY DATA

pH: strongly acid Phosphorous: very low Organic Matter: high
Potassium: medium

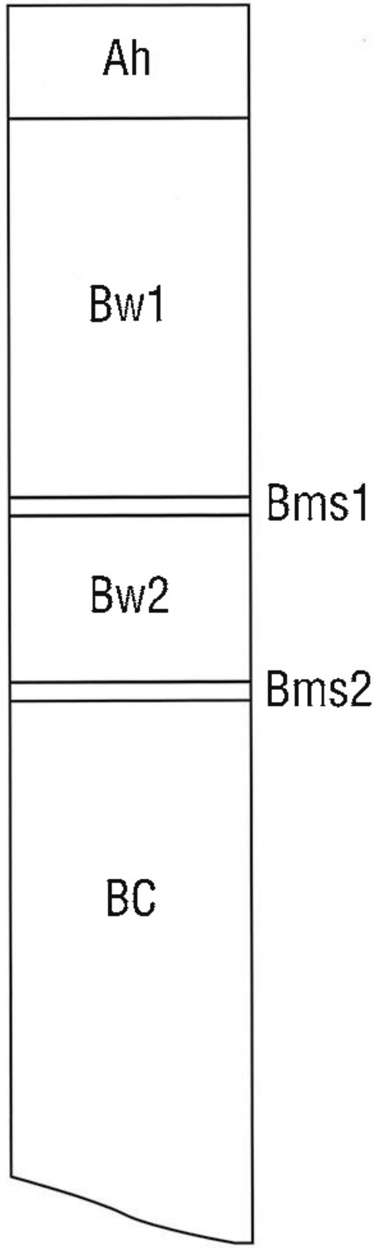
GENERAL LIMITATIONS AND POTENTIAL FOR LAND USE

Soil limitations
Floods; soil acidity; high Al.; nutrient deficiencies

Land use options for unimproved land
(a) Shifting cultivation: –
(b) Permanent use: inferior pasture

Land use options for improved land (with ameliorations)
(a) Preferred use: rice (f, i)
(b) 1st alternative: pasture (d, f)
(c) 2nd alternative: temperate climate vegetables (DF)

Namosau



- Very friable strong nut structured A horizon
- Red colours in B horizons
- Two distinct discontinuous iron pans (Bms)

NAMOSAU

Classification:

Soil Taxonomy: Typic Acrustox, clayey, gibbsitic, isohyperthermic

FAO: Acric Ferralsol

Twyford and Wright: Ferruginous latosol with strong dry season

Parent Material: Strongly weathered *in situ* rock of basic composition

Landscape Position: Old peneplain and plateaux surfaces

Moisture Regime: Ustic **Drainage Class:** Well drained

Horizon	Depth (cm)	REPRESENTATIVE PROFILE DESCRIPTION	Diagnostic Horizons
Ah	0–16 cm	reddish brown silty clay loam; strong fine nut structure; very friable; sticky; many fine and medium roots; distinct boundary,	Ochric
Bw1	16–64 cm	red clay loam; weak medium blocky structure breaking to moderate nut structure; friable; sticky; common fine roots; sharp boundary,	Cambic
Bms1	64–67 cm	metallic black with light olive brown discontinuous iron pan; massive; extremely firm; no roots; sharp boundary,	
Bw2	67–89 cm	red clay loam; few fine olive yellow mottles; weak medium blocky structure; friable; sharp boundary,	Cambic
Bms2	89–92 cm	metallic black with light olive brown discontinuous iron pan; massive; extremely firm; sharp boundary,	
BC	92–117+ cm	red silty clay loam; many medium olive yellow mottles; weak coarse blocky structure; friable.	

FERTILITY DATA

pH: strongly acid | Phosphorous: very low | Organic Matter: low
Potassium: low

GENERAL LIMITATIONS AND POTENTIAL FOR LAND USE

Soil limitations

Moisture stress (dry season); Al. toxicity; anion fixation; low mineral content; nutrient deficiencies

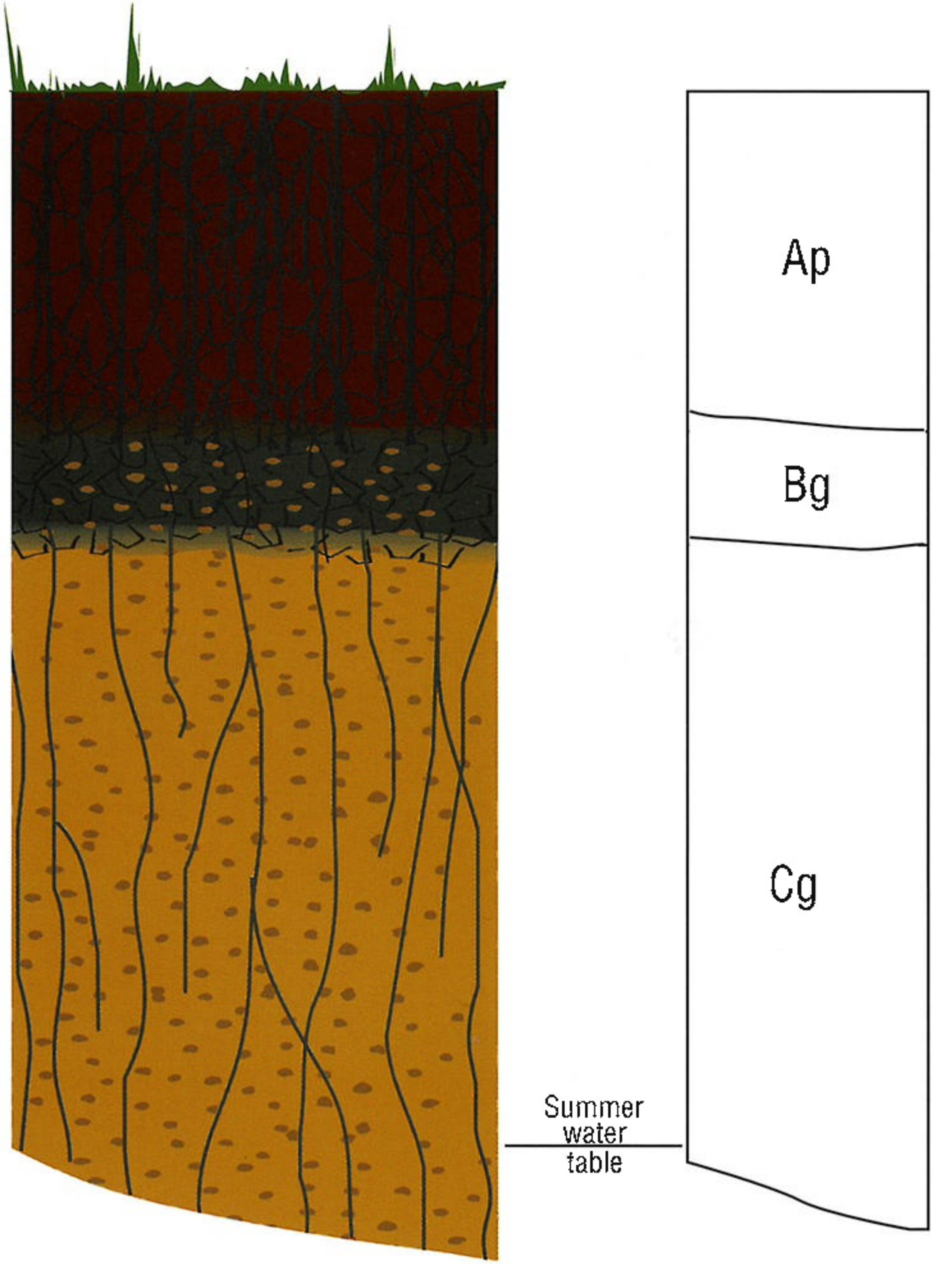
Land use options for unimproved land

(a) Shifting cultivation: tavioka, pineapples
(b) Permanent use: inferior pasture

Land use options for improved land (with ameliorations)

(a) Preferred use: pineapples(F, C), pulses (F, C)
(b) 1st alternative: cane (F, C, i), mango (F, i), pawpaw (F, i) macadamia nuts (F, i)
(c) 2nd alternative: pasture (F, i, w)

Narewa



- Humus rich black Ap horizon with prismatic structure
- Clayey textures
- Firm, sticky and plastic consistence in all horizons
- Organic coatings in subsoil

NAREWA

Classification:

Soil Taxonomy: Vertic Haplaquoll, fine, smectitic, isohyperthermic

FAO: Eutric Gleysol

Twyford and Wright: Gley soil associated with latosols with a strong dry season

Parent Material: Strongly weathered alluvium from basic and intermediate rocks

Landscape Position: Valley floors in strongly rolling hilly land

Moisture Regime: Aquic **Drainage Class:** Poorly drained

Horizon	Depth (cm)	REPRESENTATIVE PROFILE DESCRIPTION	Diagnostic Horizons
Ap	0–45 cm	black clay; strong coarse prismatic structure breaking to strong medium blocky structure firm; sticky; plastic; common fine and very fine roots; distinct boundary,	Mollic
Bg	45–63 cm	very dark grey clay; common distinct yellowish brown mottles; weak coarse blocky structure; firm; sticky; plastic; common black organic coats; few very fine roots; distinct boundary,	Cambic
Cg	63–95+ cm	light yellowish-brown clay; many yellowish-brown coarse mottles; massive; very sticky; plastic; common very dark grey organic coats to pores.	

FERTILITY DATA

pH: slightly acid Phosphorous: low Organic Matter: low
Potassium: low

GENERAL LIMITATIONS AND POTENTIAL FOR LAND USE

Soil limitations

Floods (wet season); high water table (wet season); seasonal vertic properties (gilgai, surface cracking); nutrient deficiencies

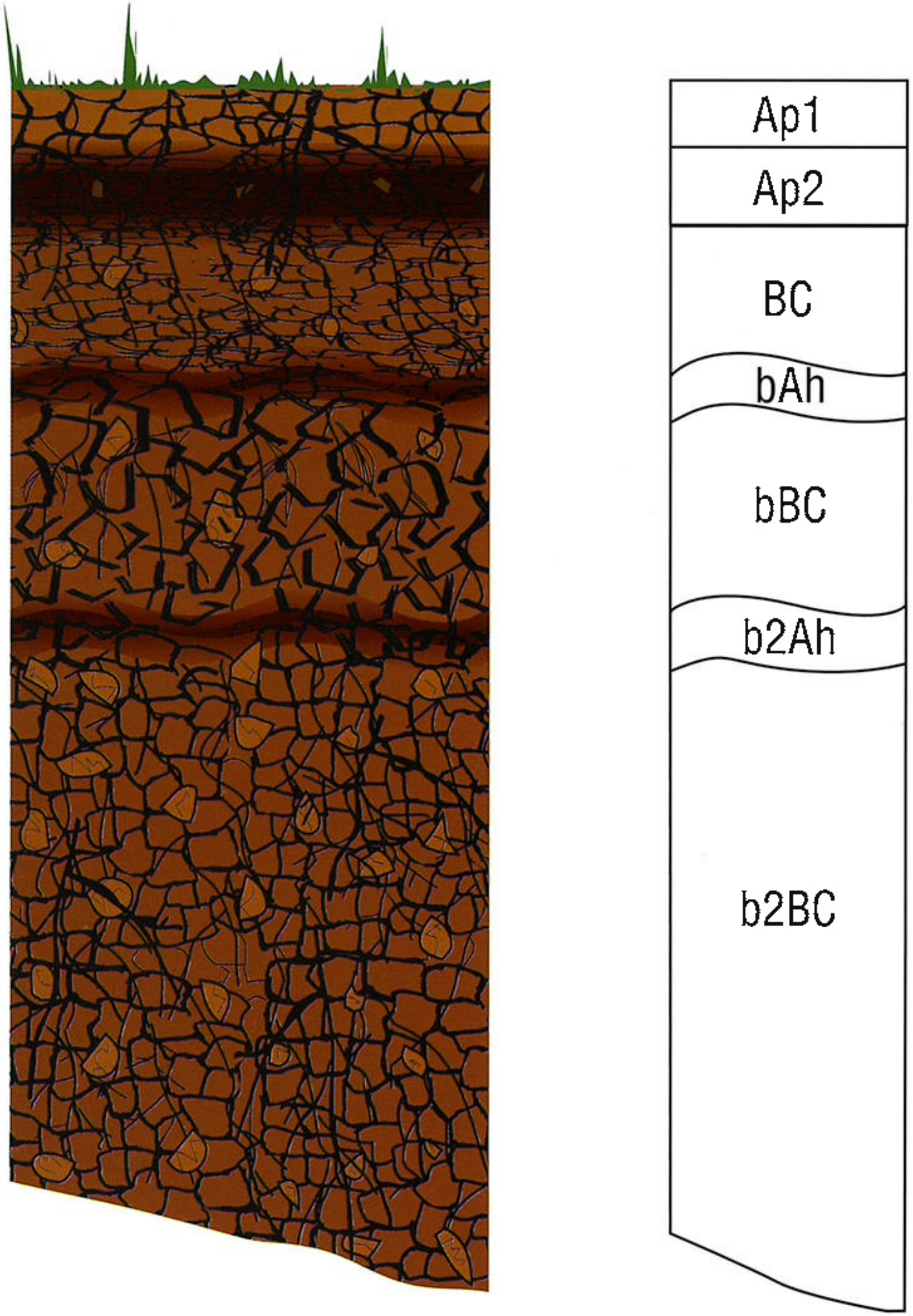
Land use options for unimproved land

(a) Shifting cultivation: dalo rice
(b) Permanent use: pasture, cane, rice

Land use options for improved land (with ameliorations)

(a) Preferred use: market gardening (d, F)
(b) 1st alternative: rice (d), cane (D)
(c) 2nd alternative: coconuts, pasture (D)

Nasou



- Reddish brown colours
- Two thin buried Ah horizons
- Most horizons have gritty textures and parent material gravels

NASOU

Classification:

- **Soil Taxonomy:** Fluventic Dystropept, fine, mixed, isohyperthermic
- **FAO:** Dystric Cambisol
- **Twyford and Wright:** Humic latosol with a strong dry season

Parent Material: Colluvium and outwash materials from weathered basic rocks

Landscape Position: Toeslopes, valley floors and sloping depressions in 'old' terrace lands

Moisture Regime: Ustic **Drainage Class:** Well drained

Horizon	Depth (cm)	REPRESENTATIVE PROFILE DESCRIPTION	Diagnostic Horizons
Ap1	0–9 cm	reddish brown clay loam; strong medium nut structure; friable; sticky; common fine and medium roots; indistinct boundary,	Ochric
Ap2	9–19 cm	dark reddish brown gritty clay; moderate fine and medium nut structure; friable; sticky; few fine and medium roots; few strongly weathered subangular gravels; distinct boundary,	
BC	19–42 cm	reddish brown gritty silt loam; weak medium nut structure; very friable; few fine and medium roots; common strongly weathered subangular gravels and stones; sharp wavy boundary	Cambic
bAh	42–45 cm	dark reddish brown silt loam; single grain; loose; common medium roots; sharp wavy boundary,	
bBC	45–77 cm	reddish brown gritty silt loam; weak coarse blocky structure; very friable; few fine roots; many strongly weathered subrounded gravels with a few subangular stones; sharp wavy boundary,	
b2Ah	77–79 cm	dark reddish brown silt loam; single grain; loose; common fine roots; sharp wavy boundary,	
b2BC	79–104+ cm	reddish brown gritty clay loam; moderate coarse nut structure; firm; few fine and medium roots; many strongly weathered gravels.	

FERTILITY DATA

pH: strongly acid　Phosphorous: low　Organic Matter: very low
Potassium: very low

GENERAL LIMITATIONS AND POTENTIAL FOR LAND USE

Soil limitations

Moisture stress (dry season); periodic flooding on slopes <2° (in wet season); high Al.; soil acidity; nutrient deficiencies; erosion risk (slopes >6°)

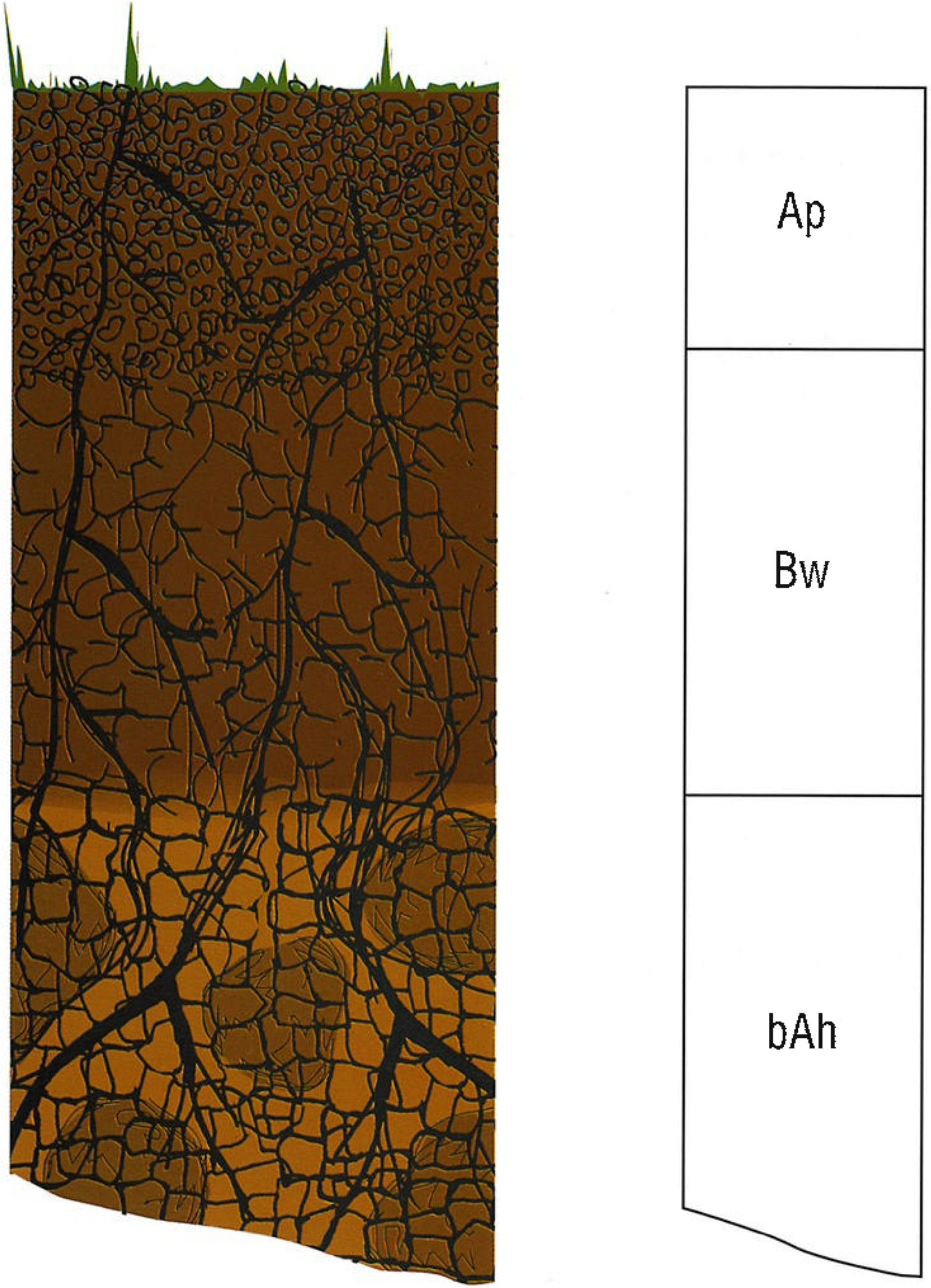
Land use options for unimproved land

(a) Shifting cultivation: most food crops
(b) Permanent use: pasture, cane, bananas

Land use options for improved land (with ameliorations)

(a) Preferred use: cane, maize, pulses, potatoes, ginger, dalo, gardening (f, i)
(b) 1st alternative: coffee, cocoa, bananas (s, f)
(c) 2nd alternative: peanuts (f), coconuts (f), pasture (i, f)

Navai



- Thick (35 cm) Ap horizon
- Buried Ah horizon below 95 cm
- Large rounded boulders in paleosol

NAVAI

Classification:

Soil Taxonomy: Fluventic Hapludoll, fine, mixed, isothermic
FAO: Haplic Phaeozem
Twyford and Wright: Upland recent soil from alluvium with moderate to weak dry season

Parent Material: Alluvium of low quartz content (i.e., from basic materials)
Landscape Position: Narrow valley floors
Moisture Regime: Udic **Drainage Class:** Well drained

Horizon	Depth (cm)	REPRESENTATIVE PROFILE DESCRIPTION	Diagnostic Horizons
Ap	0–35 cm	dark brown clay loam; strong medium granular structure; very friable; common medium fibrous roots; diffuse boundary,	Mollic
Bw	35–95 cm	dark greyish brown clay loam; weak coarse nut structure, breaking to medium granular structure; friable; common medium roots; diffuse boundary,	Cambic
bAh	95–120 cm	dark yellowish brown clay, weak coarse nut structure; firm; common large rounded unweathered boulders; few large roots.	

