ENVIRONMENTAL FACTORS RELEVANT TO VEGETATION MAPPING, GEOMORPHOLOGY AND PEDOLOGY

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1. GEOMORPHOLOGY

1.1. WHAT IS GEOMORPHOLOGY?

Geomorphology is the study of landforms and their processes or origin.

1.1.1. Landforms

Landform means the morphology of the ground surface at a given moment in time, and is, described as the combination of relief, slope form and drainage lines (figure 25).

Landforms are usually shown on maps by the contour lines which directly represent altitude and the contour intervals. A contour interval is the vertical distance separating successive contours (figure 26).

1.1.2. Processes

Process is the action of fluid agents causing the forms to change. Three main processes can be identified:

i) erosion,
ii) transport,
iii) and deposition.

In tropical countries the morphological processes are caused by three fluid agents:

i) running water in surface and underground flow systems,
ii) waves,
iii) wind blowing over the ground.

1.1.3. Geomorphology as a system

Geomorphology can be seen as a system composed of three elements:

i) forms,
ii) processes,
iii) and bed rocks; and three relationships:
   a) process to forms,
   b) process to bed rock,
   c) bed rock to forms (figure 27).

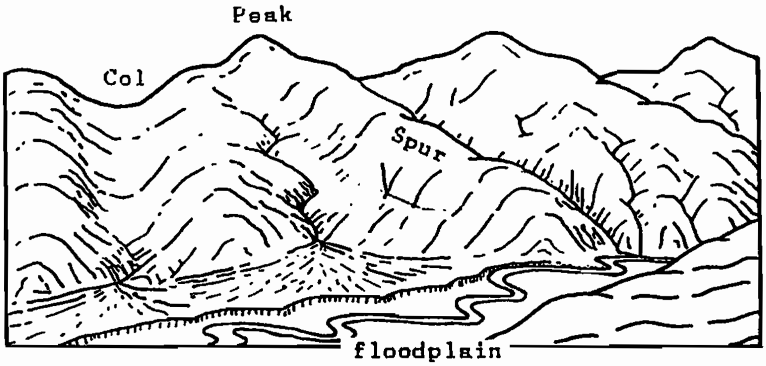

Figure 25. Examples of landforms (after Strahler and Strahler, 1978)

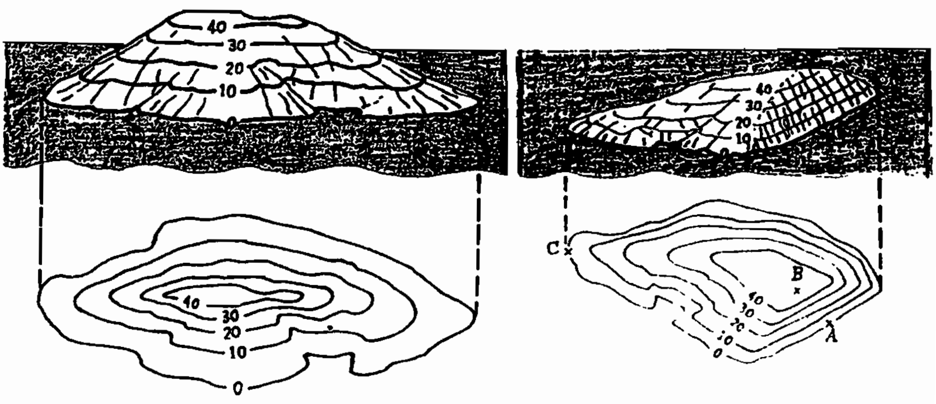

Figure 26. Contours of a small Pacific Island (after Strahler and Strahler, 1978)

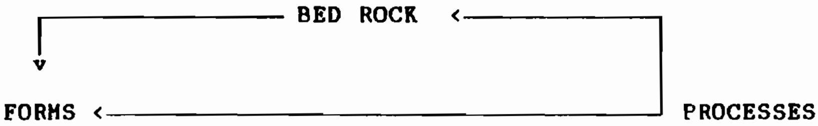

Figure 27. The Geomorphological System

1.2 GEOMORPHOLOGICAL UNITS

2.1. Slopes

The slope is the basic unit of geomorphology. Slopes may vary from 0° (horizontal) to 90° (vertical).

Slopes are a function of the rock type or surface material and the processes acting upon it. In the upper section of the slope, erosion predominates. In the middle section, transport predominates. In the lower section of the slope, deposition and transport predominate (figure 28).

On a smaller scale, the same classification can be applied between slopes, relative relief and drainage lines (figure 29):

i) slopes are mainly characterised by erosion; relative relief is mainly characterised by deposition;
ii) drainage lines are mainly characterised by transport.

1.2.2. Drainage lines

"*The total system of downslope water flow to the point of arrival at the ground surface comprises the drainage system. It consists of a branched network of stream channels, as well as the sloping ground surfaces that contribute overland flow and interflow to those channels. The entire system is bounded by drainage divide, outlining a more or less pear-shaped drainage basis*" (STRAHLER and STRAHLER, 1978) (figure 30).

In wet tropical countries such as the Solomon Islands and Vanuatu, the rocks are very strong. The rivers can not cut through them; the drainage lines can use only the weakest points of the landforms, especially the fault lines. This is the reason why usually the valleys are very narrow in mountainous regions and why the canyons are common.

At low altitudes, alluvial meanders are common (figure 31).

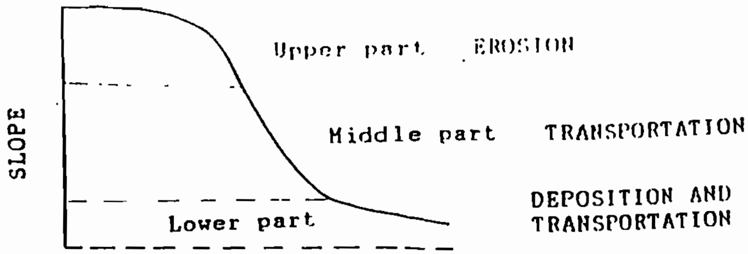

Figure 28 - Morphological processes on a slope

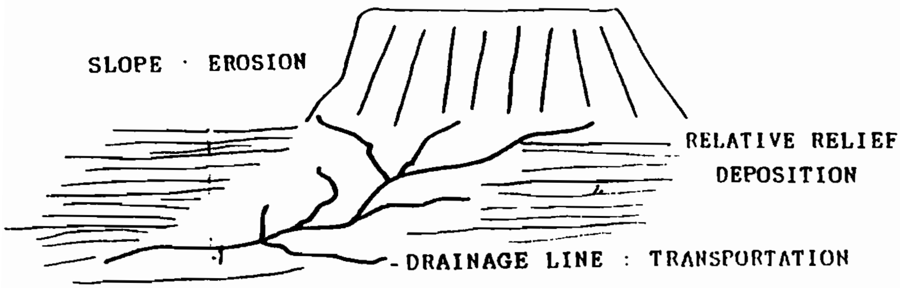

Figure 29 - Morphological processes between slopes, relief and drainage lines

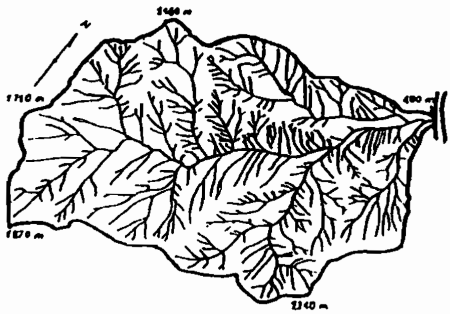

Figure 30 A drainage system

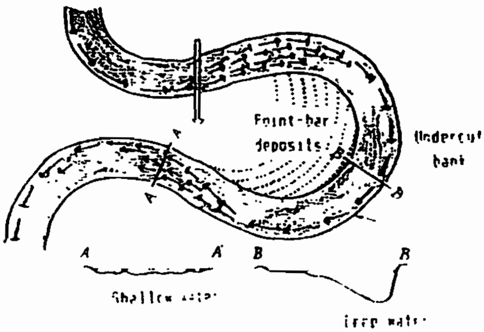

Figure 31 The hydrodynamic of a meander bend (after Strahler and Strahler, 1978)

1.3. ROCK WEATHERING

1.3.1. Physical, chemical and mechanical weathering

Weathering is the general term applied to the combined action of all processes causing bedrock to be gradually broken down into small bits and pieces then disintegrated physically and decomposed chemically because of exposure at or near the earth's surface. The products of rock weathering tend to accumulate in a soft surface layer called "*regolith*".

The regolith grades downward in bedrock, (solid and unaltered rock). Regolith in turn provides the source for sediment. The sediment consists of detached mineral particles transported or deposited in a fluid agent (figure 32).

In wet tropical countries, the fluid agent is water and the weathering is mainly of a chemical nature, except at high altitude where frost may be responsible for some physical weathering.

When the bed rock is not too deep, the roots of trees may use fractures of bed rock, enlarge them and cause mechanical weathering (figure 33).