FERTILITY DATA

pH: strongly acid Phosphorous: very low Organic Matter: very low
Potassium: low

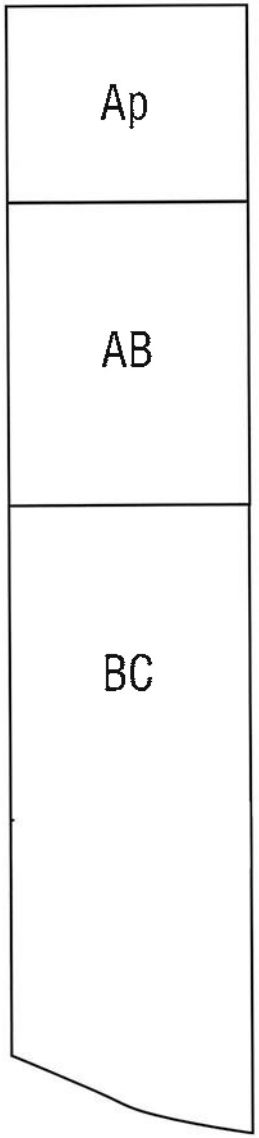
GENERAL LIMITATIONS AND POTENTIAL FOR LAND USE

Soil limitations
Floods; nutrient deficiencies

Land use options for unimproved land
(a) Shifting cultivation: dalo, tavioka, kumala
(b) Permanent use: inferior pasture

Land use options for improved land (with ameliorations)
(a) Preferred use: temperate climate vegetables (d, f), potatoes
(b) 1st alternative: pasture
(c) 2nd alternative: rice (i, f), citrus, coffee

Nika



- Black and humus rich Ap horizon
- Prismatic structures with pronounced clay coatings to peds
- BC horizon has sandy clay texture with fragments of parent material

NIKA

Classification:

Soil Taxonomy: Udic Haplustert, fine, smectitic, isohyperthermic

FAO: Pellic Vertisol

Twyford and Wright: Gley soil related to nigrescent soils with strong dry season

Parent Material: Calcerous alluvium from marls and tuffs

Landscape Position: Floors of narrow valleys in rolling hilly land

Moisture Regime: Aquic **Drainage Class:** Imperfectly drained

Horizon	Depth (cm)	REPRESENTATIVE PROFILE DESCRIPTION	Diagnostic Horizons
Ap	0–25 cm	black clay; strong medium prismatic structure; very firm; sticky; clay coats; common fine to medium roots; indistinct boundary,	Ochric
AB	25–63 cm	very dark greyish brown to yellowish red clay; moderate prismatic structure; many clay coatings; common fine roots; indistinct boundary,	Cambic
BC	63–113+ cm	very greyish brown to white sandy clay; weak coarse prismatic structure; weathered parent material, few fine roots	

FERTILITY DATA

pH: slightly acid
Phosphorous: very low
Organic Matter: medium
Potassium: low

GENERAL LIMITATIONS AND POTENTIAL FOR LAND USE

Soil limitations

Moisture stress (dry season); high Al.; nutrient deficiencies

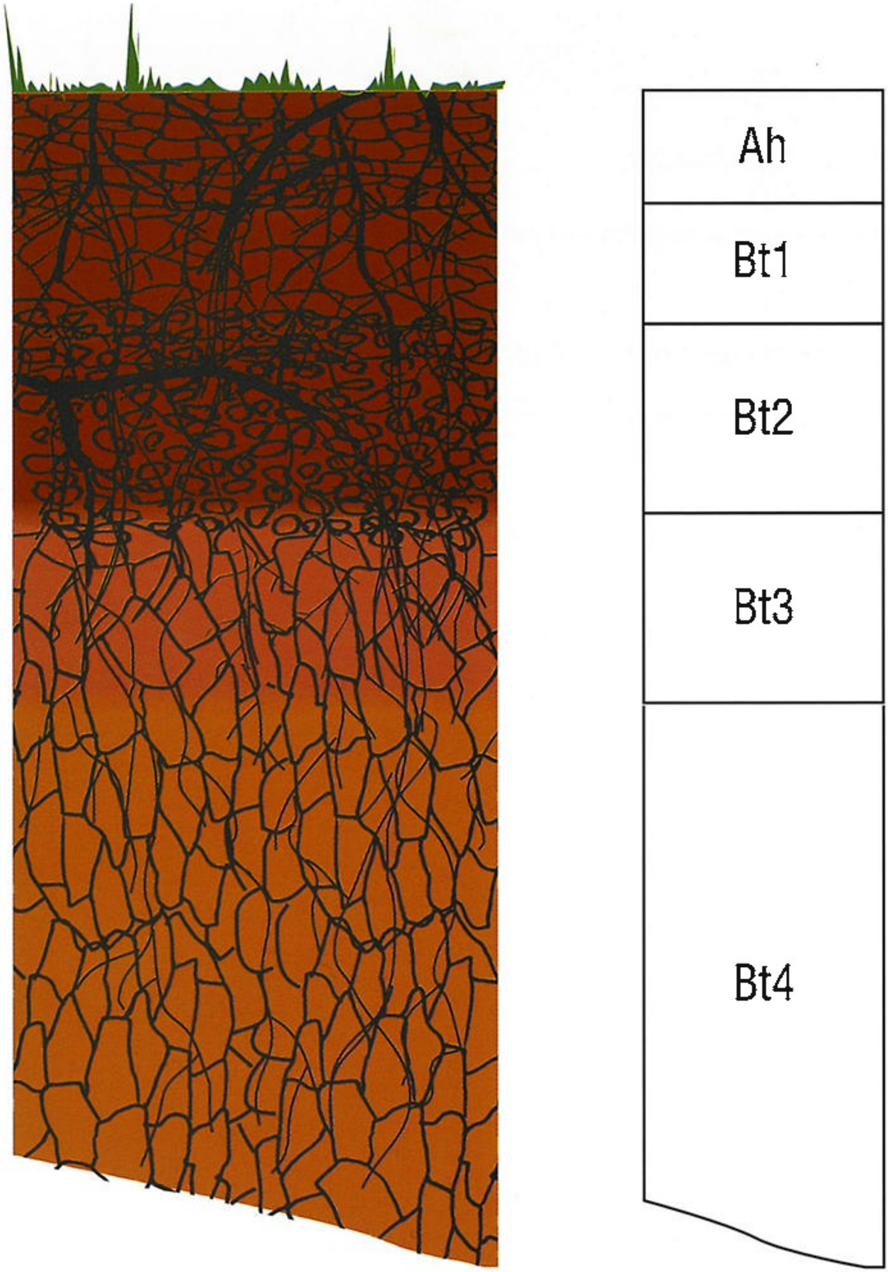
Land use options for unimproved land

(a) Shifting cultivation: dalo, rice
(b) Permanent use: pasture, cane, rice

Land use options for improved land (with ameliorations)

(a) Preferred use: market gardening (d, F)
(b) 1st alternative: rice (d), cane (D)
(c) 2nd alternative: coconuts, pasture (D)

Nukudamu



- Reddish hues
- Friable consistence
- Significant sand fraction in Bt1, Bt2, Bt3 horizons

NUKUDAMU

Classification:

Soil Taxonomy: Ustic Dystropept, fine, kaolinitic, isohyperthermic

FAO: Dystric Cambisol

Twyford and Wright: Red yellow podzolic soil with strong dry season

Parent Material: Weathered ***in situ*** acidic and quartz-rich tuffaceous rocks

Landscape Position: Convex midslopes and backslopes in hilly land

Moisture Regime: Ustic **Drainage Class:** Well drained

Horizon	Depth (cm)	REPRESENTATIVE PROFILE DESCRIPTION	Diagnostic Horizons
Ah	0–13 cm	red clay loam; moderate medium nut structure; friable; many fine medium and coarse roots; distinct boundary,	Ochric
Bt1	13–29 cm	red sandy clay loam; moderate medium blocky structure; friable; many fine and medium roots; indistinct boundary,	Cambic
Bt2	29–53 cm	red sandy clay loam; weak medium granular structure; friable; few fine and coarse roots; indistinct boundary,	
Bt3	53–79 cm	red sandy clay loam; moderate coarse blocky structure; friable; few roots; distinct boundary,	
Bt4	79–110+ cm	yellowish red clay loam; moderate coarse blocky structure; friable; few very fine roots.	

FERTILITY DATA

pH: strongly acid Phosphorous: very low Organic Matter: very low
Potassium: low

GENERAL LIMITATIONS AND POTENTIAL FOR LAND USE

Soil limitations

Moisture stress (dry season); rapid permeability; high Al.; soil acidity; nutrient deficiencies; past erosion; erosion risk on slopes >3°

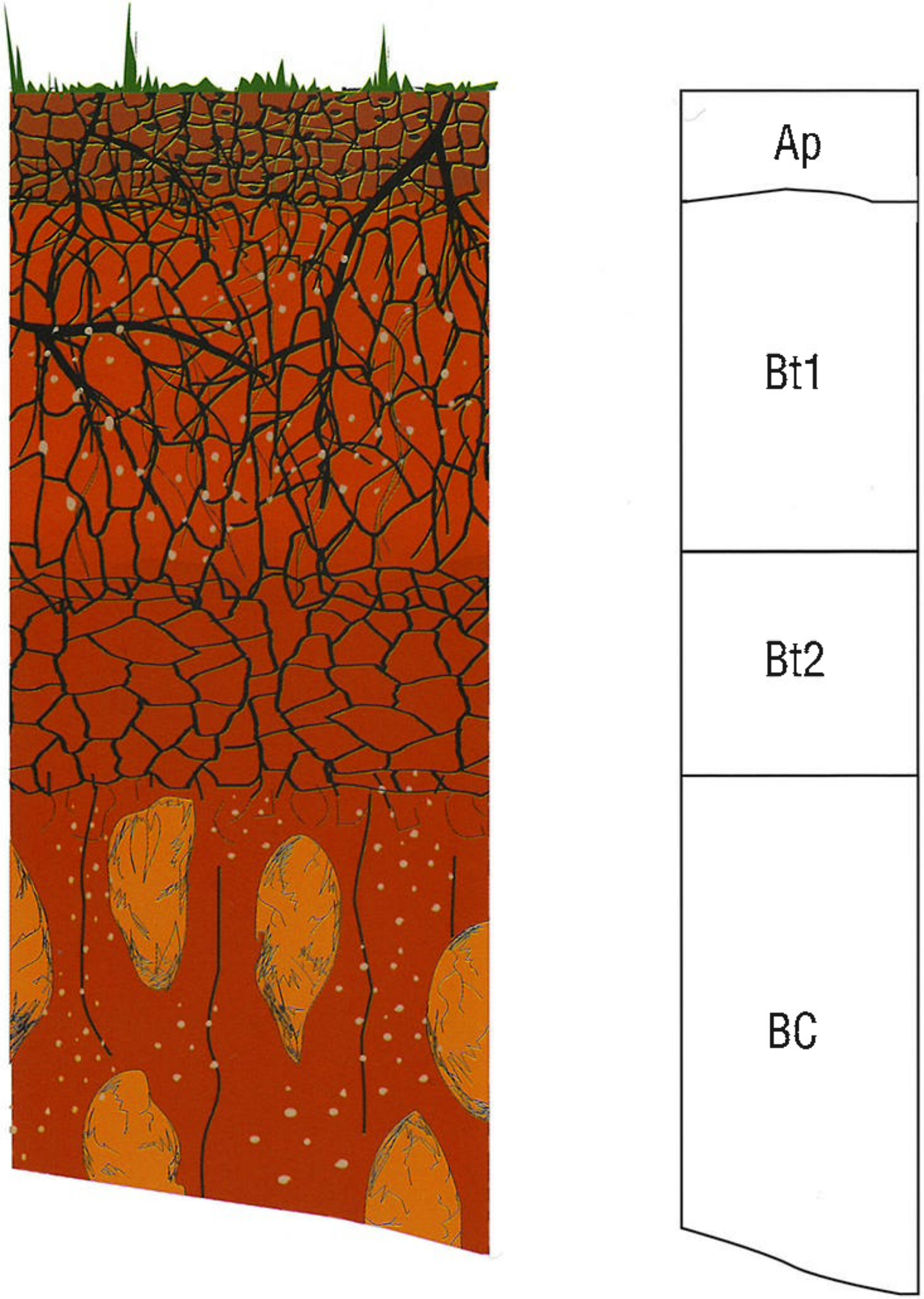
Land use options for unimproved land

(a) Shifting cultivation: tavioka, pineapples; on slopes >11° – tavioka
(b) Permanent use: inferior pasture

Land use options for improved land (with ameliorations)

(a) Preferred use: pineapples (F, C); slopes >11° – pasture
(b) 1st alternative: pasture; slopes >11° – forestry
(c) 2nd alternative: forestry

Raviravi



- Dark red Ap horizon with black manganese mottles
- Red colour in subsoils
- Coarse blocky Bt horizon structures
- Varicoloured in situ weathered rock at 93 cm

RAVIRAVI

Classification:

Soil Taxonomy: Typic Kandiustult, clayey, ferruginous, isohyperthermic
FAO: Dystric Nitosol
Twyford and Wright: Ferruginous latosol with a strong dry season

Parent Material: Strongly weathered *in situ* tuffaceous rocks of basic composition
Landscape Position: All slope positions on rolling and hilly land
Moisture Regime: Ustic **Drainage Class:** Well drained

Horizon	Depth (cm)	REPRESENTATIVE PROFILE DESCRIPTION	Diagnostic Horizons
Ap	0–13 cm	dark red clay loam; common black manganese mottles; moderate fine and medium nut structure; very friable; sticky; many fine medium and coarse roots; distinct boundary,	Ochric
Bt1	13–61 cm	red clay loam; few coarse pinkish grey parent material mottles; moderate coarse blocky structure; firm; very sticky; common fine and medium roots; diffuse boundary,	Argillic
Bt2	61–93 cm	red clay loam; moderate coarse blocky structure; firm; indistinct boundary,	
BC	93–115+ cm	red clay loam; many coarse reddish yellow and pinkish grey parent material mottles; massive; firm.	

FERTILITY DATA

pH: strongly acid   Phosphorous: very low   Organic Matter: very low
Potassium: very low

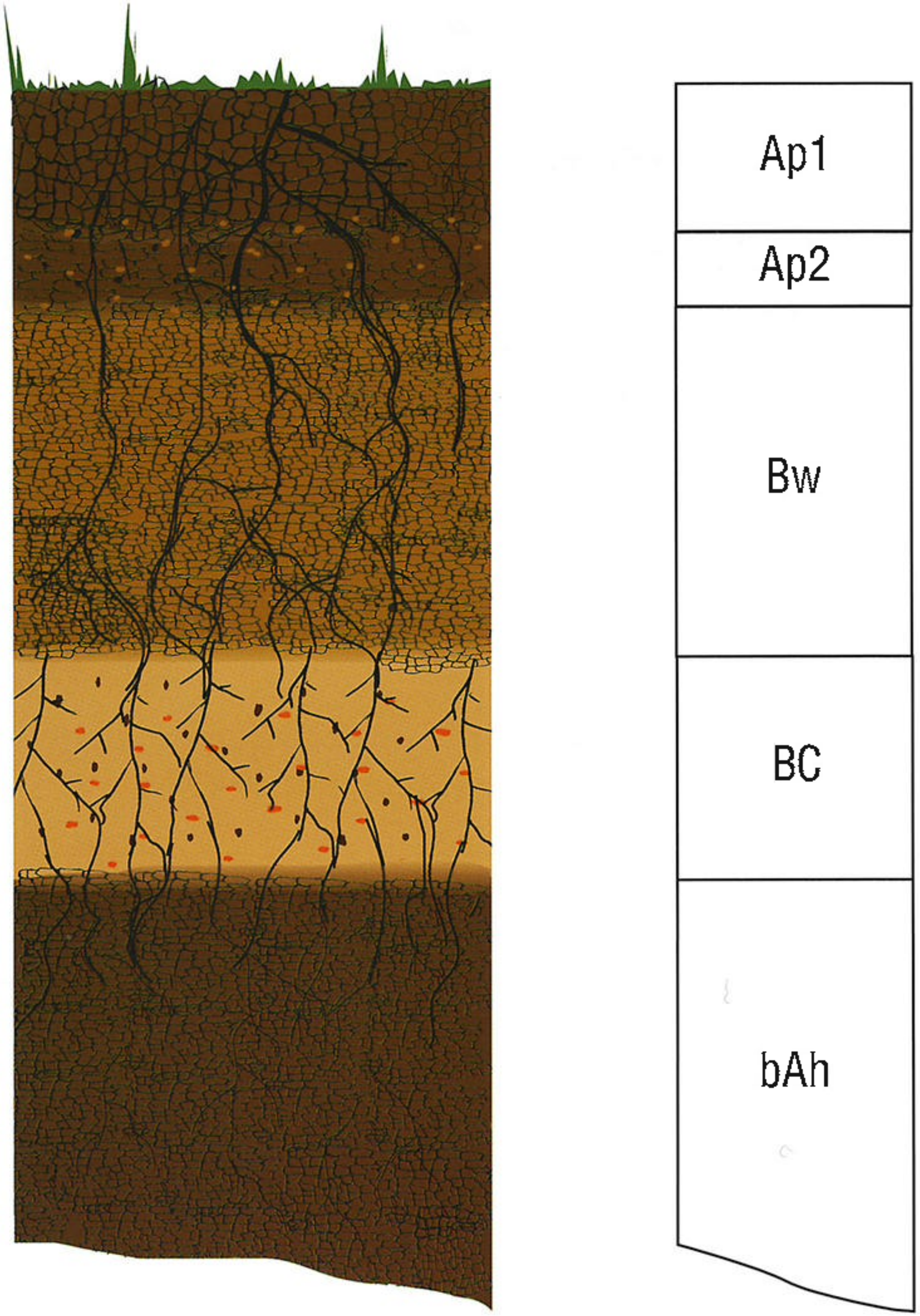
GENERAL LIMITATIONS AND POTENTIAL FOR LAND USE

Soil limitations
Moisture stress (dry season); soil acidity; high Al.; anion fixation; rapid permeability; nutrient deficiencies; erosion risk on slopes >3°

Land use options for unimproved land
(a) Shifting cultivation: tavioka, yams, kumala
(b) Permanent use: inferior pasture

Land use options for improved land (with ameliorations)
(a) Preferred use: cane (F, C, i); slopes >11° – pasture (g, f)
(b) 1st alternative: pineapples (F, C); slopes >11° – reafforestation in part
(c) 2nd alternative: citrus, coffee (F, S); slopes >11° – reafforestation in part

Rewa



- Dark brown Ap horizons
- Yellowish brown Bw and BC horizons
- Silty clay loam textures to 106 cm
- Yellow red mottles and reddish brown concretions in BC horizon
- Buried A horizon below 106 cm

REWA

Classification:

Soil Taxonomy: Fluventic Eutropept, fine silty, mixed, isohyperthermic
FAO: Eutric Fluvisol
Twyford and Wright: Recent soil with weak or no dry season

Parent Material: Alluvium of low quartz content (i.e., from basic rocks)
Landscape Position: High to middle positions on levees of major floodplains
Moisture Regime: Perudic **Drainage Class:** Moderately well drained

Horizon	Depth (cm)	REPRESENTATIVE PROFILE DESCRIPTION	Diagnostic Horizons
Ap1	0–18 cm	dark brown silty clay loam; weak fine nut structure; friable; many fine and medium roots; diffuse boundary,	Ochric
Ap2	18–28 cm	dark brown silty clay loam; few dark brown mottles; weak coarse blocky structure breaking to weak fine nut structure; friable to firm; common fine roots; indistinct boundary,	
Bw	28–77 cm	dark yellowish brown silty clay loam; weak fine nut structure; shiny ped faces with weak expressed clay coats to voids and pores; few fine roots; indistinct boundary,	Cambic
BC	77–106 cm	yellowish brown silty clay loam; common yellowish red mottles; few dark reddish iron/manganese concretions; weak coarse nut structure; friable; few fine roots; distinct boundary,	
bAh	106–126+ cm	dark brown silt loam; weak fine nut structure; friable; few roots.	

FERTILITY DATA

pH: moderately acid
Phosphorous: very low
Organic Matter: very low
Potassium: low

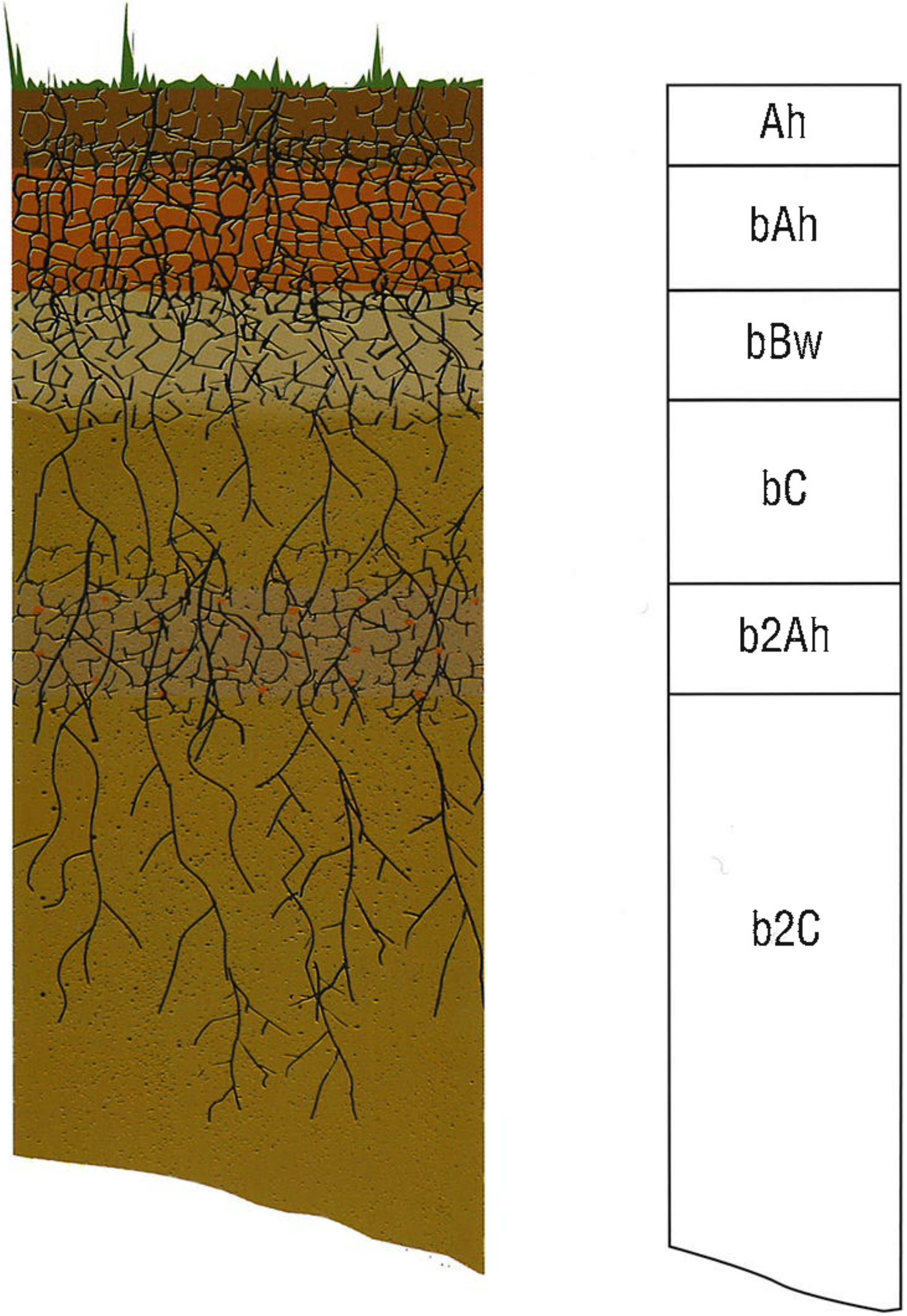
GENERAL LIMITATIONS AND POTENTIAL FOR LAND USE

Soil limitations
Periodic flooding; nutrient deficiencies

Land use options for unimproved land
(a) Shifting cultivation: most food crops
(b) Permanent use: bananas, pasture, coconuts

Land use options for improved land (with ameliorations)
(a) Preferred use: market gardening (f)
(b) 1st alternative: ginger (f), maize (f), bananas (f), pawpaw (f)
(c) 2nd alternative: pasture (f, g), coconuts (f)

Saliadrau



- Olive colours predominate below 40 cm
- Buried soil horizons throughout profile
- Most horizons sandy textured
- Horizons have loose consistence and are weakly structured

SALIADRAU

Classification:

Soil Taxonomy: Fluventic Eutropept, coarse loamy, mixed, isohyperthermic

FAO: Eutric Fluvisol

Twyford and Wright: Recent soil with weak dry season

Parent Material: Alluvium of high quartz content (from acidic rocks)

Landscape Position: Valley bottom lands and low terraces

Moisture Regime: Udic **Drainage Class:** Well drained

Horizon	Depth (cm)	REPRESENTATIVE PROFILE DESCRIPTION	Diagnostic Horizons
Ah	0–12 cm	brown loamy fine sand; weak fine nut structure; very friable; common fine roots; distinct boundary,	Ochric
bAh	12–30 cm	dark brown silt loam; few olive brown mottles; moderate fine nut structure; very friable; common fine roots; distinct boundary,	Cambic
bBw	30–45 cm	olive loam; weak medium blocky structure; loose; common fine roots; indistinct boundary,	
bC	45–70 cm	olive loamy sand; single grain; loose; few fine roots; distinct boundary,	
b2Ah	70–84 cm	olive silt loam; few dark brown mottles; weak fine and medium nut structure; very friable; few fine roots; distinct boundary,	
b2C	84–125+ cm	olive loamy sand; single grain; loose; few fine roots.	

FERTILITY DATA

pH: strongly acid | Phosphorous: low | Organic Matter: very low
Potassium: low

GENERAL LIMITATIONS AND POTENTIAL FOR LAND USE

Soil limitations

Floods; moisture stress (dry season); rapid permeability; soil acidity; nutrient deficiencies

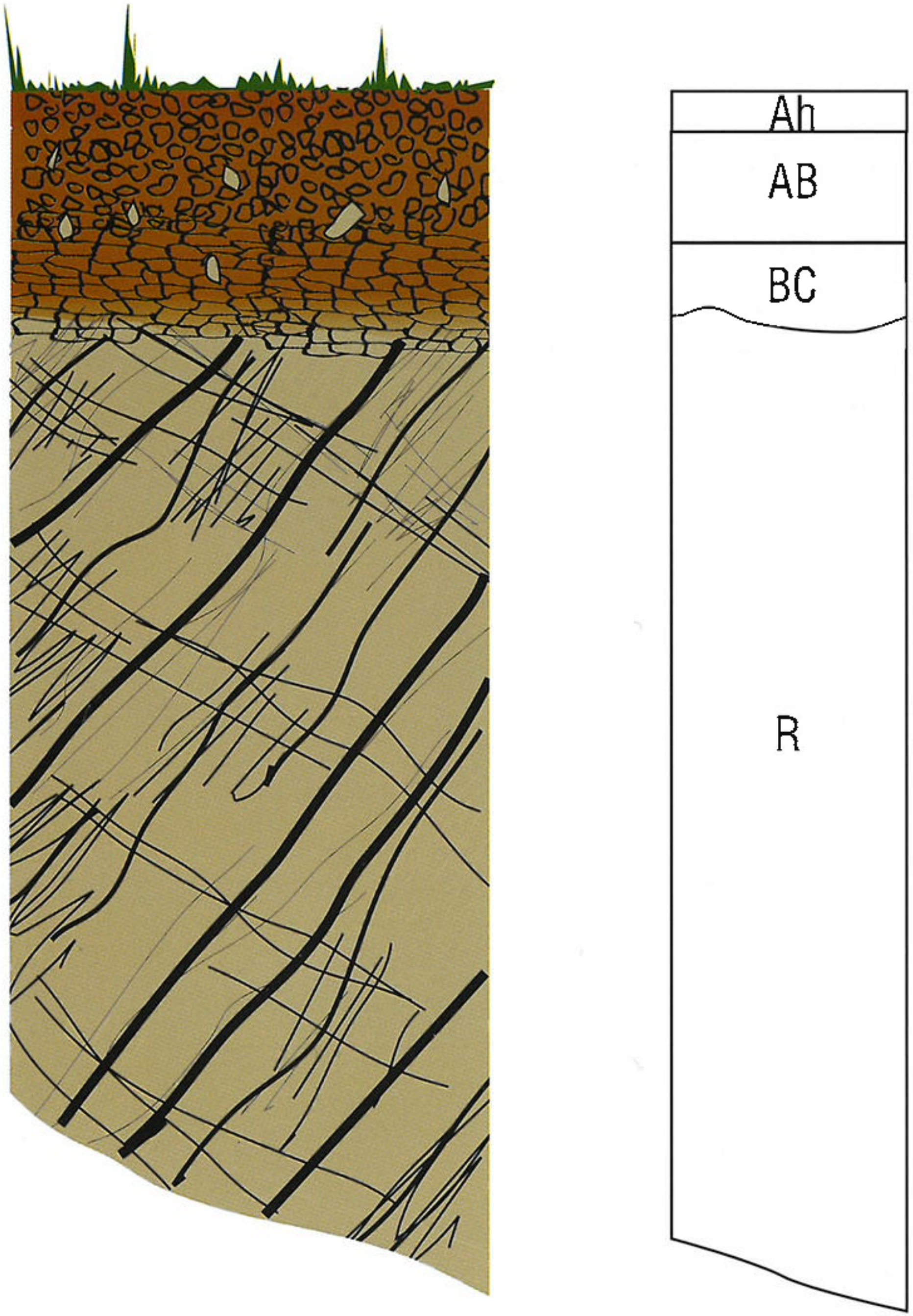
Land use options for unimproved land

(a) Shifting cultivation: tavioka, kumala
(b) Permanent use: coconuts, bananas, pasture

Land use options for improved land (with ameliorations)

(a) Preferred use: bananas (F), yaqona (f)
(b) 1st alternative: cocoa (F, S), coconuts (f), cane (F), market gardening (F)
(c) 2nd alternative: pasture (f, g)

Samabula



- Shallow profile; in situ marl at 30 cm
- Parent material stones throughout
- Friable, sticky and plastic consistence

SAMABULA

Classification:

Soil Taxonomy: Lithic Hapludoll, fine, smectitic, isohyperthermic
FAO: Lithic Phaeozem
Twyford and Wright: Nigrescent soil with no or weak dry season

Parent Material: Moderately weathered ***in situ*** marls and calcerous tuffs
Landscape Position: Convex ridges, backslopes and midslopes in hilly land
Moisture Regime: Udic (Perudic) **Drainage Class:** Well drained

Horizon	Depth (cm)	REPRESENTATIVE PROFILE DESCRIPTION	Diagnostic Horizons
Ah	0–5 cm	dark brown clay; some small pieces of marl; moderate medium granular structure; friable; sticky; plastic; many roots; indistinct boundary,	Mollic
AB	5–20 cm	dark yellowish brown stony clay; many pieces of marl; friable; sticky; plastic; moderate fine granular structure; few roots; indistinct boundary,	
BC	20–30 cm	dark yellowish brown stony and bouldery clay; friable; sticky; plastic; moderate fine nut structure; 60% marl pieces; distinct boundary (lithic contact),	Cambic
R	***on***	weekly weathered ***in situ*** marl.	

FERTILITY DATA

pH: slightly acid Phosphorous: low Organic Matter: medium
Potassium: very high

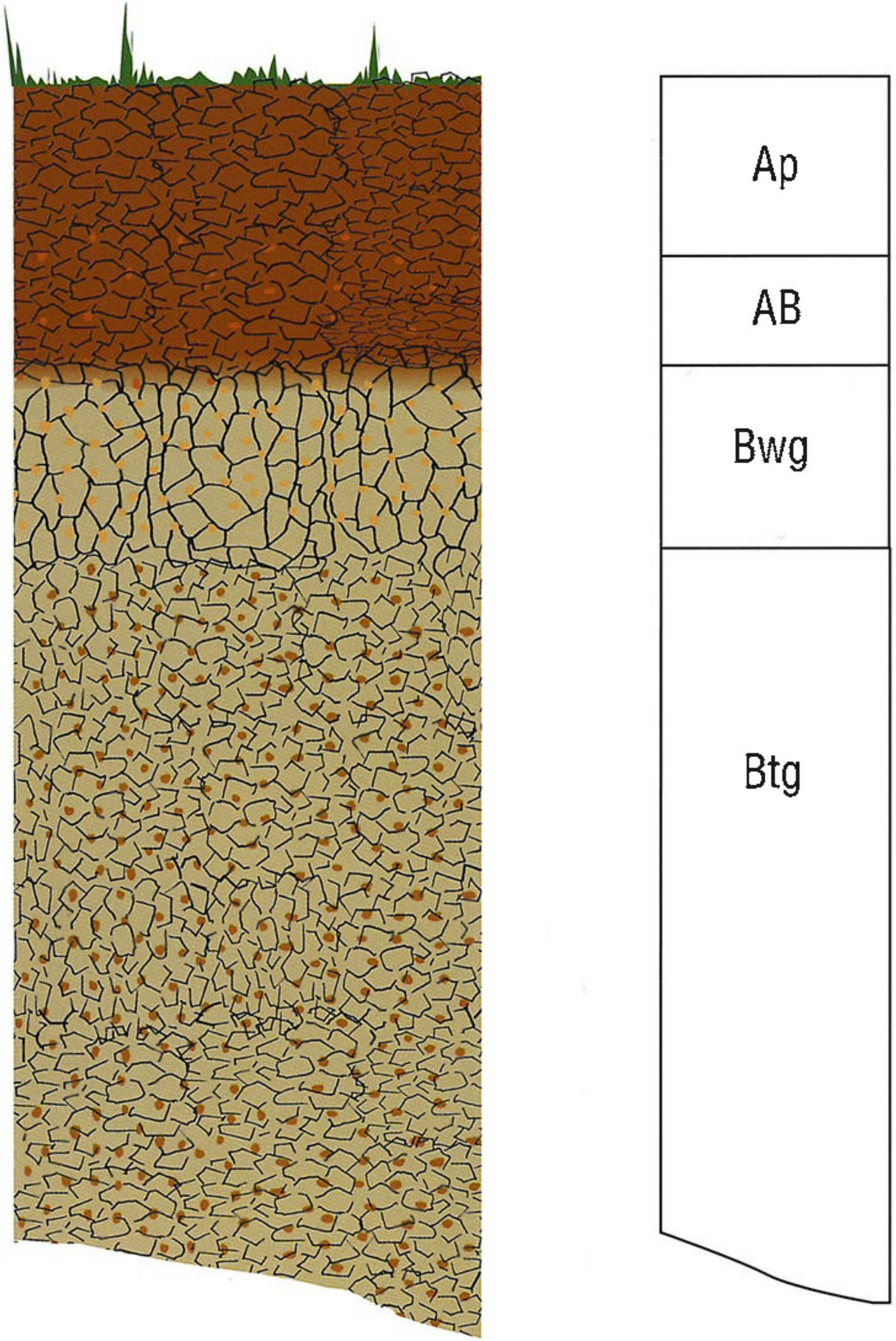
GENERAL LIMITATIONS AND POTENTIAL FOR LAND USE

Soil limitations
Shallowness; clayey; trace element deficiencies (due to high pH); erosion risk on slopes when cultivated

Land use options for unimproved land
(a) Shifting cultivation: most food crops
(b) Permanent use: pasture, cocoa, coconuts

Land use options for improved land (with ameliorations)
(a) Preferred use: market gardening (C, T, f); slopes >11° – pasture
(b) 1st alternative: cocoa, bananas (f); yaqona
(c) 2nd alternative: pasture (f), coffee, coconuts; slopes >11° – market gardening (T, C, f))

Saunaka



- Dark brown friable A and AB horizons
- Light grey mottled yellow brown subsoils
- Massive B horizons

SAUNAKA

Classification:

Soil Taxonomy: Oxyaquic Dystropept, fine, kaolinitic, isohyperthermic

FAO: Dystric Cambisol

Twyford and Wright: Gley soil related to latosols with strong dry season

Parent Material: Colluvium and alluvium from intermediate and basic rocks

Landscape Position: Toeslopes and valley floors of small streams

Moisture Regime: Aquic **Drainage Class:** Imperfectly drained

Horizon	Depth (cm)	REPRESENTATIVE PROFILE DESCRIPTION	Diagnostic Horizons
Ap	0–25 cm	dark brown, fine sandy clay loam; friable; weak fine blocky structure; distinct boundary,	Ochric
AB	25–38 cm	dark brown clay loam; few yellowish red mottles; friable; moderate fine blocky structure; distinct boundary,	Cambic
Bwg	38–60 cm	light grey clay loam; abundant yellowish brown mottles; massive breaking to weak fine blocky structure; distinct boundary,	
Btg	60–110+ cm	light grey fine sandy clay; many dark yellowish brown mottles; friable; massive breaking to weak fine blocky structure; few clay coats.	Argillic

FERTILITY DATA

pH: strongly acid | Phosphorous: very low | Organic Matter: very low
Potassium: very low

GENERAL LIMITATIONS AND POTENTIAL FOR LAND USE

Soil limitations

Moisture conditions (summer); moisture stress (dry season); Al. toxicity; nutrient deficiencies

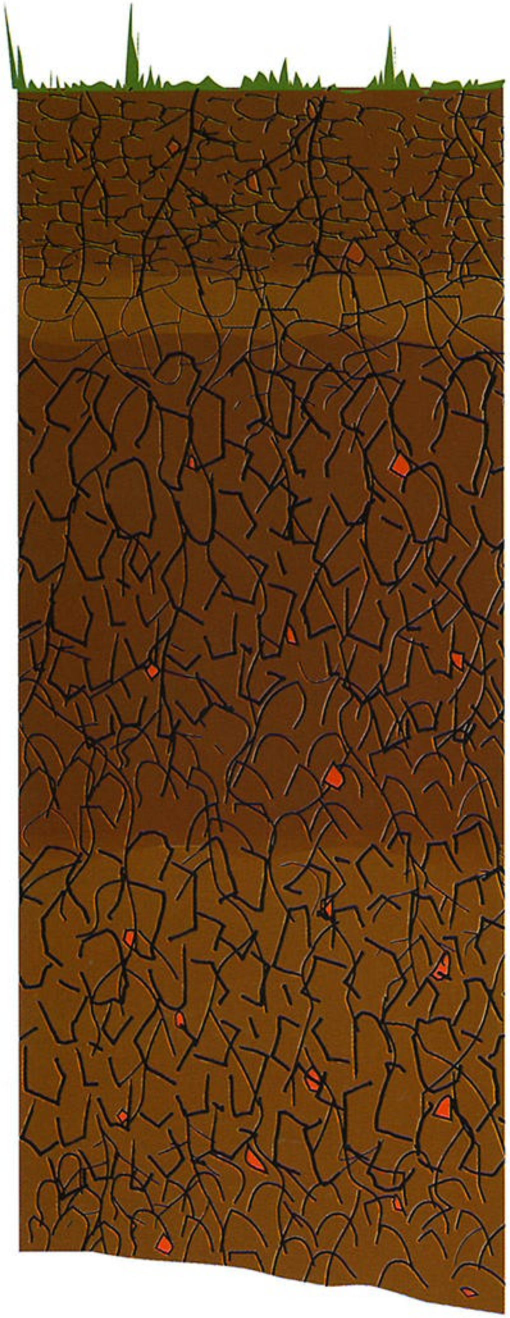
Land use options for unimproved land

(a) Shifting cultivation: rice, dalo
(b) Permanent use: inferior pasture, cane, rice

Land use options for improved land (with ameliorations)

(a) Preferred use: cane (D, F)
(b) 1st alternative: rice (d, F), pasture (d, F)
(c) 2nd alternative: tavioka, peanuts (D. F)

Sigatoka



- Ap horizon dark brown with nut structured clay loam textures
- Greyish brown subsoil with blocky structures
- Thick (86 cm) buried A horizons
- Fragments of parent material throughout
- Humus coatings to peds and along root channels

SIGATOKA

Classification:

Soil Taxonomy: Cumulic Haplustoll, fine silty, mixed, isohyperthermic

FAO: Eutric Fluvisol

Twyford and Wright: Recent soil with a moderate to strong dry season

Parent Material: Alluvium of low quartz content (i.e., from basic rocks)

Landscape Position: High terrace surface of major floodplains

Moisture Regime: Ustic **Drainage Class:** Well drained

Horizon	Depth (cm)	REPRESENTATIVE PROFILE DESCRIPTION	Diagnostic Horizons
Ap	0–24 cm	dark brown clay loam; sticky; friable; moderate nut structure; few fine roots; many humus coats; many fine light yellowish brown parent material grains; indistinct boundary,	Mollic
bAh1	24–32 cm	brown silt loam; firm; strong coarse blocky structure; abundant very dark grey humus coats; few fine roots; few fine white parent material grains; indistinct boundary,	Buried Soil
bAh2	32–100 cm	very dark greyish brown clay loam; firm; sticky; plastic; weak coarse blocky structure; abundant very dark grey humus coats; few fine roots; few coarse reddish brown parent material fragments; indistinct boundary,	
BC	100–120+ cm	dark greyish brown fine sandy clay loam; soft; weak coarse blocky structure; few black humus coats in root channels; few red parent material fragments.	Cambic

FERTILITY DATA

pH: moderately acid Phosphorous: very low Organic Matter: very low
Potassium: high

GENERAL LIMITATIONS AND POTENTIAL FOR LAND USE

Soil limitations

Rare flood risk; soil structure breakdown under intensive continuous cropping

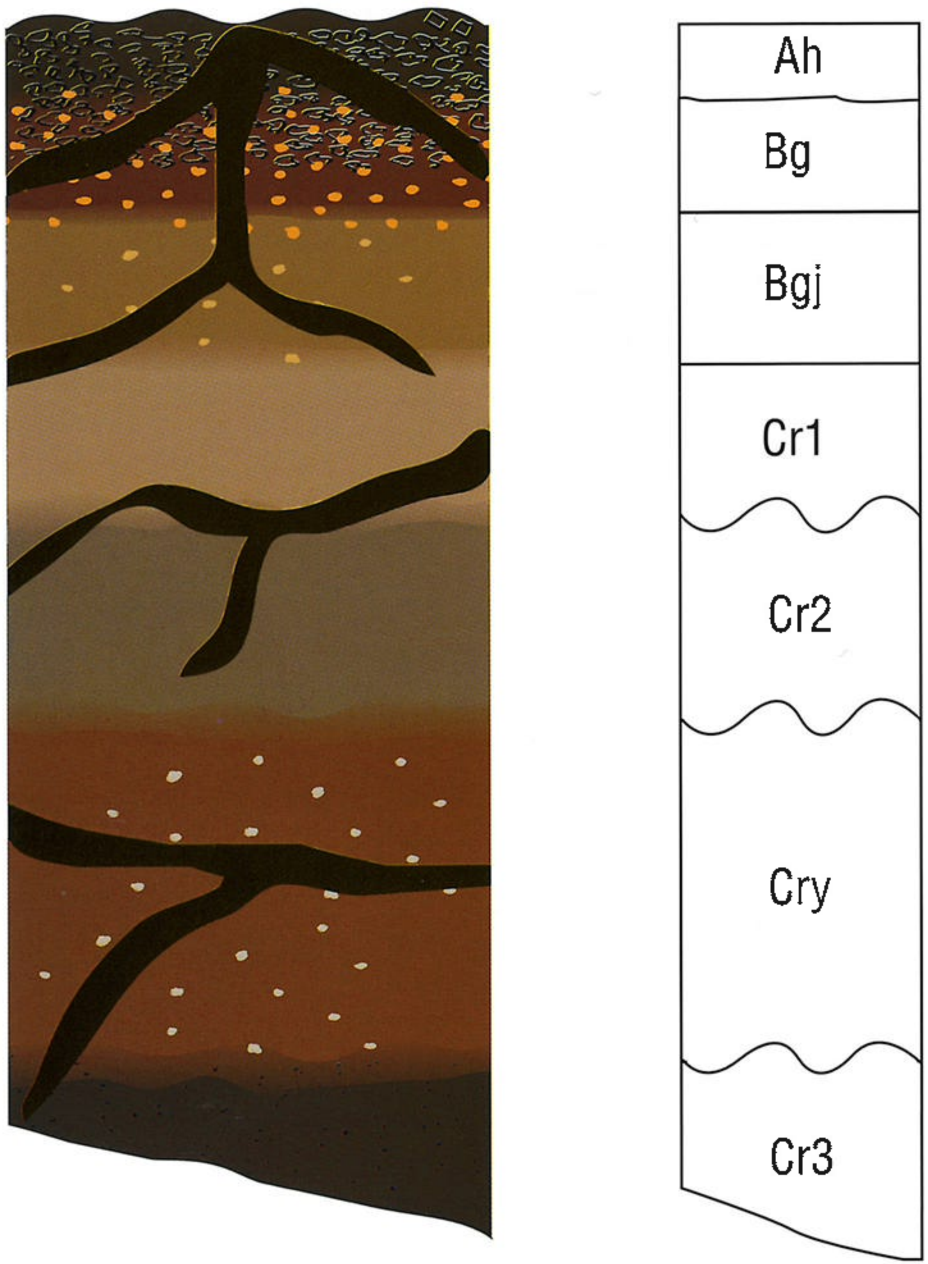
Land use options for unimproved land

(a) Shifting cultivation: most food crops
(b) Permanent use: pasture, cane, bananas

Land use options for improved land (with ameliorations)

(a) Preferred use: cane, maize, pulses, potatoes, tomatoes (f), dalo, market gardening (f, i)
(b) 1st alternative: bananas (s, f), cocoa, coffee, mango, avocado, pawpaw
(c) 2nd alternative: peanuts (f), coconuts (f), pasture (i, f)

Soso



- Humus-rich peaty silty clay Ah horizon
- Gleyed grey massive and firm Bg horizons
- Prominent jarosite mottles in Bg j horizon
- Dead mangrove roots in all horizons
- Water table at 40 cm
- Gypsum crystals in Cry horizon
- Common shell fragments in Cr horizons

SOSO

Classification:

Soil Taxonomy: Typic Tropaquept, clayey, mixed, isohyperthermic

FAO: Dystric Gleysols

Twyford and Wright: Saline soil of the marine marsh

Parent Material: Alluvia from marine and river sources

Landscape Position: Deltas and river edges inland of mangrove swamps

Moisture Regime: Aquic **Drainage Class:** Very poorly drained

Horizon	Depth (cm)	REPRESENTATIVE PROFILE DESCRIPTION	Diagnostic Horizons
Ah	0–8 cm	black peaty silty clay; few yellowish brown mottles; moderate crumb structure; friable; abundant fine dead roots; distinct boundary,	Ochric
Bg	8–24 cm	grey to light grey clay; many yellowish brown mottles along root channels; massive; very firm; plastic; many fine dead roots; distinct boundary,	Cambic
Bgj	24–44 cm	light brownish grey clay; abundant coarse yellow to yellowish brown mottles; massive; firm; plastic; many fine dead roots; sharp boundary,	
Cr1	44–67 cm	grey to greyish brown clay; massive; firm; plastic; common fine dead roots; distinct wavy boundary,	
Cr2	67–95 cm	dark grey silty clay; massive; friable; sticky; many dead roots; distinct wavy boundary,	
Cry	95–142 cm	dark brown to brown silty clay loam; few light grey weathered shell fragments; friable; sticky; massive; many dead roots; many gypsum crystals along root channels; distinct wavy boundary,	
Cr3	142–160+ cm	very dark grey loamy fine sand; single grain; loose; few dead roots.	