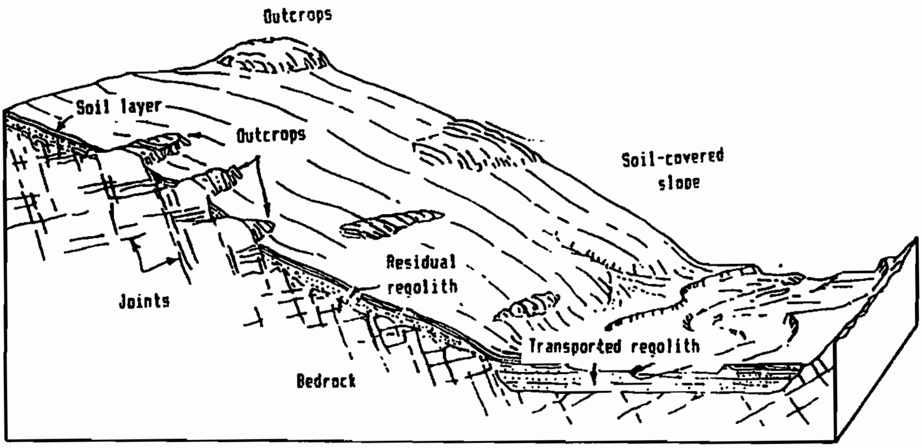

Figure 32. Regolith on a hillslope (after Strahler and Strahler, 1978)

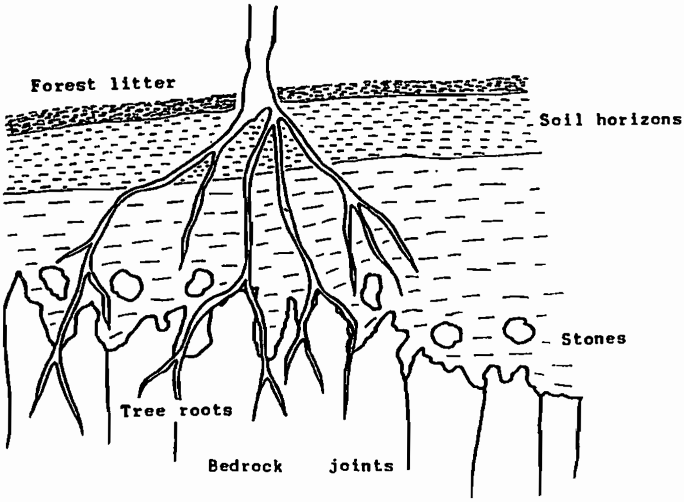

Figure 33. Mechanical weathering caused by tree roots

1.3.2. Chemical weathering or mineral alteration

The heat, the humidity and the precipitation are the three climatological agents causing chemical weathering in wet tropical countries (figure 34).

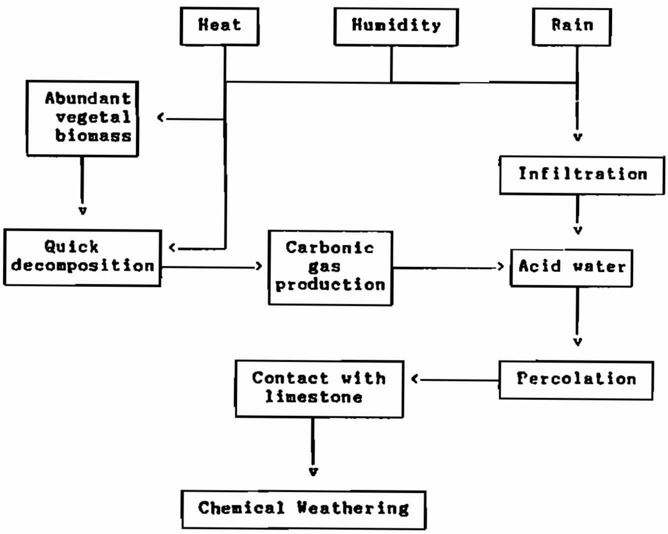

Figure 34. Chemical weathering

1.4. THE EROSION AND TRANSPORT PROCESS

1.4.1. Surface wash and overland flow

The surface wash is the downslope transport of regolith material along the ground surface through the medium of moving water. The surface wash can be divided into two main categories: the raindrop impact and the surface flow.

i) The raindrop impact causes *splash erosion*, a geyserlike splashing in which soil particles are lifted and then dropped into new positions.

ii) The surface flow can be divided into two types: the sheet *wash* and the *rill wash* (figure 35).

- The term *"sheet wash"* is used when the ground is entirely or largely covered by a moving layer of water. When the water is very turbid another term is used: *"sheet flood"*, instead of *"sheet wash"*.
- The term *"rill wash"* is used when the water flows mainly as micro channels. In rill wash, the channels frequently change their route on slopes. Where channels are constant in location the process is called: *"gullying"*.

In a forest environment rill wash is more common than sheet wash. Surface wash is also called *overland flow* " (figure 36).