FERTILITY DATA

pH: extremely acid	Phosphorous: low	Organic Matter: high
Potassium: medium	Salinity: high	

GENERAL LIMITATIONS AND POTENTIAL FOR LAND USE

Soil limitations

Moisture conditions; drainage; salt water effects; soil acidity; low P

Land use options for unimproved land

(a) Shifting cultivation: --

(b) Permanent use: inferior pasture

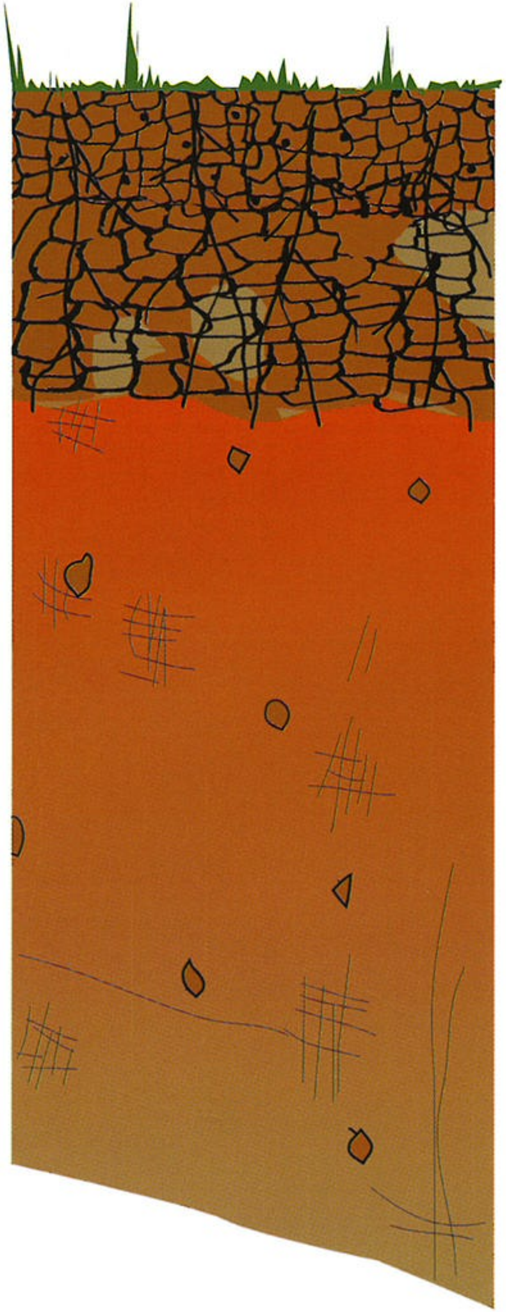
Land use options for improved land (with ameliorations)

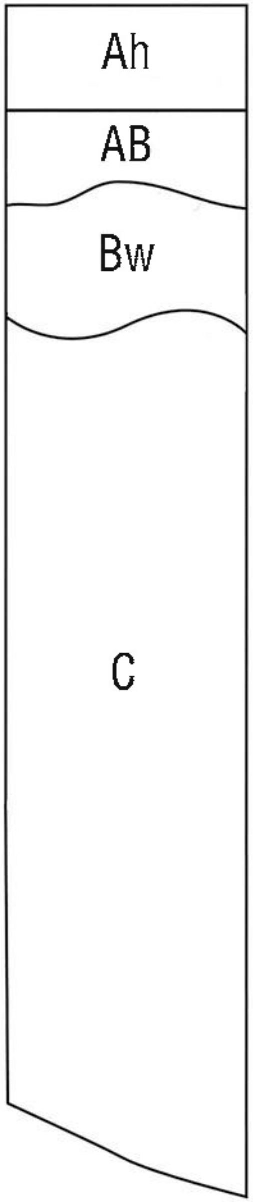
(a) Preferred use: rice (D, f)

(b) 1st alternative: pasture (D, f)

(c) 2nd alternative: cane, market gardening (D,f)

Sote





- Clayey profile textures
- Sticky and plastic consistence
- Predominant red colours in the Bw and C horizons

SOTE

Classification:

Soil Taxonomy: Typic Humitropept, very fine, kaolinitic, isohyperthermic
FAO: Humic Cambisol
Twyford and Wright: Humic latosol with little or no dry season

Parent Material: Strongly weathered ***in situ*** tuffs and siltstones of basic composition
Landscape Position: Crests, midslopes in hilly land
Moisture Regime: Perudic **Drainage Class:** Well drained

Horizon	Depth (cm)	REPRESENTATIVE PROFILE DESCRIPTION	Diagnostic Horizons
Ah	0–13 cm	dark brown clay loam; friable; sticky; plastic; moderate fine nut structure; common yellowish red mottles; few fine roots; distinct boundary,	Ochric
AB	13–32 cm	dark brown and red clay loam; friable; sticky; plastic; moderate medium nut structure; few fine roots; distinct wavy boundary,	Cambic
Bw	22–65 cm	red clay; firm; sticky; plastic; weak medium nut structure; few fine roots; indistinct wavy boundary,	
C	65–100+ cm	red and pale yellow clay; firm; sticky; plastic; massive; few strongly weathered stones.	

FERTILITY DATA

pH: strongly acid Phosphorous: very low Organic Matter: medium
Potassium: low

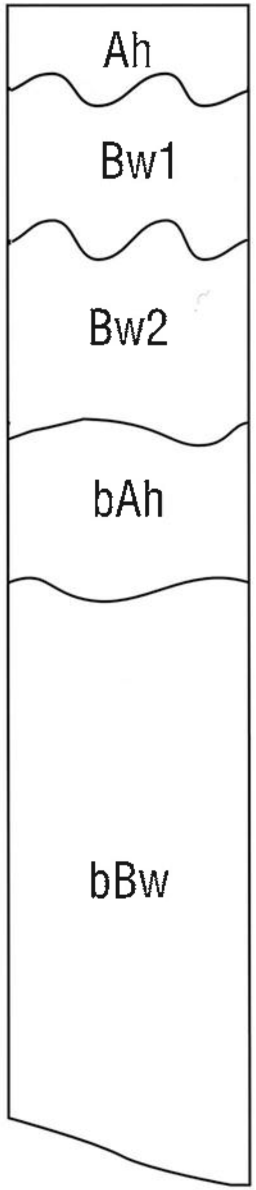
GENERAL LIMITATIONS AND POTENTIAL FOR LAND USE

Soil limitations
Soil acidity; nutrient deficiencies; erosion risk when forest cleared or cultivated

Land use options for unimproved land
(a) Shifting cultivation: kumala, tavioka
(b) Permanent use: inferior pasture

Land use options for improved land (with ameliorations)
(a) Preferred use: pasture (g, d, F); slopes >11° – native timber species, mahogany
(b) 1st alternative: coffee, citrus on slopes <11°
(c) 2nd alternative: pineapples, tavioka (F)

Taveuni



- Stones throughout profile
- Very bouldery at depth in solum
- Dark profile colours
- Friable consistence
- Loamy textures

TAVEUNI

Classification:

Soil Taxonomy: Hydric Melanudand, hydrous, isohyperthermic
FAO: Humic Andosol
Twyford and Wright: Latosolic soil with a weak dry season

Parent Material: Shallow volcanic ash over weathered older lava flows of basic composition
Landscape Position: Rolling and hilly land of the volcanic ring surfaces and ring plains to the central volcanic core of Taveuni
Moisture Regime: Udic **Drainage Class:** Well drained

Horizon	Depth (cm)	REPRESENTATIVE PROFILE DESCRIPTION	Diagnostic Horizons
Ah	0–11 cm	black humic loam; very friable; weak fine nut structure; abundant fine roots; weakly weathered basalt stones,	Umbric
Bw1	11–31 cm	very dark greyish brown clay loam; very friable; sticky; plastic; weak medium nut structure; many fine roots; weakly weathered basalt stones,	Cambic
Bw2	31–54 cm	dark brown loam; friable; moderate coarse blocky structure; common fine roots; common weathered basalt stones,	
bAh	54–75 cm	very dark greyish brown silty clay loam; friable; sticky; plastic; moderate medium nut structure; common clay coats; common fine roots; many basalt stones; distinct boundary,	Buried Horizons
bBw	75–114+ cm	dark yellowish brown gravelly loam; friable; single grain; distinct humic coats; few fine roots; profuse basalt boulders.	

FERTILITY DATA

pH: moderately acid — Phosphorous: very low — Organic Matter: high
Potassium: low

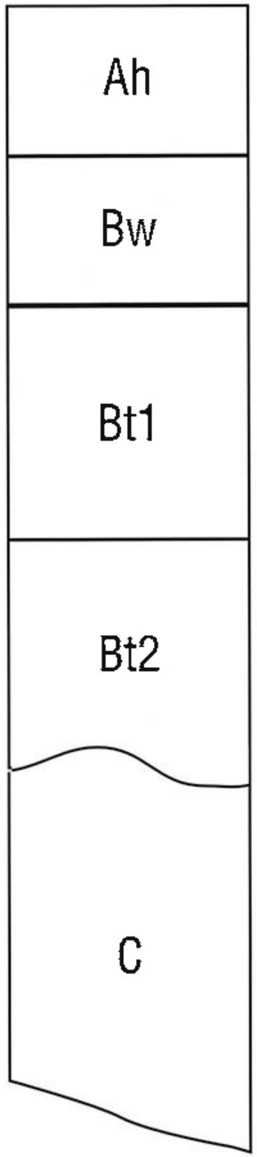
GENERAL LIMITATIONS AND POTENTIAL FOR LAND USE

Soil limitations
Anion fixation; profile boulders; soil acidity; erosion risk

Land use options for unimproved land
(a) Shifting cultivation: most food crops
(b) Permanent use: coconuts, pasture

Land use options for improved land (with ameliorations)
(a) Preferred use: cocoa (f), bananas (f), yaqona (f); slopes >11° – pasture
(b) 1st alternative: pasture (f), coconuts, coffee; slopes >11° – cocoa, bananas (f, T), yaqona
(c) 2nd alternative: maize, vanilla; slopes >11° – market gardening (T, C, f), coconuts (f)

Tavua



- Black coloured Ah horizon
- Strongly weathered stones in all soil horizons
- Clay coatings to Bt horizon peds
- Sticky and plastic consistence
- Weathered in situ rock at 1m

TAVUA

Classification:

Soil Taxonomy: Typic Haplustalf, fine, smectitic, isohyperthermic
FAO: Eutric Nitosol
Twyford and Wright: Nigrescent soil with a strong dry season

Parent Material: Deep strongly weathered *in situ* basalt rocks
Landscape Position: All slope positions in hilly land
Moisture Regime: Ustic **Drainage Class:** Well drained

Horizon	Depth (cm)	REPRESENTATIVE PROFILE DESCRIPTION	Diagnostic Horizons
Ah	0–18 cm	black clay loam; moderate coarse blocky structure; friable; sticky; plastic; common very fine roots; few weathered stones; indistinct boundary,	Ochric
Bw	18–38 cm	dark brown clay loam; strong fine blocky structure; friable; sticky; plastic; common very fine roots; few weathered stones; indistinct boundary,	Cambic
Bt1	38–70 cm	dark brown clay; moderate medium blocky structure; friable; sticky; plastic; common dark reddish brown clay coats; common fine roots; few strongly weathered stones; indistinct boundary,	Argillic
Bt2	70–100 cm	reddish brown clay; strong medium blocky structure; firm; sticky; plastic; prominent dark reddish brown clay coats; few very fine roots; many strongly weathered stones; distinct irregular boundary	
C	*on*	green weathered *in situ* basalt rock.	

FERTILITY DATA

pH: moderately acid Phosphorous: very low Organic Matter: low
Potassium: high

GENERAL LIMITATIONS AND POTENTIAL FOR LAND USE

Soil limitations

Moisture stress (dry season); surface boulders; slope; erosion risk on slopes >11°

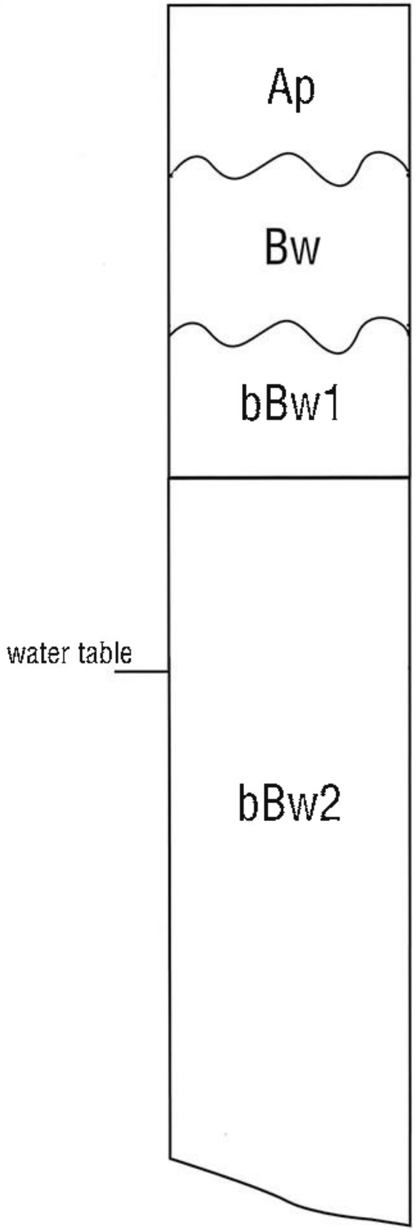
Land use options for unimproved land

(a) Shifting cultivation: kumala; dalo, yam, bananas
(b) Permanent use: pasture

Land use options for improved land (with ameliorations)

(a) Preferred use: pasture
(b) 1st alternative: pulses, maize (C, T, I, f)
(c) 2nd alternative: cane, market gardening (C, T, I, F), peanuts; slopes >11° – coffee (S, f, C)

Togoru



- Dark grey profile colours
- Sandy textures
- Organic matter high in all horizons
- Water table at 90 cm
- Coral and shell fragments at depth

TOGORU

Classification:

Soil Taxonomy: Typic Tropaquept, sandy, mixed, isohyperthermic
FAO: Dystric Gleysol
Twyford and Wright: Gley soil related to red yellow podzolic soils with no dry season

Parent Material: Alluvial sands of high quartz content derived from acidic rocks
Landscape Position: Low-lying land inland of coastal sands and saline areas
Moisture Regime: Aquic **Drainage Class:** Very poorly drained

Horizon	Depth (cm)	REPRESENTATIVE PROFILE DESCRIPTION	Diagnostic Horizons
Ap	0–23 cm	very dark grey sandy loam; strong medium nut structure; friable; few fine roots; few medium organic mottles; distinct wavy boundary,	Ochric
Bw	23–46 cm	dark grey and grey heavy sandy loam; weak coarse blocky structure; very firm; few stones; medium organic matter; distinct wavy boundary,	
bBw1	46–68 cm	dark grey sandy loam; moderate coarse blocky structure; high organic matter, dead mangrove roots; distinct boundary,	Cambic
bBw2	68–92+ cm	dark grey loam; weak coarse blocky structure; sticky; abundant shell fragments; few stones; many coral fragments; high organic matter.	

FERTILITY DATA

pH: moderately acid	Phosphorous: very low	Organic Matter: very low
Potassium: medium	Salinity: high	

GENERAL LIMITATIONS AND POTENTIAL FOR LAND USE

Soil limitations

Moisture conditions; floods; high water table; soil acidity; Al. toxicity; nutrient deficiencies

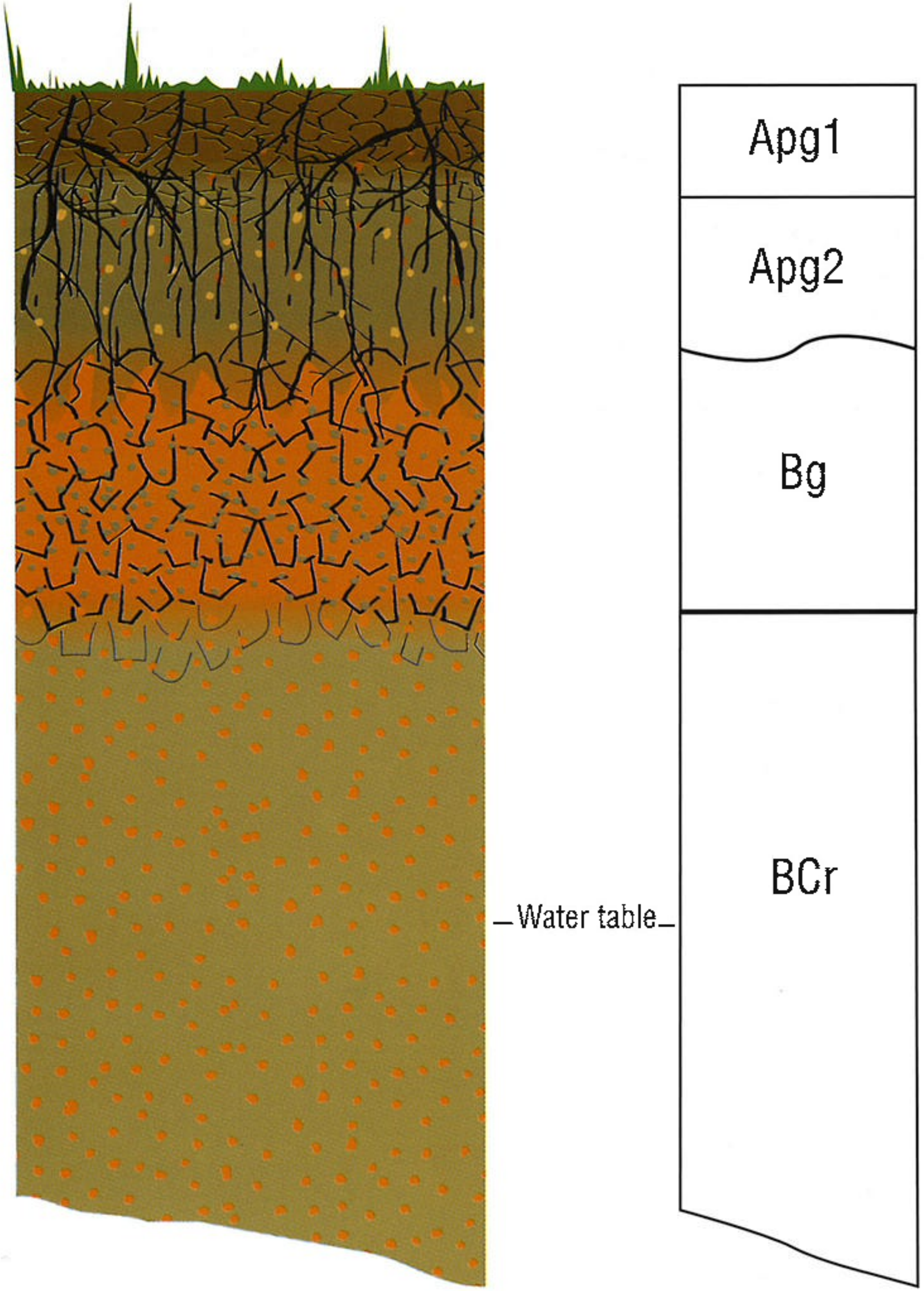
Land use options for unimproved land

(a) Shifting cultivation: dalo, tavioka
(b) Permanent use: rice, inferior pasture

Land use options for improved land (with ameliorations)

(a) Preferred use: rice (i, F)
(b) 1st alternative: pasture (d, f)
(c) 2nd alternative: –

Tokotoko



- Strongly gleyed and mottled Apg2 horizon
- Distinct worm mixing at Apg2-Bg interface
- Subsoils clayey
- Strong brown with greenish grey mottled Bg horizon
- Olive grey, mottled strong brown and massive BCr horizon
- Water table at 1m

TOKOTOKO

Classification:

Soil Taxonomy: Aeric Tropaquept, very fine, kaolinitic, isohyperthermic
FAO: Eutric Gleysol
Twyford and Wright: Gley soil related to latosols with no dry season

Parent Material: Alluvium from intermediate and basic rocks
Landscape Position: Low-lying surfaces on the major flood plains
Moisture Regime: Aquic **Drainage Class:** Very poorly drained

Horizon	Depth (cm)	REPRESENTATIVE PROFILE DESCRIPTION	Diagnostic Horizons
Apg1	0–17 cm	dark greyish brown silty clay loam; common yellowish-red mottles; weak coarse blocky structure; friable; many fine and medium roots; indistinct boundary,	Ochric
Apg2	17–37 cm	olive grey clay loam; common dark yellowish brown mottles; weak coarse prismatic structure; friable to firm; many fine roots; distinct wavy boundary,	
Bg	37–69 cm	strong brown clay; many greenish grey mottles; weak medium blocky structure; firm; sticky; few very fine, roots; worm mixing in upper 10 cm; diffuse boundary,	Cambic
BCr	69–134 cm	olive grey clay; profuse coarse prominent strong brown mottles; massive; sticky; plastic; firm	

FERTILITY DATA

pH: strongly acid Phosphorous: very low Organic Matter: low
Potassium: high

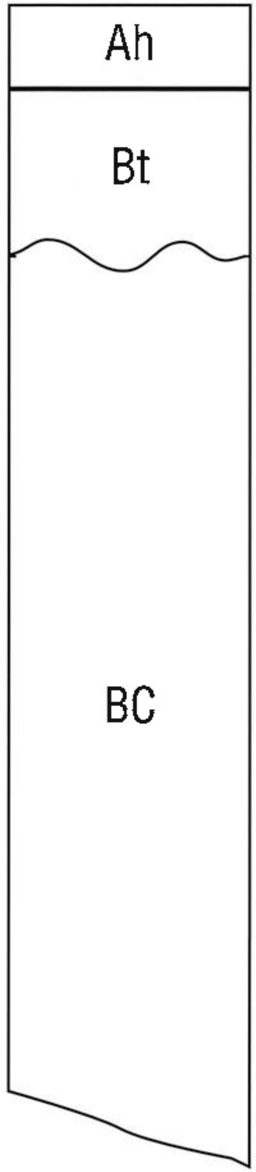
GENERAL LIMITATIONS AND POTENTIAL FOR LAND USE

Soil limitations
Poor drainage; high water table (in wet season); floods; clayey; soil acidity; nutrient deficiencies

Land use options for unimproved land
(a) Shifting cultivation: dalo, tavioka, bananas
(b) Permanent use: rice, inferior pasture

Land use options for improved land (with ameliorations)
(a) Preferred use: rice (i, F)
(b) 1st alternative: pasture
(c) 2nd alternative: –

Tuva



- Shallow soil with weathered in situ rock at 36 cm (BC)
- Red clay coatings to peds and voids in Bt horizon
- Pink and red mottled brownish yellow BC horizon

TUVA

Classification:

Soil Taxonomy: Typic Kanhaplustult, clayey, ferruginous, isohyperthermic
FAO: Ferric Acrisol
Twyford and Wright: Ferruginous latosol with a strong dry season

Parent Material: Weathered colluvium over ***in situ*** rocks of basic composition
Landscape Position: All slopes in rolling and hilly land
Moisture Regime: Ustic **Drainage Class:** Moderately well drained

Horizon	Depth (cm)	REPRESENTATIVE PROFILE DESCRIPTION	Diagnostic Horizons
Ah	0–12 cm	dark reddish-brown silty clay loam; moderate fine nut structure; very friable; many medium and coarse roots; distinct boundary,	Ochric
Bt	12–36 cm	red clay loam; moderate medium blocky structure; friable; few red clay coats to voids; common medium and coarse roots; distinct wavy boundary,	Argillic
BC	36–126+ cm	pink red clay loam; many fine brownish yellow mottles; massive; friable to firm; few red discontinuous clay coats to rock fissures; few fine roots.	Cambic

FERTILITY DATA

pH: moderately acid
Phosphorous: very low
Organic Matter: very low
Potassium: low

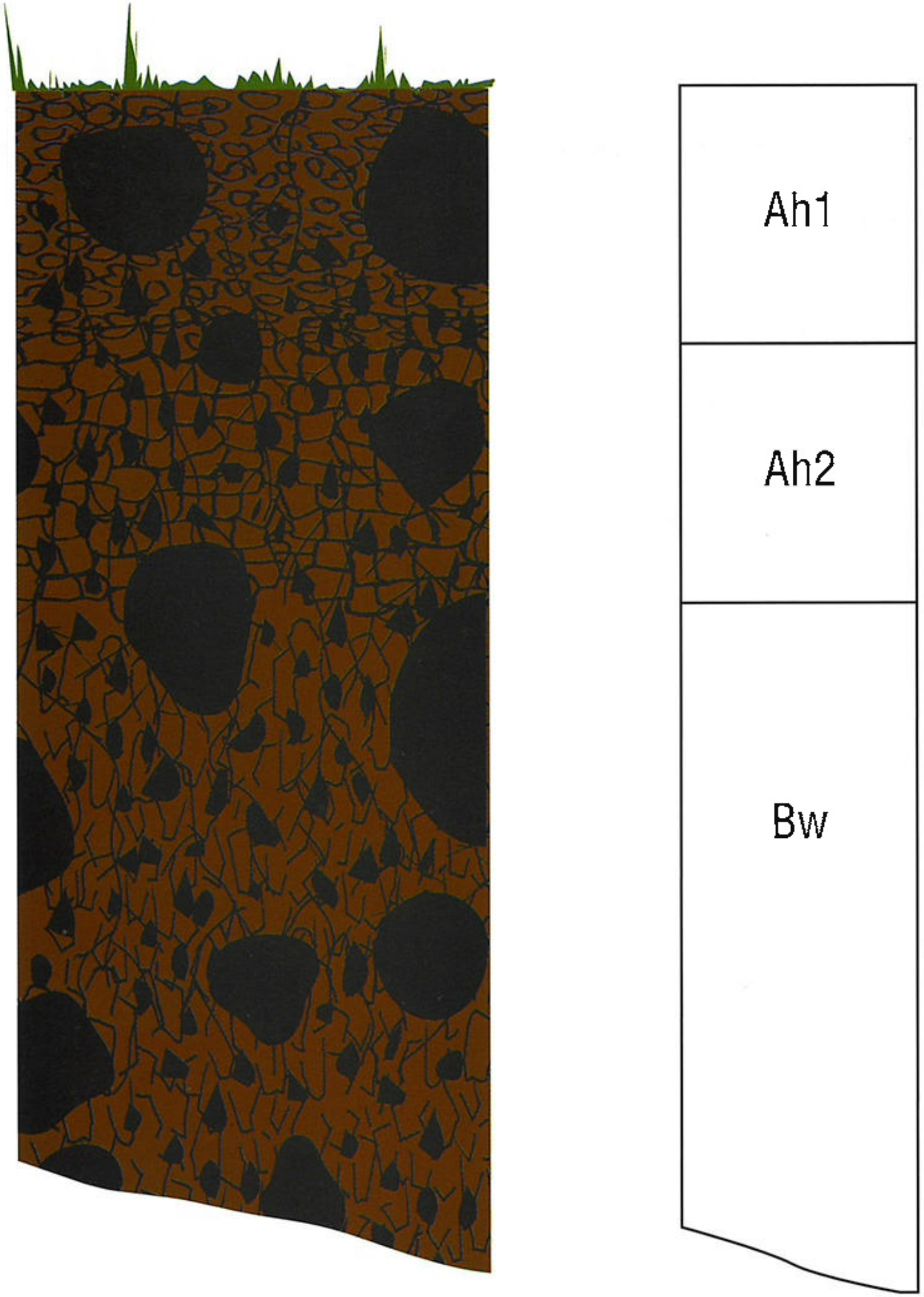
GENERAL LIMITATIONS AND POTENTIAL FOR LAND USE

Soil limitations
Moisture stress (dry season); soil acidity; high Al.; low mineral content; nutrient deficiencies; erosion risk on slopes >3°

Land use options for unimproved land
(a) Shifting cultivation: tavioka, kumala
(b) Permanent use: inferior pasture

Land use options for improved land (with ameliorations)
(a) Preferred use: pasture (F, g)
(b) 1st alternative: cane (F, C); slopes >11° – citrus (T, F, C), reafforestation
(c) 2nd alternative: pineapples, tavioka, citrus (f); slopes >11° – reafforestation

Vakawau



- Thick (70 cm) Ah horizons
- Friable smeary consistence
- Stones and boulders in all horizons

VAKAWAU

Classification:

Soil Taxonomy: Hydric Melanudand, medial-skeletal, isohyperthermic
FAO: Humic Andosol
Twyford and Wright: Latosolic soil with no dry season

Parent Material: Latosolic soil with no dry season
Landscape Position: Young bouldery basalt flow rocks with some ash
Moisture Regime: Perudic **Drainage Class:** Well drained

Horizon	Depth (cm)	REPRESENTATIVE PROFILE DESCRIPTION	Diagnostic Horizons
Ah1	0–35 cm	very dark greyish brown silty clay loam; moderate medium granular structure; very friable; smeary; many stones and boulders; many fine roots; diffuse boundary,	Umbric
Ah2	35–70 cm	dark brown loam; moderate very coarse nut structure; friable; smeary; few fine roots; abundant stones and many boulders; diffuse boundary,	
Bw	70–105+ cm	dark yellowish brown silt loam; weak fine blocky structure; very friable; smeary; few fine roots; abundant stones and boulders.	Cambic

FERTILITY DATA

pH: strongly acid
Phosphorous: very low
Organic Matter: high
Potassium: medium

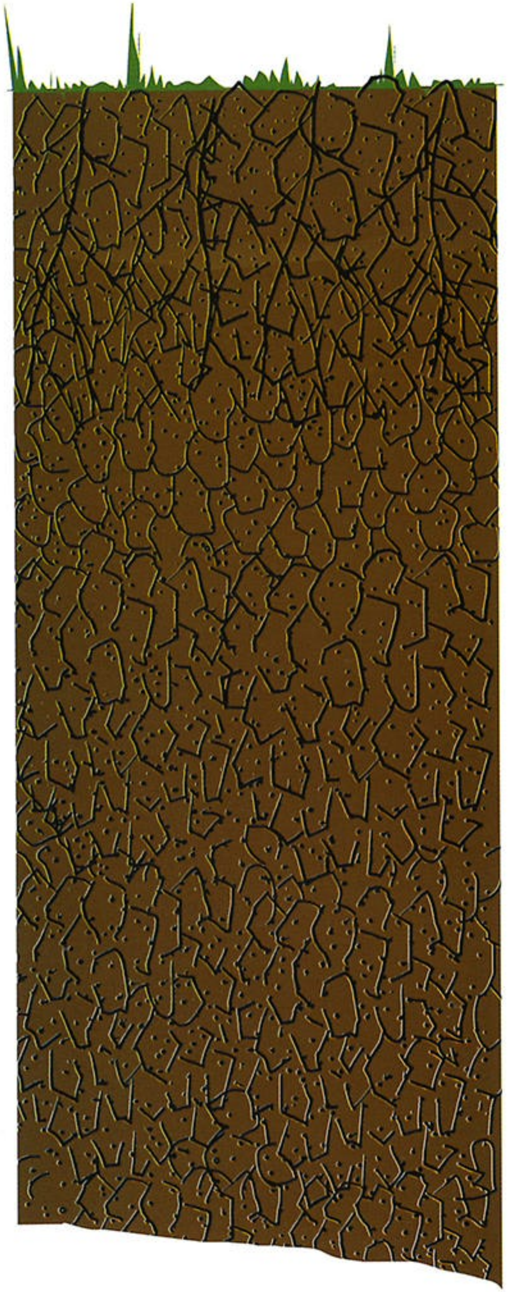
GENERAL LIMITATIONS AND POTENTIAL FOR LAND USE

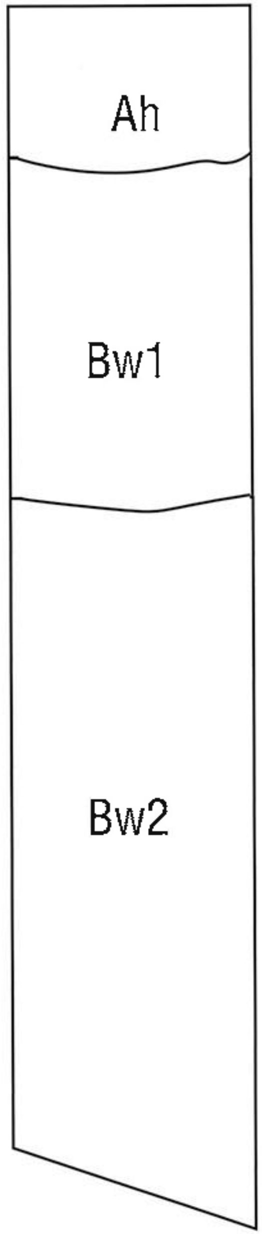
Soil limitations
Anion fixation; rock outcrops; profile boulders and stones; nutrient deficiencies; erosion risk

Land use options for unimproved land
(a) Shifting cultivation: most food crops; slopes >11° – yams, tavioka
(b) Permanent use: coconuts, inferior pastures; slopes >11°– pasture, cocoa, coconuts

Land use options for improved land (with ameliorations)
(a) Preferred use: pasture (f)
(b) 1st alternative: coffee, citrus, coconuts; on slopes >11° – coconuts, bananas, yaqona, cocoa (C, T, f)
(c) 2nd alternative: cocoa (F), pineapples (F), bananas (f); slopes >11° – citrus, coconut, coffee, tea (d, F)

Volivoli





- Dark brown and very friable to 100 cm
- Medium sand textures and weak blocky structures in all horizons

VOLIVOLI

Classification:

Soil Taxonomy: Ustic Humitropept, sandy, siliceous, isohyperthermic
FAO: Humic Cambisol
Twyford and Wright: Recent soil from coastal sands with a strong dry season

Parent Material: Non-calcareous brownish sands of high quartz content
Landscape Position: Easy rolling stabilized sand dunes
Moisture Regime: Ustic
Drainage Class: Somewhat excessively drained

Horizon	Depth (cm)	REPRESENTATIVE PROFILE DESCRIPTION	Diagnostic Horizons
Ah	0–20 cm	very dark greyish brown medium sand; very friable; blocky structure; abundant fine roots; indistinct boundary,	Ochric
Bw1	20–66 cm	dark brown medium sand, very friable; weak medium blocky structure; few fine roots in upper 20 cm; indistinct boundary,	Cambic
Bw2	66–150+ cm	dark brown medium sand; very friable; weak medium to coarse blocky structure.	

FERTILITY DATA

pH: slightly acid
Potassium: low
Phosphorous: very low
Organic Matter: very low

GENERAL LIMITATIONS AND POTENTIAL FOR LAND USE

Soil limitations

Excessively drained; moisture stress; nutrient deficiencies; erosion risk (saltation)

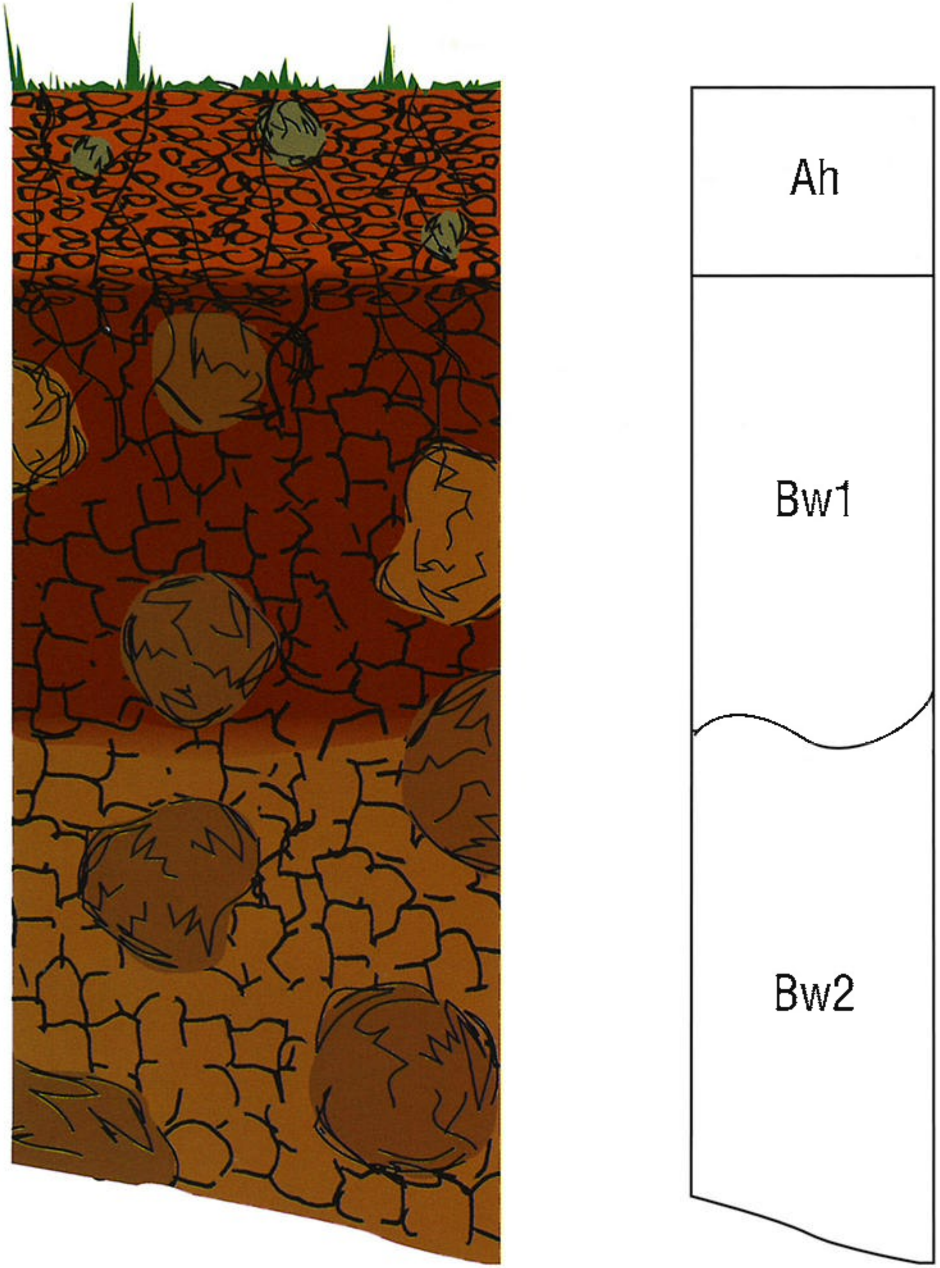
Land use options for unimproved land

(a) Shifting cultivation: most food crops
(b) Permanent use: coconuts, pasture

Land use options for improved land (with ameliorations)

(a) Preferred use: market gardening (F)
(b) 1st alternative: maize, peanuts, cane, kumala, potatoes, pulses
(c) 2nd alternative: coconuts

Wailulu



- Boulders in all horizons
- Clayey and plastic Bw horizons
- Weak structural development

WAILULU

Classification:

Soil Taxonomy: Oxic Humitropept, fine, kaolinitic, isothermic

FAO: Humic Cambisol

Twyford and Wright: Upland humic latosol with a weak dry season

Parent Material: Strongly weathered ***in situ*** basalt rock

Landscape Position: Rolling and undulating slopes in upland hilly land

Moisture Regime: Udic **Drainage Class:** Well drained

Horizon	Depth (cm)	REPRESENTATIVE PROFILE DESCRIPTION	Diagnostic Horizons
Ah	0–25 cm	red clay loam; moderate fine granular structure; friable; few medium rounded boulders; common fine roots; distinct boundary,	Ochric
Bw1	25–85 cm	yellowish red clay; patches of yellowish brown and brownish yellow; weak coarse nut structure; firm plastic; many large strongly weathered olive boulders; diffuse wavy boundary,	Cambic
Bw2	85–120+ cm	strong brown clay; weak coarse nut structure; friable; many strongly weathered boulders.	

FERTILITY DATA

pH: strongly acid Phosphorous: very low Organic Matter: very low
Potassium: very low

GENERAL LIMITATIONS AND POTENTIAL FOR LAND USE

Soil limitations

Soil acidity; high Al.; nutrient deficiencies; erosion risk on slopes >7°

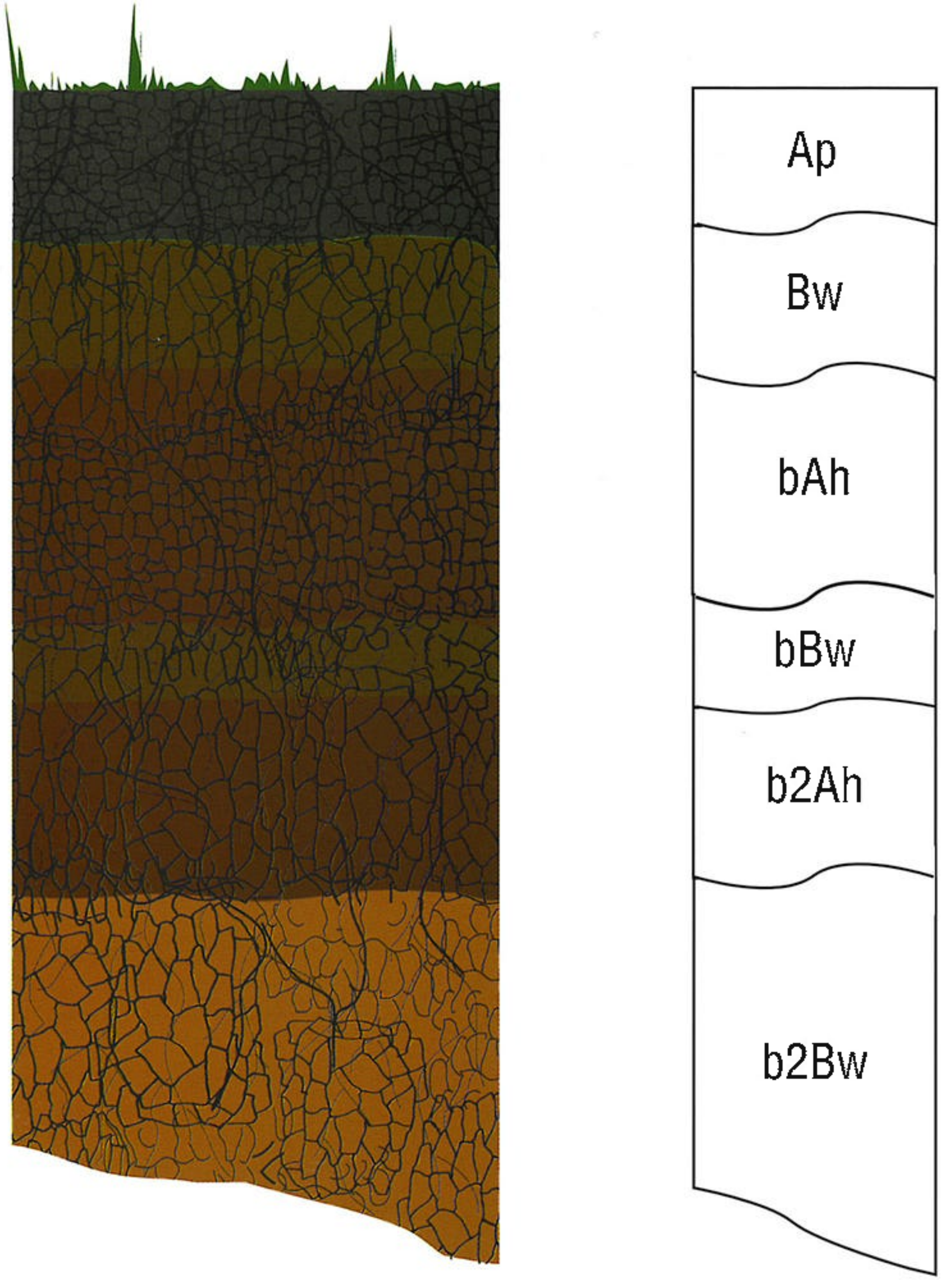
Land use options for unimproved land

(a) Shifting cultivation: tavioka
(b) Permanent use: inferior pasture

Land use options for improved land (with ameliorations)

(a) Preferred use: pasture (F, g); slopes >11° – tea, coffee, citrus (T, C, F)
(b) 1st alternative: tea, coffee, citrus (d, F); slopes >11° – pasture
(c) 2nd alternative: forestry on all slopes

Wainibuka



- Clayey textures, firm, sticky and plastic consistence in all horizons
- Two buried A horizons

WAINIBUKA

Classification:

Soil Taxonomy: Fluventic Hapludoll, fine, smectitic, isohyperthermic
FAO: Haplic Phaeozem
Twyford and Wright: Recent soil with weak to moderate dry season

Parent Material: Alluvium of low quartz content (i.e., from basic rocks)
Landscape Position: High terrace surface
Moisture Regime: Udic **Drainage Class:** Well drained

Horizon	Depth (cm)	REPRESENTATIVE PROFILE DESCRIPTION	Diagnostic Horizons
Ap	0–20 cm	very dark grey clay; firm; sticky; plastic; moderate fine nut structure; many fine roots; distinct wavy boundary,	Mollic
Bw	20–39 cm	brown clay; dark greyish humus coats; friable; sticky; plastic; moderate medium blocky structure; many fine roots; distinct wavy boundary,	Cambic
bAh	39–68 cm	very dark greyish brown clay; dark grey humus coats; firm; sticky; plastic; moderate fine blocky structure; few fine roots; distinct wavy boundary,	Buried Horizons
bBw	68–83 cm	brown clay to clay loam; dark greyish brown humus coats; firm; sticky; plastic; moderate medium blocky structure; few fine roots; distinct wavy boundary,	
b2Ah	83–108 cm	very dark greyish brown clay; firm; sticky; moderate medium blocky structure; few fine roots; distinct wavy boundary,	
b2Bw	108–120+ cm	dark yellowish brown clay; firm; sticky; plastic; moderate medium blocky structure.	

FERTILITY DATA

pH: moderately acid — Phosphorous: very low — Organic Matter: low
Potassium: high

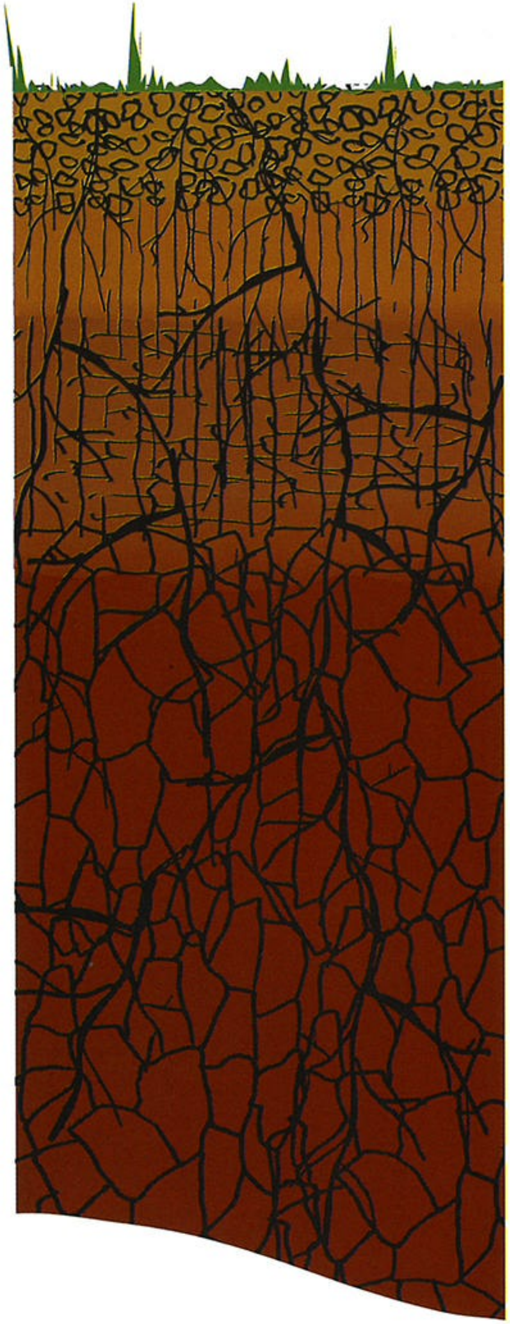
GENERAL LIMITATIONS AND POTENTIAL FOR LAND USE

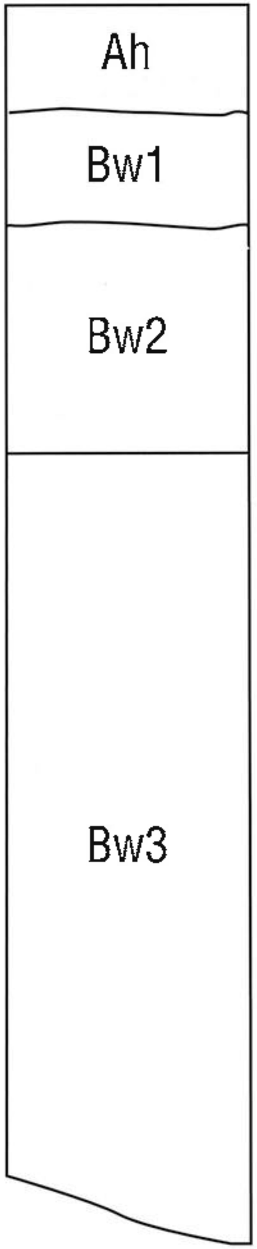
Soil limitations
Infrequent flooding; slow subsoil permeability; moisture stress (in some dry seasons)

Land use options for unimproved land
(a) Shifting cultivation: most food crops
(b) Permanent use: coconuts, bananas, pasture

Land use options for improved land (with ameliorations)
(a) Preferred use: bananas (f), market gardening (F), yaqona (f)
(b) 1st alternative: cocoa (f), maize (f), vanilla (f), cane (f), ginger (f), pawpaw (f)
(c) 2nd alternative: pasture (f, g), coconuts (f), mango (f)

Wainunu





- Humus-rich, very friable Ah horizon
- Prismatic structures in Bw horizons
- Very firm Bw horizons

WAINUNU

Classification:

Soil Taxonomy: Oxic Humitropept, very fine, kaolinitic, isohyperthermic
FAO: Humic Cambisol
Twyford and Wright: Humic latosol soil with no dry season

Parent Material: Weathered ***in situ*** basalts and basic tuffs
Landscape Position: All slope positions on undulating hilly land
Moisture Regime: Udic (Perudic) **Drainage Class:** Well drained

Horizon	Depth (cm)	REPRESENTATIVE PROFILE DESCRIPTION	Diagnostic Horizons
Ah	0–16 cm	dark yellowish brown humic clay loam; very friable; strong granular structure; abundant fine roots; distinct boundary,	Ochric
Bw1	16–30 cm	dark brown silty clay; very firm; sticky; moderate fine prismatic structure breaking to fine nut structure; many medium roots; distinct boundary,	Cambic
Bw2	30–60 cm	reddish brown clay; very firm; moderate coarse prismatic structure breaking to weak medium nut structure; common medium roots; indistinct boundary,	
Bw3	60–120+ cm	yellowish red clay; very firm; sticky; strong very coarse prismatic structure breaking to medium blocky structure; few medium roots.	

FERTILITY DATA

pH: extremely acid
Potassium: medium
Phosphorous: very low
Organic Matter: medium

GENERAL LIMITATIONS AND POTENTIAL FOR LAND USE

Soil limitations

Soil acidity; P fixation; high Al.; clayey; nutrient deficiencies; erosion risk

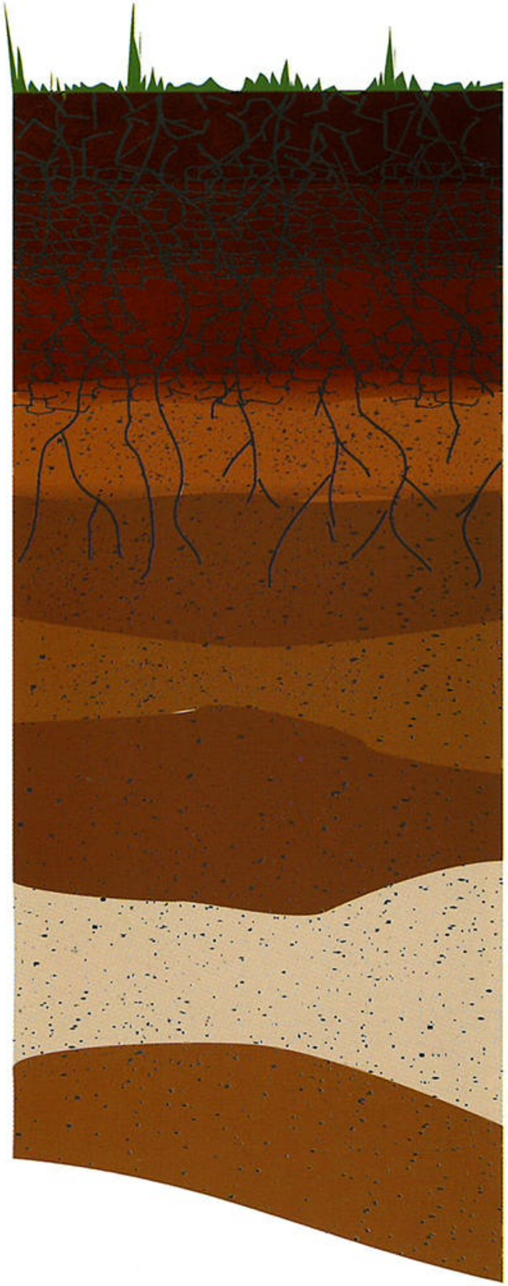
Land use options for unimproved land

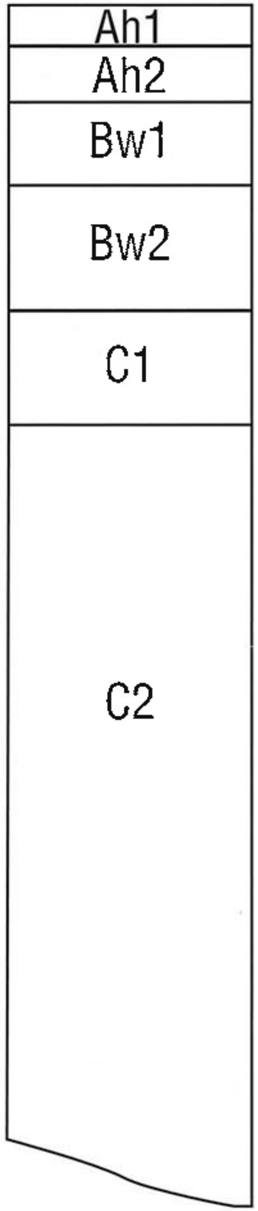
(a) Shifting cultivation: tavioka
(b) Permanent use: inferior pasture

Land use options for improved land (with ameliorations)

(a) Preferred use: pasture
(b) 1st alternative: coffee, citrus (d, f); slopes >11° – pasture, forestry (native timbers)
(c) 2nd alternative: pineapples, tea (d, F); slopes >11° – citrus, coffee, tea (d, F)

Waiqere





- Humus rich Ah horizons
- Textural variation between horizons
- Layered ash beds below 61 cm

WAIQERE

Classification:

Soil Taxonomy: Acrudoxic Hapludand, medial, isohyperthermic
FAO: Humic Andosol
Twyford and Wright: Latosolic soil with a weak dry season

Parent Material: Young volcanic ash of basic composition
Landscape Position: Sloping land on the volcanic ring plains to the central volcanic core of Taveuni
Moisture Regime: Udic **Drainage Class:** Well drained

Horizon	Depth (cm)	REPRESENTATIVE PROFILE DESCRIPTION	Diagnostic Horizons
Ah1	0–7 cm	very dark grey silt loam; weak medium blocky structure; friable; abundant fine roots; distinct boundary,	Ochric
Ah2	7–15 cm	dark reddish brown silt loam; weak medium blocky structure; friable; abundant fine roots; distinct boundary,	
Bw1	15–27 cm	dark reddish brown clay loam; moderate fine nut structure; friable; many fine roots; indistinct boundary,	Cambic
Bw2	27–45 cm	dark reddish brown silt loam; weak fine nut structure; friable; few fine roots; indistinct boundary,	
C1	45–61 cm	reddish brown sandy loam; very friable; single grain; few fine roots; distinct boundary,	
C2	61–120+ cm	ash beds.	

FERTILITY DATA

pH: strongly acid
Phosphorous: very low
Organic Matter: high
Potassium: medium

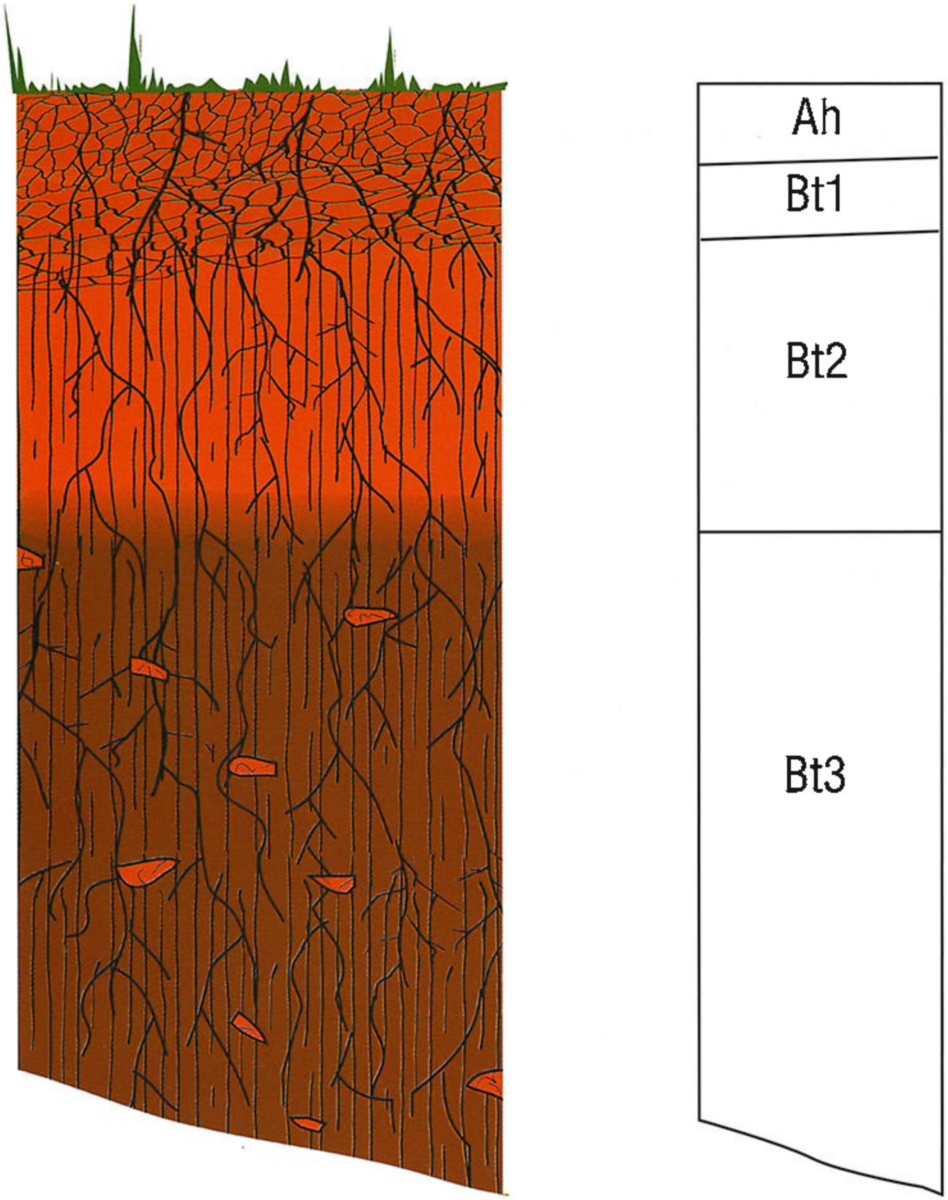
GENERAL LIMITATIONS AND POTENTIAL FOR LAND USE

Soil limitations
Rapid permeability; high Al.; anion fixation; soil acidity; erosion risk

Land use options for unimproved land
(a) Shifting cultivation: most food crops
(b) Permanent use: coconuts, pasture

Land use options for improved land (with ameliorations)
(a) Preferred use: cocoa (f), bananas (f), yaqona (f); slopes >11° – pasture
(b) 1st alternative: pasture (f), coconuts, coffee; slopes >11° – cocoa, bananas (f, T), yaqona
(c) 2nd alternative: maize, vanilla; slopes >11° – market gardening (T, C, f), coconuts (f)

Yaqara



- Reddish brown profile colours
- Well structured, with tendency to be prismatic in Bt horizons
- Sticky and plastic consistence
- Clay coatings to peds in Bt horizons

YAQARA

Classification:

- **Soil Taxonomy:** Kanhaplic Haplustalf, fine, kaolinitic, isohyperthermic
- **FAO:** Eutric Nitosol
- **Twyford and Wright:** Nigrescent soil with strong dry season

Parent Material: Colluvium from basaltic rocks

Landscape Position: Toeslopes and easy rolling valley floors

Moisture Regime: Ustic **Drainage Class:** Moderately well drained

Horizon	Depth (cm)	REPRESENTATIVE PROFILE DESCRIPTION	Diagnostic Horizons
Ah	0–10 cm	dark reddish brown silty clay loam; strong fine blocky structure; very friable; sticky; plastic; many fine roots; indistinct boundary,	Ochric
Bt1	10–22 cm	dark reddish brown silty clay; moderate fine and medium blocky structure; friable; very sticky; plastic; common clay coats; many fine roots; indistinct boundary,	Argillic
Bt2	22–57 cm	red silty clay; moderate fine prismatic structure; friable; very sticky; plastic; common clay coats; common fine roots; diffuse boundary,	
Bt3	57–97+ cm	reddish brown silty clay; moderate fine prismatic structure; firm; very sticky; plastic; clay coats; few roots; few strongly weathered gravels.	

FERTILITY DATA

pH: moderately acid Phosphorous: very low Organic Matter: medium
Potassium: medium

GENERAL LIMITATIONS AND POTENTIAL FOR LAND USE

Soil limitations

Moisture stress (dry season); high Al.; nutrient deficiencies

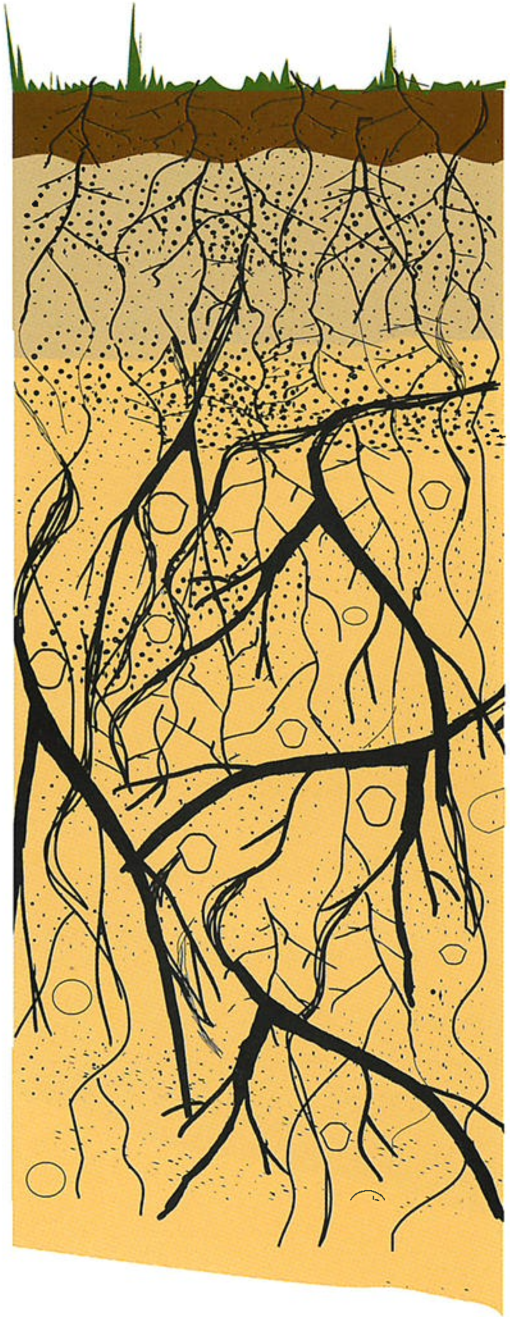
Land use options for unimproved land

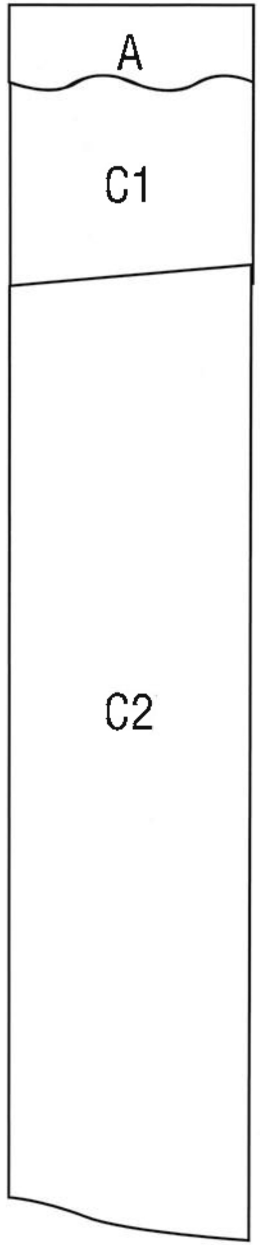
(a) Shifting cultivation: most food crops
(b) Permanent use: pasture, cane, bananas

Land use options for improved land (with ameliorations)

(a) Preferred use: cane, maize, pulses, potatoes, dalo, market gardening (f, i)
(b) 1st alternative: bananas (s, f), cocoa, coffee, mango, avocado, pawpaw
(c) 2nd alternative: peanuts (f), coconuts (f), pasture (i, f)

Yasawa





- Thin dark greyish brown A horizon
- Sandy textures and single grain in all horizons
- Pale brown C horizons with coral stones

YASAWA

Classification:

Soil Taxonomy: Typic Ustipsamment, carbonitic, isohyperthermic
FAO: Arenosol
Twyford and Wright: Recent soil from coastal sands with strong dry season

Parent Material: White calcareous sands (with pumice)
Landscape Position: Coastal beach strand
Moisture Regime: Ustic **Drainage Class:** Excessively drained

Horizon	Depth (cm)	REPRESENTATIVE PROFILE DESCRIPTION	Diagnostic Horizons
A	0–10 cm	very dark greyish brown medium sand; loose; single grain; abundant fine and medium roots; distinct wavy boundary,	Ochric
C1	10–61 cm+	pale brown medium sand; loose; single grain; many coarse roots; coral stones up to 10 cm; humic coats along root channels; charcoal flecks; common pumice stones; indistinct boundary,	
C2	100–130+ cm	pale brown coarse sand; loose; single grain; many coarse roots; many coral stones.	

FERTILITY DATA

pH: moderately alkaline	Phosphorous: very low	Organic Matter: very low
Potassium: low	Salinity: low	

GENERAL LIMITATIONS AND POTENTIAL FOR LAND USE

Soil limitations
Excessively drained; moisture stress; texture; alkalinity; low OM; erosion risk

Land use options for unimproved land
(a) Shifting cultivation: calcicole crops, e.g., vudi, via
(b) Permanent use: coconuts, pasture

Land use options for improved land (with ameliorations)
(a) Preferred use: coconuts (f)
(b) 1st alternative: pasture (f)
(c) 2nd alternative: bananas (f, i), peanuts (f)

Appendix 2: Soil Morphological Properties

Terms used to describe mottles

Abundance *(% area occupied by mottles)*		Size *(mm, measured along greatest length)*	
very few	>2	**extremely fine**	>2
few	2–10	**very fine**	2–6
common	10–15	**fine**	6–10
many	25–50	**medium**	10–20
abundant	50–75	**coarse**	>20
profuse	>75		

Contrast	
faint	indistinct mottles evident only on close examination
distinct	although not striking, the mottles are easily seen
prominent	the mottles are most obvious, and mottling a main feature of the horizon

Soil particle size classes (diameters, mm)

(a) Classes for fine earth fraction	
coarse sand	0.2 –2
fine sand	0.02 – 0.2
silt	0.002–0.02
clay	<0.002
(b) Classes for large particles	
boulders	>200
very coarse gravel	60–200
coarse gravel	20–60
medium gravel	6–20
fine gravel	2–6

Scheme for assessing consistence of moist soil

Consistence Category	*Behaviour of soil material in response to pressure between thumb and forefinger*
loose	non-coherent
very friable	soil crushes with very gentle pressure
friable	soil crushes with gentle to moderate pressure
firm	soil crushes under moderate pressure but resistance is noticeable
very firm	crushes under strong pressure, barely crushable
extremely firm	crushes only under very strong pressure, cannot be crushed between thumb and forefinger

Grades of soil structure

Apedal

No observable aggregation, without a definite orderly arrangement of natural planes of weakness

single grain	>85% by weight of individual coarse particles ranging in size from sand to very coarse gravel
massive	without peds, clods or fragments, and having no partings or fissures at spacings <200 mm

Pedal

Observable natural planes of weakness that define the surface of peds in some part of the soil

weakly developed	Poorly formed, indistinct, weakly formed peds that are not easily observed. Only 15–25% of soil comprises peds
moderately developed	Moderately formed peds that are easily seen but not distant. 25–75% of soil comprises peds
strongly developed	Well-formed peds that are very distinct. Peds separate cleanly when soil is disturbed. Little or no unaggregated material. >75% of soil comprises peds

Soil structure size classes (mm)

Class	Size (mm)
very fine	<6
fine	6–10
medium	10–20
coarse	20–60
very coarse	60–100
extremely coarse	>100

Appendix 3: Classified List of Fijian Soils (after Twyford and Wright, 1965)

Soils developing under a very strong weathering environment (soils of lowland and foothills, 0–600 m altitude)

Recent soils (mainly flat and undulating land);

Recent soils from coastal sands
from white calcareous sands
– strong to moderate dry season *(Yasawa)*
– weak dry season *(Nuku)*
from black sands of low quartz content
– strong to moderate dry season *(Dawasamu)*
– weak dry season *(Naselesele)*
from brownish sands of high quartz content
– strong to moderate dry season *(Volivoli)*
– weak dry season *(Vunibau)*

Recent soils from river alluvium (inclusing closely related young soils)
derived from basic and intermediate (quartz-poor) rocks
– very weak or no dry season *(Rewa, Serea)*
– weak dry season *(Wainibuka, Waibula)*
– moderate and strong dry season *(Sigatoka)*
derived from acidic (quartz-rich) rocks
– no dry season *(Saliadrau, Navunikodi)*
– strong to moderate dry season *(Lato, Lagilagi)*

Nigrescent soils (undulating to rolling downland and related hill soils) including related, slightly degraded, soils of high-base status
from limestone
– moderate dry season *(Korotuku, Ekubu)*
from mainly basic tuffs and marls, but including silicified and pumiceous materials
– no or weak dry season *(Samabula, Suva, Nadawa)*
– moderate dry season *(Dobuilevu, Matawailevu, Sabeto, Yakita)*
– strong dry season *(Yako, Momi, Emuri, Vatuvonu)*
from basalt and calcareous agglomerates, etc.
– weak dry season *(Navava, Naweni)*
– moderate dry season *(Nanukuloa, Rewasa)*
– strong dry season *(Tavua, Yaqara)*

Latosolic soils (undulating to rolling downland and related hill soils)
from young basic ash, scoriae and flows
– no dry season *(Ura, Vakawau, Tabaka)*
– weak dry season *(Waiqere, Vuna, Laucala, Lomaje, Taveuni, Nabeka, Dulevi)*
– moderate dry season *(Nacamaki)*
from limestone
– weak to moderate dry season *(Cikobia, Nayau, Ogea, Tuvuca)*
– strong dry season *(Naevuevu)*

Humic latosols (from parent materials of basic or intermediate composition) (undulating to rolling downland and related hill soils)
no dry season *(Daria, Waidina, Waimaro Namosi, Solevu, Sote, Batiwai, Wainunu, Nakavika, Bureni)*
weak dry season *(Gau, Lomaiviti, Lodoni, Nasegai)*

moderate dry season — *(Totoya, Delaimatai, Burenitu)*

strong dry season — *(Nasou, Tabia, Nadi, Makomako, Rukuruku)*

Ferruginous latosols (*talasiga* soils) (from parent materials of basic and intermediate composition) (undulating to rolling downland and related hill soils)

weak dry season — *(Galoa)*

moderate dry season — *(Kubuna, Tuva, Lau)*

strong dry season — *(Raviravi, Lekutu, Bua, Ba, Nabiti, Namosau)*

Red yellow podzolic soils (and related soils from parent materials of acidic composition) (undulating to rolling downland and related hill soils)

no dry season — *(Lutu, Driti, Koronivia)*

weak dry season — *(Namatiu, Namara)*

moderate dry season — *(Yavuna, Dogotuki, Koroniqala)*

strong dry season — *(Kelikoso, Uaua, Kurukuru, Namaka, Nukusa, Wainikoro, Nukudamu, Lovonivia)*

Gley soils (mainly flat land)

related to nigrescent soils

— strong dry season — *(Nika)*

related to latosols

— no dry season — *(Navua, Wainivesi, Tokotoko, Nausori, Nakelo)*

weak dry season — *(Sawakasa, Vurevure)*

moderate to strong dry season — *(Lautoka, Molamolau, Veisaru, Bucaisau, Saunaka, Matavelo, Saweni, Narewa)*

related to red yellow podzolic and allied soils

— no dry season — *(Nacokula, Deuba)*

— strong to moderate dry season — *(Kedra, Naqilai, Talacagi)*

Steepland soils of foothills (moderately steep to steep, and steep to very steep slopes)

Related to or associated with nigrescent soils — *(Wailotua, Vatulele, Tau, Keiyasi, Ledrutua, Naqalotu,* *Nadroga, Koromavu,* *Delaibo, Vaidoko, Vatukoula)*

Related to or associated with latosolic soils — *(Tavuyaga, Ravilevu, Waioba, Nacaugai, Koro, Waioru, Nasau, Lami)*

Related to or associated with humic latosols — *(Visa, Nauluvata, Seatura, Nailoca, Lobau, Serua, Tailevu, Nacula, Vuya, Kavula)*

Related to or associated with ferruginous latosols — *(Lakeba, Nairai, Macuata, Varaciva)*

Related to or associated with red yellow podzolic soils — *(Narayawa, Gaigai, Savudrodro, Sarowaqa, Vunatoto, Vatubaba, Namuana, Rauriko, Vitawa, Cuku, Nabuono, Malolo)*

Organic soils — *(Melimeli)*

Saline soils of the marine marsh

— moderately saline — *(Soso)*

— strongly saline — *(Dogo)*

— reclaimed — *(new name)*

Soils developing under a less strong weathering environment (soils of uplands, 600–1200m altitude)

Recent soils (from alluvium)
from basic rocks
– moderate to weak dry season *(Navai)*

Latosolic soils (undulating to rolling, dissected plateau land and related soils) from young basaltic ash, scoriae and flows
– no dry season *(Naitata, Tagimaucia, Matana, Manuka)*

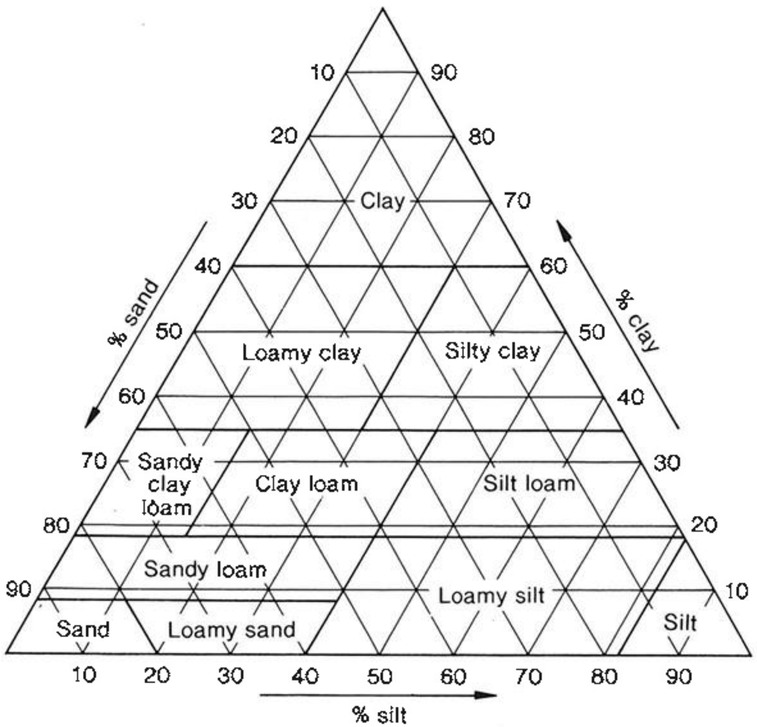
Humic latosols (undulating to rolling, dissected plateau land and related hill soils)
from basic parent materials
– no dry season *(Waibici, Nabuesa, Nadala)*
– moderate to weak dry season *(Wailulu)*

Ferruginous latasols (undulating to rolling, dissected plateau land and related hill soils)
from basic parent materials
– moderate to weak dry season *(Lewa)*

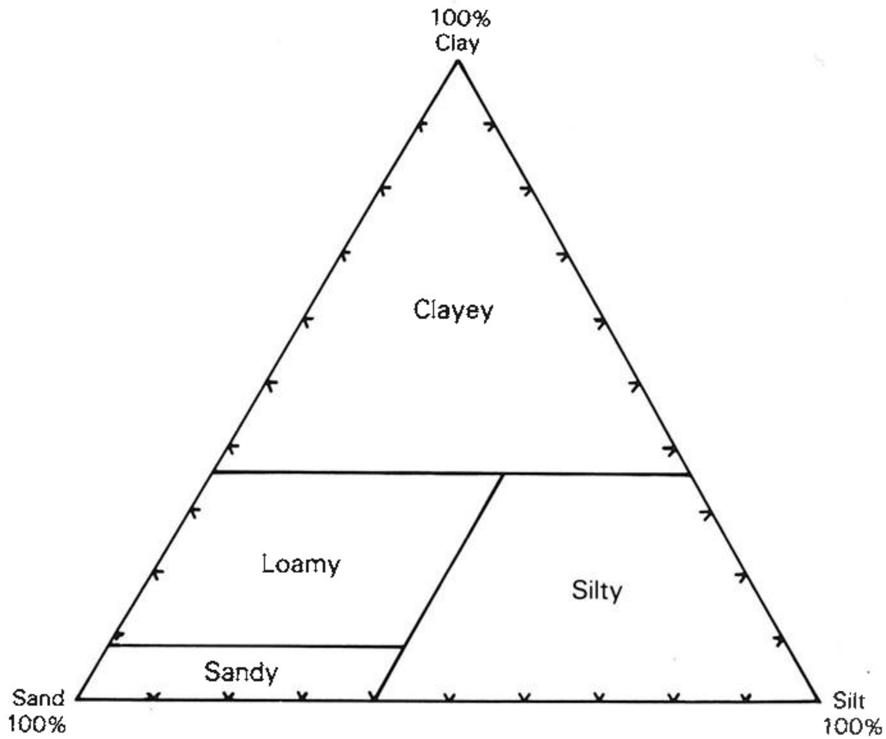
Steepland soils of the uplands
related to or associated with latosolic soils *(Salialailai, Soqulu, Ucunilawe)*
related to or associated with humic latosols *(Monosavu, Nadarivatu)*

Gley soils
related to humic latosols
– no dry season *(Nadrau)*

Organic soils *(Kuta, Nadranu)*



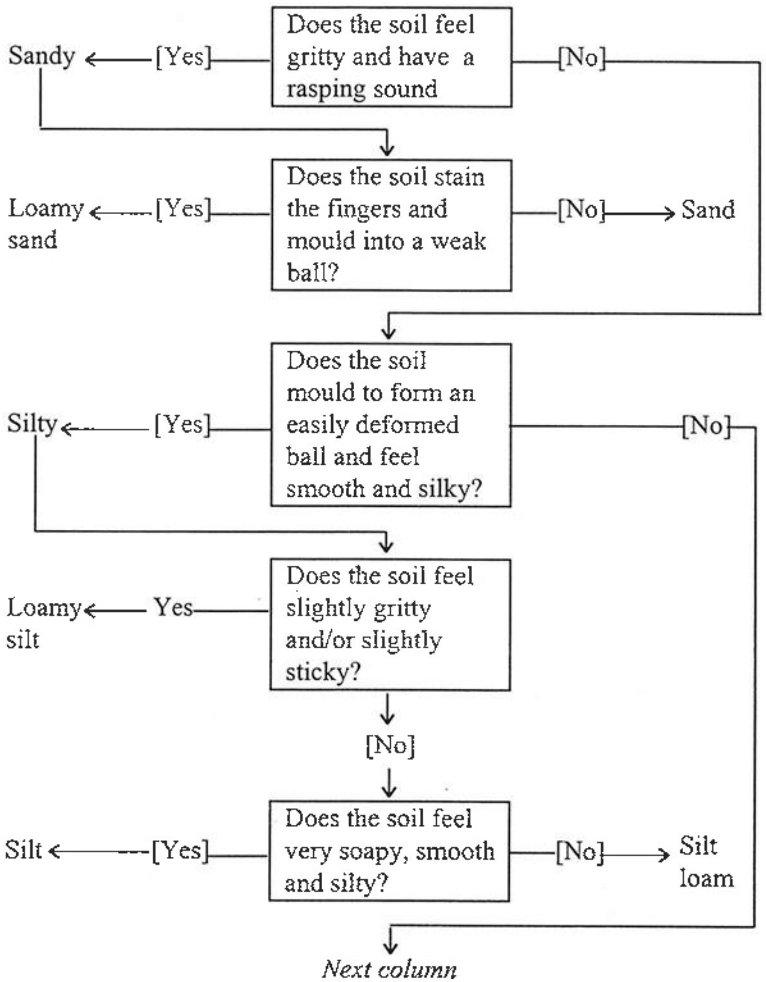
Soil texture classes

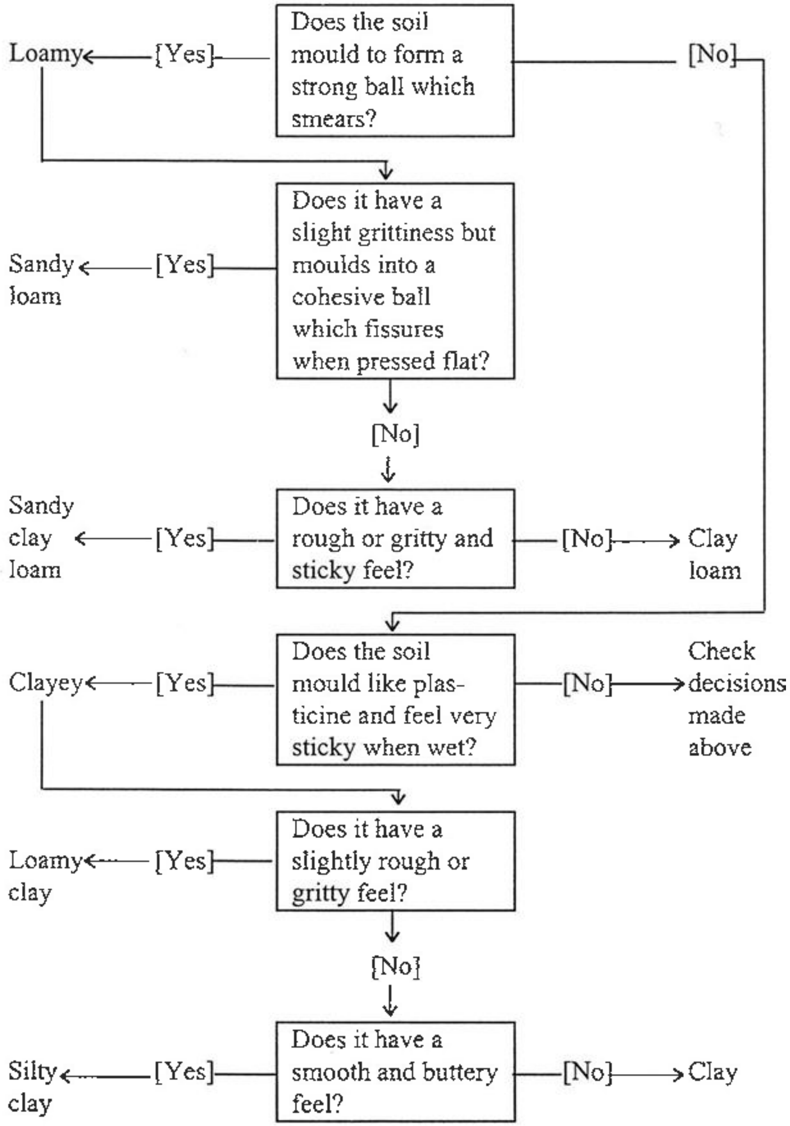


Soil texture groups

Appendix 5: Guide to Assessing Soil Texture

Take about 25 g of soil and moisten gradually, working thoroughly between finger and thumb. The soil is at the required consistency when plastic and mouldable like moist putty.





Appendix 6: List of Headings Used in Soil Taxonomic Unit Description (STUDs)

1. Reference
2. Soil Classification
3. Land System(s)
4. Included Mapping Units and Symbols
5. Geographical Distribution
6. Parent Rock
7. Parent Material
8. Physiographic Position/Landform
9. Slope Class and Range of Slopes
10. Vegetation and Land Use
11. Range of Elevation
12. Mean Annual Rainfall
13. Soil Moisture Regime
14. Temperature Range
15. Soil Temperature Regime
16. Soil Drainage Class
17. Permeability Class
18. Flooding
19. Erosion
20. Characteristic Profile Features
21. Diagnostic Horizons
22. Range of Profile Features
23. Variants
24. Similar Soils and Distinguishing Features
25. General Chemical, Physical and Mineralogical Properties
26. Laboratory Numbers
27. Soil Limitations
28. Typifying Profile

Reference: Leslie, D.M. and Seru, V.B. "Soil Taxonomic Unit Descriptions for the Republic of Fiji, 1997."

A, A1, A2 Horizon See **Soil Profile**

Acid Soil A soil giving an acid reaction throughout most or all of the soil profile (precisely, below a pH of 7.0; practically, below a pH of 6.5). Generally speaking, acid soils become a problem when the pH drops below 5.5. At this level, and particularly below 5.0, the following specific problems may occur – aluminium toxicity, manganese toxicity, calcium deficiency and/or molybdenum deficiency. Such problems adversely affect plant growth and root nodulation, which may result in a decline in plant cover and increase in erosion hazard.

The term is frequently used to describe soils with the acidity problems just described. Correction of the acidity is normally carried out by the application of appropriate amounts of lime to bring the soil pH to a level of 6.0–6.5. See also **pH**.

Acidity The chemical activity of hydrogen ions in soil expressed in terms of pH. See also **Acid Soil, pH**.

Aggregates Lumps of various size formed by soil particles sticking together. See **Soil Structure**.

Alkaline Soil A soil giving an alkaline reaction throughout most or all of the soil profile (precisely, above a pH of 7.0; practically, above a pH of 8.0). Many alkaline soils have a high pH indicated by the presence of calcium carbonate, and are suitable for agriculture. However, others are problem soils because of salinity. Soils with a pH above 9.5 are generally unsuitable for agriculture. See also **pH**.

Alkalinity The chemical condition of soil with a pH greater than 7.0. Often associated with saline soils and sodic soils. See also **pH**.

Allophane A non-crystalline soil mineral often found in soils formed in volcanic ash; an oxide of silicon and aluminium with a high water content.

Alluvial Describes material deposited by, or in transit in, flowing water. See also **Alluvium**.

Alluvial Soil A soil developed from recently deposited alluvium, normally characterised by little or no modification of the deposited material by soil-forming processes, particularly with respect to soil horizon development.

Alluvium Material such as sand, silt or gravel, which has been deposited by rivers, streams and other running waters.

Andesite A dark-coloured volcanic rock intermediate in composition between rhyolite and basalt. Molten andesite flows slowly and eruptions usually feature both lava flows and tephra.

Argillite A rock formed by the hardening of mudstone or siltstone.

Available Nutrient The portion of any element or compound in the soil that can be taken up and assimilated by plants to enhance their growth and development.

Available Soil Water That part of the water in the soil that can be absorbed by plant roots. The amount of water held between the moisture content prevailing at any point in time and the moisture content at which plant growth ceases.

Plants have difficulty extracting moisture when the available soil water approaches wilting point. Where soil moisture can be controlled, the aim is to maintain it at a level where it can be readily extracted by plants, that is, to prevent moisture depletion below about 50% of the available range. See also **Field Capacity.**

Available Water-holding Capacity The amount of water in the soil, generally available to plants. The amount of water that can be held between field capacity and the moisture content at which plant growth ceases. Sometimes also known as the **Plant-available Water Capacity.**

B, B1, B2 Horizon See **Soil Profile**.

Basalt A type of volcanic rock which is rich in iron and magnesium but poor in silica. Molten basalt flows easily and it usually gives rise to oozy volcanic eruptions with little ash being formed.

Bedrock The solid rock that underlies soil or other loose material.

Biota All living microscopic and macroscopic plants and animals.

Bog Waterlogged, spongy ground with decaying vegetation that may develop into peat. Examples are high moor or raised bog; low moor or basin bog.

Bulk Density The mass of dry soil per unit bulk volume. The bulk volume is determined before drying to constant weight at 105°C. The unit of measurement is usually grams per cubic centimetre.

Bulk density is a measure of soil porosity, with low values meaning a highly porous soil and vice versa. It does not, however, give any indication of the number, sizes, shapes, distribution or continuity of soil pores.

This parameter is also used as an indicator of the structural condition of a soil, with low values indicating a better state of aggregation than high values. The range for soils in natural condition would typically be from 1 to 2 g/cm;.

Buried Soil (Paleosol) One or more layers of soil which were formerly at the surface, but which have been covered by a more recent deposition, usually to a depth greater than the thickness of the solum.

C Horizon See **Soil Profile.**

Calcareous Containing calcium carbonate.

Catena A repetitive sequence of soils generally of similar age and parent material, encountered between hillcrests and the valley floor.

The soils in the sequence occur under similar climatic conditions, but have different characteristics due to variation in relief, drainage and the past history of the land surface. Such variations are normally manifest in differential transport of eroded material and the leaching, translocation and redeposition of mobile chemical constituents.

In soil mapping, the use of this term has been largely replaced by the more general term ***toposequence.***

Cation Exchange Capacity The total amount of exchangeable cations that a soil can adsorb, expressed in centimoles of positive charge per kilogram of soil. Cations are positive ions such as calcium, magnesium, potassium, sodium, hydrogen, aluminium and manganese, these being the most important ones found in soils. Cation exchange is the process whereby these ions interchange between the soil solution and the clay or organic matter complexes in the soil. The process is very important as it has a major controlling effect on soil properties and behaviour, stability of soil structure, the nutrients available for plant growth, soil pH and the soil's reaction to fertilisers and other ameliorants added to the soil.

Cemented Describes soil materials having a hard, brittle consistency because the particles are held together by cementing substances such as humus, calcium carbonate or the oxides of silicon, iron and aluminium. The hardness and brittleness persist even when the soil is wet. Cf. **Indurated.**

Chroma See **Soil Colour.**

Clay Soil material which consists of particles less than 0.002 mm in diameter.

Clay Loam A soil texture group representing a well-graded soil composed of approximately equal parts by weight of clay, silt and sand. See also **Soil Texture**.

Claypan A pan made up of a concentration of dense clays in the subsoil. The term is also used for the impermeable clay surface produced as a result of scalding, although this usage is colloquial.

Colluvial Describes material transported largely by gravity. See also **Colluvium**.

Colluvium Rock fragments and soil material which have accumulated at the base of steep slopes as a result of gravity.

Compaction The process whereby the density of soils is increased by tillage, stock trampling and/or vehicular traffic, often resulting in the formation of plough-pans. Such compaction gives rise to lower soil permeability and poorer soil aeration with resultant increases in erosion hazard and lowered plant productivity. Deep ripping and conservation tillage are used to alleviate the condition.

Concretion A local concentration of a chemical compound in soils (e.g., iron oxide or calcium carbonate) forming a grain or lump of varying size, shape, hardness, and colour.

Conglomerate A coarse sedimentary rock consisting of pebbles and boulders set in sand or silt and commonly cemented by iron oxide or other minerals.

Consistence Syn. **Soil Consistence.**

Crumb Structure A soil structural condition in which most of the soil aggregates are soft, porous and more or less rounded units from 1 to 5 mm in diameter. The typical surface condition of medium-textured soils recently cultivated after a period of well-managed pasture.

Debris Loose and unconsolidated material arising from the disintegration of rocks, soil, vegetation or other material transported and deposited in an erosion event. It is generally superficial and contains a significant proportion of coarse material.

Delta The low land made up of alluvial deposits at the mouth of a river, commonly forming a triangular or fan-shaped plain.

Detritus Loose material arising from the mechanical weathering of rocks and transported and deposited in an erosion event. Cf. **Debris**.

Dolomite Specifically a calcium magnesium carbonate mineral, also the rock which predominantly contains the mineral dolomite.

Downland Undulating land; usually an extensive area of gently rolling land around the margin of a plain.

Dune Sands Sands that have been blown into piles (dunes) by wind.

Effective Soil Depth The depth of soil material that plant roots can penetrate readily to obtain water and plant nutrients. It is the depth to a layer that differs sufficiently from the overlying material in physical or chemical properties to prevent or severely retard the growth of roots.

Eluviation The removal of soil material from horizons of a soil. Leaching is one form of eluviation.

Erosion The wearing away of the land surface by running water, wind, ice, or other agents.

Escarpment A long cliff or steep slope separating two, more or less, level surfaces.

Expansive Soil (Swelling Soil) A soil which significantly changes its volume with changes in moisture content. It typically cracks when drying out, and expands on wetting. The shrinking/swelling characteristic is normally due to the presence of montmorillonite type clays in the soil, and is characterised by testing for linear shrinkage.

Fan A gently sloping, fan-shaped mass of material.

Fertilisers Plant nutrients added to the soil by humans.

Fertility Syn. **Soil Fertility**.

Field Capacity The amount of water that a soil holds 2–3 days after it has been saturated and practically all of the freely draining water has gone.

Floodplain The relatively smooth land adjacent to a river channel; built of alluvium deposited by the river. Valley terraces are abandoned floodplains.

Friable A soil consistence term relating to the ease with which soils crumble.

Gilgai Surface microrelief associated with some clayey soils, consisting of hummocks and/or hollows of varying size, shape and frequency. This phenomenon is a continuing long-term process due to the shrinking and swelling of deep subsoils with changes in moisture content. It is usually associated with the occurrence of expansive soils.

Normal gilgai are irregularly spaced and have subcircular depressions with vertical intervals usually less than 300 mm and horizontal intervals usually 3 to 10 m. They are associated with flat or very gently sloping terrain.

Gleying Processes that occur mostly in wet, poorly drained soils, and that involve the reduction of iron and result in grey or bluish-grey colours. Gleying may be induced by groundwaters rising up through the soil, or by 'surface' or 'perched' water which comes down from above but which is held up by a relatively impervious horizon in the soil.

Granite A hard igneous rock that has crystallised deep below the earth's surface. It is rich in crystals of quartz, feldspars, and shiny black and white micas.

Gravel Rock fragments greater than 2 mm in diameter.

Groundwater Water which occurs in the soil or rocks below the ground surface, and which is free to flow.

Hill Land See **Slope Classes**.

Horizon A general term used to describe individual layers within a soil. See also **Soil Horizon**.

Hue See **Soil Colour**.

Humus Well decomposed organic matter in a soil.

Hydraulic Conductivity The flow of water through soil per unit of energy gradient. For practical purposes, it may be taken as the steady-state percolation rate of a soil when infiltration and internal drainage are equal, measured as depth per unit time.

Illuviation The process of deposition of soil material in the lower horizons of a soil as a result of its removal from upper horizons through eluviation. Materials deposited may include clay, organic matter and iron and aluminium oxides.

Ilmenite A black mineral, an oxide of iron and titanium; often found in black beach sands.

Impervious Describes a soil through which water, air or roots penetrate slowly or not at all. No soil is absolutely impervious to water and air all the time.

Indurated Rendered hard. Refers to the hardening of sediments in rock or soil layers into pans by heat and/or pressure and/or cementation.

Infiltration The downward movement of water into the soil. It is largely governed by the structural condition of the soil, the nature of the soil surface including presence of vegetation, and the antecedent moisture content of the soil.

Infiltration Rate The rate at which water moves downward into the soil at any given time. It is measured as volume flux per unit of surface area, in units of mm/h.

Runoff occurs when the rainfall rate exceeds the infiltration rate for a given soil condition. The saturated (or 'steady-state') infiltration rate is the rate which occurs when the soil is saturated and infiltration and drainage are equal.

See also **Hydraulic Conductivity**.

Interfluve Raised area between two adjacent streams flowing in the same direction.

Internal Drainage (Profile Drainage) The rate of downward movement of water through the soil governed by both soil and site characteristics. It is assessed in terms of soil water status and the length of time horizons remain wet (soil bolus exudes water when squeezed). It can be difficult to assess in the field and cannot be based solely on soil profile morphology. Vegetation and topography may be useful guides. Soil permeability, groundwater level and seepage are also important. The presence of mottling often, but not always, reflects poor drainage.

Categories are as follows:

Very poorly drained: Free water remains at or near the surface for most of the year. Soils are usually strongly gleyed. Typically a level or depressed site and/or a clayey soil.

Poorly drained: All soil horizons remain wet for several months each year. Soils are usually gleyed, strongly mottled and/or have orange or rusty linings of root channels.

Imperfectly drained: Some soil horizons remain wet for periods of several weeks. Subsoils are often mottled and may have orange or rusty linings of root channels.

Moderately well-drained: Some soil horizons may remain wet for a week after water addition. Soils are often whole coloured, but may be mottled at depth and of medium to clayey texture.

Well-drained: No horizon remains wet for more than a few hours after water addition. Soils are usually of medium texture and not mottled.

Rapidly drained: No horizon remains wet except shortly after water addition. Soils are usually of coarse texture, or shallow, or both, and are not mottled.

Kaolinite A crystalline mineral found in the clay fraction of some soils.

Karst A type of landscape characterised by sinkholes, caves and underground drainage; often formed in limestone by the dissolving action of water.

Landform Any feature of the Earth's surface having a characteristic shape and produced by natural causes.

Landscape An association of landforms that can be seen in a single view.

Lapilli Pebble-sized fragments of tephra.

Laterite Red, strongly weathered, iron-rich, soil material often used for making bricks in tropical countries.

Lava The molten rock that exudes from a volcano. Also the solid rock formed from cooling the molten material.

Leaching The removal of dissolved materials from the soil by water.

Levée Any naturally produced low ridge, but usually built of sand and silt by a stream on its floodplain.

Limestone A rock composed predominantly of calcium carbonate (lime).

Lithosol (Skeletal Soil) A shallow soil showing minimal profile development and dominated by the presence of weathering rock and fragments therefrom. Such soils are typically found on steep slopes, exposed hillcrests and rocky ranges where natural erosion exceeds the formation of new soil material

Litter Dead plant materials (leaves, twigs, etc.) that accumulate above the A horizon of a soil.

Loam A soil with desirable physical properties for plant growth, usually containing approximately equal proportions of sand, silt, clay, and organic matter.

Lowland Low-lying land; often near the coast.

Marine Terrace A platform formed by coastal sea waves, which has been exposed by uplift or by lowering of the sea level.

Marl Soft and unconsolidated calcium carbonate, usually mixed with varying amounts of clay or other impurities.

Massive Refers to that condition of a soil layer in which the layer appears as a coherent, or solid, mass which is largely devoid of peds, and is more than 6 mm thick. Cf. **Self-mulching**.

Matrix Finer grained fraction, typically a cementing agent, within a soil or rock in which larger particles are embedded.

Metamorphic Rocks Rocks that have been altered by heat and pressure deep below the earth's surface.

Microclimate The climate associated with a relatively small area. A microclimate may vary from the accepted norm for the region because of the effect of local landscape on the weather.

Montmorillonite Clay material comprising a group of aluminosilicate minerals with a 2:1 expanding crystal lattice structure. They are reactive clays generally with high shrink-swell potential and high cation exchange capacity. See also **Kaolinite.**

Mottles Spots or blotches of colour different from the predominant soil colour. Very often the mottles are rusty in colour and are due to concentrations of iron oxides.

Muck Highly decomposed organic material in which the original plant parts are not recognisable. Contains more mineral matter and is usually darker in colour than peat.

Mudstone Soft sedimentary rock formed from material which contains a large proportion of clay.

Munsell Color System See **Soil Colour**.

Nitrogen Fixation Generally, the conversion of free nitrogen to nitrogen combined with other elements. Specifically in soils, the assimilation of atmospheric nitrogen from the soil air by soil organisms to produce nitrogen compounds that eventually become available to plants.

Nodule (Concretion) A small segregated mass of material that has accumulated in the soil because of the concentration of one or more particular constituents, usually by chemical or biological action. Nodules vary widely in size, shape, hardness and colour, and may be composed of iron or manganese compounds, calcium carbonate or other materials.

Non-plastic Describes soil material which shows no plastic behaviour, irrespective of its moisture content. See also **Soil Plasticity.**

Nutrient A chemical required for the nutrition of a plant or an animal.

Organic Matter See **Soil Organic Matter**.

Organic Soil A soil in which soil organic matter dominates the profile. The surface 30 cm should contain 20% or more organic matter if the clay content of the mineral soil is 15% or lower, or 30% or more organic matter if the clay content of the mineral soil is higher than 15%.

Outcrop The exposure at the surface of rock that is inferred to be continuous with underlying bedrock.

Paleosol A soil which formed at the land surface and was subsequently buried by other material.

Pan A layer in a soil that is strongly compacted or very high in clay content. A pan usually impedes the downward movement of water. Many pans are formed through the precipitation of iron oxide minerals and are called 'iron pans'.

Parent Material Material in which the soil develops.

Parent Rock The rock from which the parent material is derived by weathering.

Peat Partly decomposed plant remains in a water-saturated environment, such as a bog. When dried, peat burns freely. 'Blanket peat' is a term for a peat layer which blankets the landscape.

Ped An individual, natural soil aggregate.

Pedogenic To do with soil formation.

Pedology The study of soils. Most often used in relation to the study of soil morphology, genesis, and classification.

Pedon The smallest volume that can be called "a soil". It has three dimensions. It extends downward to the depth of plant roots or to the lower limit of the genetic soil horizons. Its lateral cross section is roughly hexagonal and ranges from 1–10 m^2 in size.

Peneplain An undulating plain resulting from a very long period of erosion.

Permeability Syn. **Soil Permeability**.

pH The measure of the degree of acidity or alkalinity; values below 7.0 lie in the acidic range, those above 7.0 in the alkaline range. Soil pH values typically fall between 3.5 and 9.5, but most have slightly acid pH values, (i.e., about 6).

Phosphate Retention The ability of a soil to hold on firmly to phosphate, tending to make it unavailable to plants.

Plant-available Able to be taken up from the soil by plants.

Plant-available water capacity The maximum amount of water than can be held by a soil and be drawn up by plant roots. Expressed as a percentage of the volume of the soil.

Plastic Describes soil material which is in a condition that allows it to undergo permanent deformation without appreciable volume change or elastic rebound, and without rupture.

Plateau An extensive flat area elevated above the surrounding land.

Pumice A soft, light-coloured, frothy, glassy rock with the appearance of a sponge; usually formed by the trapping of bubbles of volcanic gases in molten rhyolite.

Quartz Crystalline silicon dioxide. A common, hard, rock-forming mineral, which weathers relatively slowly, and is often found in soils.

Regolith The layer or mantle of loose non-cohesive or cohesive rock material, of whatever origin, that nearly everywhere forms the surface of the land and rests on bedrock. It comprises rock waste of all sorts; volcanic ash; glacial drift; alluvium; windblown deposits; accumulations of vegetation, such as peat; and soil.

Relict Term applied to parts of a topographic feature remaining after other parts have been removed through natural causes.

Rendzina Soils with deep black topsoils overlying pale yellow calcareous parent material; developed under grasslands in humid to semi-arid climates.

Rhyolite A type of volcanic rock which is rich in silica, but poor in iron and magnesium. Molten rhyolite is very stiff and it usually gives rise to explosive volcanic eruptions with the emission of large quantities of ash. Granite is the plutonic equivalent of rhyolite.

Ringplain The lower and flatter part of the cone of a typical basaltic or andesitic volcano. The upper limit is usually where the lava flows have stopped.

Rolling Land See **Slope Classes**.

Saline Soil Soil that contains enough soluble salts to interfere with the growth of most crop plants.

Sand Material which consists of particles between 0.05 and 2.00 mm in diameter.

Sandstone Sedimentary rock consisting of compressed or cemented sand-sized particles.

Scoria Volcanic rock, usually formed by the trapping of bubbles of volcanic gases in andesitic or basaltic lava; denser and darker than pumice.

Sedimentary Rocks Rocks resulting from the consolidation of loose material that has accumulated in layers, usually on the bed of the sea, in lakes, or in rivers.

Silt Soil material which consists of particles between 0.05 and 0.002 mm in diameter.

Siltstone Sedimentary rock formed mainly from silt.

Skeletal Soils Very weakly developed shallow soils.

Slip Erosion Sliding or slipping of soil upon an underlying surface.

Slope Classes The following terms are used for land of varying slopes measured in degrees from the horizontal:

flatland	–	less than 3 degrees
rolling land	–	between 3 and 12 degrees
hill land	–	between 12 and 28 degrees
steep land	–	greater than 28 degrees

Soil Aggregate A unit of soil structure consisting of primary soil particles held together by cohesive forces or by secondary soil materials such as iron oxides, silica or organic matter. Aggregates may be natural, such as peds, or formed by tillage, such as crumbs.

Soil Class The common taxonomic unit for a group of soils that are characterised by a particular set of morphological features or surface features that are related to soil management. It is commonly used in the mapping of soils for specific purposes and represents a group of soils that respond similarly to a set of management practices.

While no specific taxonomic units can be attributed to a soil class, as their definition depends on the purpose of the soil mapping, soil class often coincides with soil series, soil phase or an extended principal profile form.

Soil Classification The systematic arrangement of soils into groups or categories on the basis of similarities and differences in their characteristics. Soils can be grouped according to their genesis (taxonomic classification), their morphology (morphological classification), their suitability for different uses (interpretative classification) or according to specific properties.

Soil Colour The colour of soil material is determined by comparison with a standard Munsell soil colour chart (Munsell Color Company, 1975) or its equivalent. The colour designation thus determined specifies the relative degrees of the three variables of colour – **hue**, **value** and **chroma**. Hue represents the spectral colour, for soils normally in terms of red and yellow. Value represents the lightness or darkness of colouration, and chroma its intensity. For example, 5YR 4/6 has a hue of 5YR, a value of four and chroma of six. Equivalent descriptive colour names can be used if desired, using those listed in the Munsell chart.

Soil Conservation Protection of soils against erosion or against loss of fertility.

Soil Consistence The way soil particles are held together. Soil consistency is described by terms which relate to the cohesion and adhesion, and to resistance to deformation or rupture, of pieces of soil. Terms used for describing consistence of soil materials at various soil moisture contents and degrees of cementation are:

wet – non-sticky, slightly sticky, sticky, very sticky, non-plastic, loose, very friable, friable, firm, very firm, and extremely firm;

dry – loose, soft, slightly hard, hard, very hard and extremely hard;

cementation – weakly cemented, strongly cemented and indurated.

Soil Creep Slow movement of soil down steep slopes caused by gravity and aided by saturation with water and by alternate freezing and thawing.

Soil Drainage Loss of water from a soil by surface run-off or flow through the soil.

Soil Fertility The capacity of soil to provide adequate supplies of nutrients in proper balance for the growth of specified plants, when other growth factors such as light, moisture and temperature are favourable. The more general concept of soil fertility can be divided into three components:

- **Chemical fertility** refers specifically to the supply of plant nutrients in the soil;
- **Physical fertility** refers specifically to soil structure conditions which provide for aeration, water supply and root penetration;
- **Biological fertility** refers specifically to the population of micro-organisms in the soil, and its activity in recycling organic matter.

Soil Genesis The formation and development of soils with time.

Soil Horizon A layer within a soil that differs from adjacent layers in properties such as colour, structure, texture, and composition. Principal horizons are:

- O horizons – formed by fresh and decomposing plant material on the surface of the land;
- A horizons (topsoils) – the upper part of the mineral soil; usually dark in colour, they are the mineral horizons of maximum biological activity;
- B horizons (subsoils) – usually lighter in colour than A horizons, and have considerably less biological activity; often accumulate material moved downwards from A horizons;
- C horizons – relatively little changed by soil-forming processes; usually consist of the parent material of the A and B horizons above.

Soil Landscape The pattern of soils in relation to the landforms in any landscape.

Soil Moisture Deficit Occurs when the soil is so dry that plants are unable to take up the little water remaining.

Soil Morphology Physical arrangement, shape and constitution of parts of a soil; particularly the colour, thickness and arrangement of soil horizons, and the texture, consistency, and porosity of each horizon.

Soil Organic Matter The organic part of the soil. Includes plant and animal remains and products at various stages of decomposition (see also **Humus**)

Soil Permeability The ease with which something can pass through a soil; usually refers to water, sometimes to air or other gases.

Soil Phase A subdivision of a soil taxonomic unit based on characteristics that affect the use and management of the soil, but do not change the classification of the soil. Such characteristics include slope, erosion, depth, stoniness and rockiness, drainage, depositional layers, gilgai or scalding.

Soil Plasticity The degree to which a soil is plastic. A highly plastic soil has plastic properties over a wide range of moisture contents.

Soil Porosity The amount and nature of holes in a soil. A soil with high porosity allows water and gases to pass relatively easily.

Soil Profile A vertical cross-sectional exposure of a soil, extending downwards from the soil surface to the parent material or, for practical purposes, to a depth of 1 m where the parent material cannot be differentiated. It is generally composed of three major layers designated A, B and C horizons. The A and B horizons are layers that have been modified by weathering and soil development and comprise the solum. The C horizon is weathering parent material which has not, as yet, been significantly altered by biological soil-forming processes. A surface organic (O) horizon may also occur.

The boundaries between successive soil horizons are specified by their width and shape.

- **O horizon:**
  A surface layer of plant materials in varying stages of decomposition not significantly mixed with the mineral soil. Often not present or only poorly developed in Australian soils, except in some forests. When highly developed, it can be divided into two parts:

  O1 horizon is the surface layer of undecomposed plant materials.

  O2 horizon is the layer beneath the O1 which is partly decomposed.

- **A horizon:**
  This is the original top layer of mineral soil. It can be divided into two parts:

  A1 horizon is the surface soil and generally referred to as topsoil. Relative to other horizons it has a high content of organic matter, a dark colour and maximum biological activity. This is the most useful part of the soil for revegetation and plant growth. It is typically from 5 to 30 cm thick.

  A2 horizon is a layer of soil of similar texture to the A1 horizon, but is paler in colour, poorer in structure and less fertile. A white or grey colouration, known as bleaching, is often caused by impeded soil drainage and/or eluviation. The A2 horizon is typically from 5 to 70 cm thick, but does not always occur.

- **B horizon:**
  The layer of soil below the A horizon. It is usually finer in texture (that is, more clayey), denser and stronger in colour. In most cases it is a poor medium for plant growth. Thickness ranges from 10 cm to over 2 m. It can be divided into two parts:

  B1 horizon is a transitional horizon dominated by properties characteristic of the underlying B2 horizon.

  B2 horizon is a horizon of maximum development due to concentration of silicate clay and/or iron, and/or aluminium and/or translocated organic material. Structure and/or consistence are unlike that of the A and C horizons and colour is typically stronger.

- **C horizon:**
  Layers below the B horizon which may be weathered, consolidated or unconsolidated parent material little

affected by biological soil-forming processes. The C horizon is recognised by its lack of pedoligical development, and by the presence of remnants of geologic organisation. Its thickness is very variable.

- **R horizon:**
  Hard rock that is continuous.

Soil Salinity The characteristic of soils relating to their content of water-soluble salts. Such salts predominantly involve sodium chloride, but sulphates, carbonates and magnesium salts occur in some soils. High salinity adversely affects the growth of plants, and therefore increases erosion hazard.

Soil Sequence A group of soils usually chosen to have variation in only one soil-forming factor, e.g., a ***chronosequence*** (variation in time) or a ***climosequence*** (variation in climate).

Soil Series A unit of soil classification and soil mapping comprising or describing soils which are alike in all major profile characteristics. Each soil series is developed from a particular parent material, or group of parent materials, under similar environmental conditions. It approximates to the extended principal profile form. The name given to a soil series is geographic in nature, and indicates a locality where the soil series is well developed.

Soil Structure The combination or spatial arrangement of primary soil particles (clay, silt, sand, gravel) into aggregates such as peds or clods and their stability to deform. Structure may be described in terms of the grade, class and form of the soil aggregates, as follows.

Grade – expresses the degree and strength of soil aggregation determined on moist soil. The grades range from structureless, if there is no observable aggregation, to strong, where more than two-thirds of the soil is aggregated.

Class – expresses the main size range of the aggregates.

Form – expresses the shape of the individual aggregates as crumb, granular, subangular blocky, angular blocky, prismatic, columnar or platy.

Soil structure is an important property with respect to the stability, porosity and infiltration characteristics of the soil. Well-structured soils tend to be more resistant to erosion due to their ability to absorb rainfall more freely and over longer periods, and because of the resistance of their aggregates to detachment and transport by raindrop splash and/or overland flow. They also have good soil/water/air relationships for the growth of plants. Poorly structured soils have unstable aggregates and low infiltration rates. They tend to break down quickly under heavy rainfall which leads to soil detachment and erosion. Under certain conditions, surface sealing occurs and this gives rise to rapid and excessive runoff.

Soil Taxonomic Unit A general term for a grouping of soils based on similarities of the soils within the group, and differences compared with other groups. Note that the general taxonomic units such as great soil group and principal profile form need to be distinguished from the soil survey taxonomic units such as soil series and soil association.

Soil Texture The relative proportion of the various sizes of particles (sand, silt, clay) that make up a soil, but is also influenced by organic matter content, clay content and degree of soil structural development.

Six main soil texture groups are recognised:

Texture Group		Approx. clay content
1. Sands	Coarse	< 5%
2. Sandy loams		10–15%
3. Loams	Medium	20–25%
4. Clay Loams		30%
5. Light Clays	Fine	35–40%
6. Heavy Clays		> 45%

For field identification of these main groups, take a small handful of soil and knead with water until a homogeneous soil ball or bolus is obtained. Large pieces of grit and organic material should be discarded. Small clay peds should be crushed and worked with the rest of the soil. The feel, behaviour and resistance of the soil to manipulation during this process are important. The bolus should be kept moist so that it just fails to stick to the fingers. The six main texture groups should be apparent as follows.

1. ***Sands*** – have very little or no coherence and cannot be rolled into a stable ball. Individual sand grains adhere to the fingers.

2. ***Sandy Loams*** – have some coherence and can be rolled into a stable ball, but not a thread. Sand grains can be felt during manipulation.

3. ***Loams*** – can be rolled into a thick thread, but this will break up before it is 3 to 4 mm thick. The soil ball is easy to manipulate and has a smooth spongy feel with no obvious sandiness.

4. ***Clay Loams*** – can be easily rolled to a thread 3 to 4 mm thick, but it will have a number of fractures along its length. Soil becoming plastic, capable of being moulded into a stable shape.

5. ***Light Clays*** – can be rolled to a thread 3 to 4 mm thick without a fracture. Plastic behaviour evident, smooth feel with some resistance to rolling out.

6. ***Heavy Clays*** – can be rolled to a thread 3 to 4 mm thick and formed into a ring in the palm of the hand without fracture. Smooth and very plastic, with moderate – strong resistance to rolling out.

In a soil conservation context, soil texture is very important as it not only has a major influence on the erodibility of soils, but also on their performance when used in water storage structures. In particular, it largely determines soil permeability.

Soil Type A general term used to describe a group of soils that can be managed similarly and which exhibit similar morphological features. It is largely a layman's term and now has no formal soil taxonomic meaning.

Soil Variant A soil having a morphology which is distinct from the surrounding soils, but comprises such a limited geographic area that the delineation of a new map unit, or the naming of a new soil taxonomic unit, is not justified.

Soil Water The water present in a soil.

Soil Workability The ease or difficulty with which a soil may be manipulated for a specific purpose, such as growth of crops or road construction.

Solum The upper part of a soil profile above the parent material, in which current processes of soil formation are active. The solum consists of either the A and B horizons or the A horizon alone when no B horizon is present. The living roots and other plant and animal life characteristic of the soil are largely confined to the solum.

Steep Land See **Slope Classes**.

Subsoil General term for the lower horizons of a soil; usually B horizons and below.

Tephra A general term for all solid (rather than molten) materials ejected from a volcano during an eruption, e.g., boulders, lapilli and ash.

Terrace A nearly level, narrow plain bordering a river, lake, or sea. Rivers are often bordered by a number of terraces at different levels.

Tilth The ability of a soil to form a finely granular structure suitable for sowing seeds.

Toeslope The lowest part of a slope.

Toposequence A repetitive sequence of soils encountered between hillcrests and the valley floor. A catena is a special case of a toposequence in which the parent material is uniform.

Topsoil General term for the upper part of a soil; usually the A horizon.

Toxicity The characteristic of a soil relating to its content of elements or minerals which adversely affect plant growth. It is of particular concern in relation to acid soils. Soils with pH less than 5.0 may give rise to manganese and aluminium toxicities, which reduce plant growth and hence ground cover. It is also of concern in the rehabilitation of heavy metal mines, where toxic levels of such elements as copper, zinc and lead in mine tailings create difficulties in their revegetation.

Truncated Describes a soil profile that has been cut down by accelerated erosion or by mechanical means. The profile may have lost part or all of the A horizon and sometimes the B horizon, leaving only the C horizon. Comparison of an eroded soil profile with a virgin profile of the same area, soil type and slope conditions indicates the degree of truncation.

Tuffs A general term for consolidated volcanic tephras.

Upland An extensive region of relatively high land, usually distant from the coast.

Value See **Soil Colour**.

Volcanic Ash Fine ash-like rock particles ejected from volcanoes during eruptions; may be transported large distances by wind.

Water Balance An estimated state of equilibrium within the soil moisture regime based on rainfall, evapotranspiration, runoff, drainage and soil moisture storage.

The water balance provides information as to suitable tillage and sowing times, condition of ground cover and also whether other activities are restricted by wet or dry soil conditions. It also gives useful information concerning periods of major catchment flow and trickle flows. However, being based on monthly averages, short periods of intense rainfall are omitted. This rainfall is important in initiating soil erosion and providing runoff for stock watering purposes.

Waterlogged — The conditions of a soil which is saturated with water and in which most or all of the soil air has been replaced. The condition, which is detrimental to most plant growth, may be caused by excessive rainfall, irrigation or seepage, and is exacerbated by inadequate site and/or internal drainage.

Watertable — At a depth below the surface, the ground is saturated with water. The upper surface of this zone of saturation is termed the watertable.

Weathering — The breakdown and decomposition of rocks by factors such as air, water, sun and frost. Physical weathering refers to the breaking of rocks into smaller and smaller pieces; chemical weathering refers to alteration of the chemical composition of minerals.

Wilting Point — The amount of water that a soil holds when plants begin to wilt. At wilting point the water remaining in the soil is held so tightly that plants are unable to compete satisfactorily for it.

Zonal soils — Are formed on freely drained stable sites within the landscape, and that have well developed profiles. The diagnostic characteristics of zonal soils result from processes controlled by the climate and vegetation regimes of the geographic zones in which they have developed. Zonal soils are separated by the extent to which leaching has taken place, as controlled by the moisture regime, and subgroups are distinguished by the extent of weathering that has occurred, as influenced by the temperature regime.

References and Further Reading

The following is a list of books, papers and reports which deal with subjects in greater detail:

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