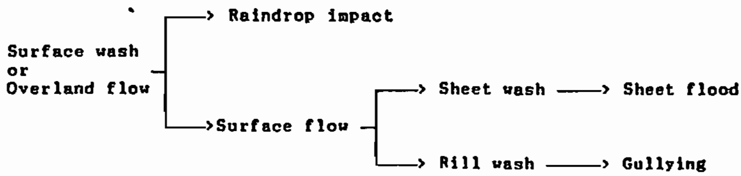

Figure 35. The different components of the surface wash

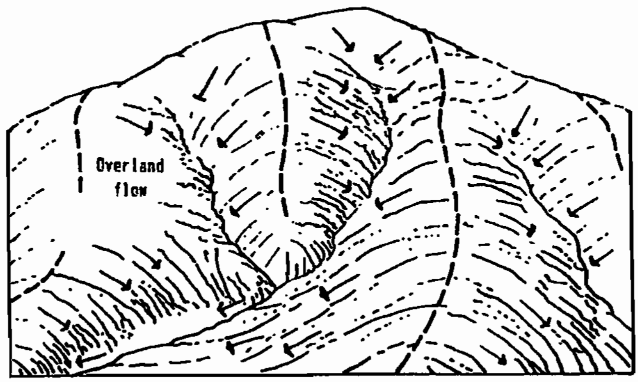

Figure 36. Overland flow from slopes (after Strahler and Strahler, 1978)

1.4.2. Soil creep

The term is applied to the extremely slow movement of soil and regolith.

1.4.3. Earth flow

This process occurs in humid regions. The term *earth flow* means any downslope movement of a mass of water-saturated soil, regolith or weak clay which move down a steep slope under the influence of gravity. An earth flow mass is always sluggish. An earthflow can take several hours. Small earth flows are common on steep forested slopes saturated by heavy rains.

1.4.4. Mud flow

This process is usually common to dry regions, but it can occur in tropical countries as cyclone Namu showed in May 1987 in Guadalcanal (figure 37).

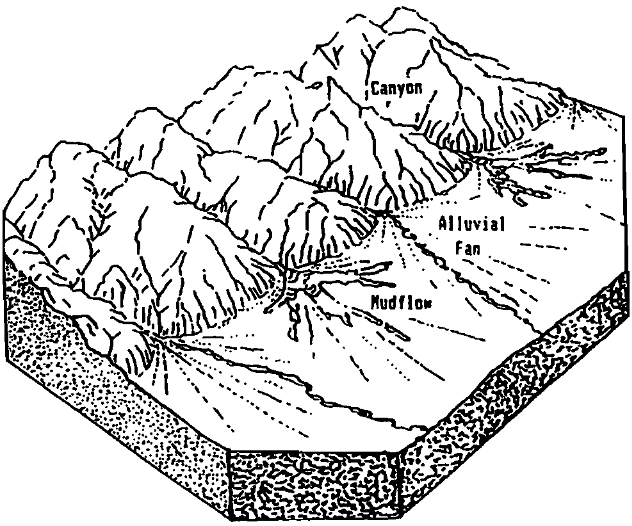

Figure 37. Mudflow on overlogged mountains (after Strahler and Strahler, 1978)

1.4.5. Landslides

Landslides and *earth flow* are closely related processes. The only difference is that landslide mass is always rigid, composed of regolith or bedrocks. Two basic forms of landslides are:

i) rockslide which may involve slipping on a nearly plane surface,
ii) and slump block which moves down a curved slippery surface with rotation on a horizontal axis.

2. BASIC CONCEPTS OF PEDOLOGY OR SOIL SCIENCE

2.1. WHAT IS SOIL?

A soil is a natural body having both depth and surface area. It is a complex mixture of inorganic minerals (mostly clay, silt and sand), decaying organic matter, living organisms, air and water. Soil is a product of nature resulting from both destructive and synthetic forces.

Each type of soil can be analysed in terms of:
i) colour,
ii) texture or porosity based on the percentage of sand, silt and clay particles in the soil,
iii) structure, which refers to the grade size of soil particles and the soil consistency,
iv) ratio (organic matter/inorganic minerals),
v) acidity and alkalinity,
vi) chemical composition of the soil solution, the part of the soil which is composed of air and water.

2.2. BASIC PEDOGENIC PROCESSES

Three main pedogenic processes can be identified:

i) addition of material to the soil body,
ii) translocation of material within the soil body,
iii) transformation of material within the soil body.

2.1.1. Addition of material

This process is usually called *"soil enrichment"*. Four types of soil enrichment can be identified:

i) the organic enrichment of the soil surface by decomposition of the organic litter from the vegetable biomass growing on the soil;

ii) the inorganic enrichment of the soil surface by colluvium, sediments brought by running water;

iii) the inorganic enrichment of the soil surface by sediments transported by the wind (volcanic ash for example);

iv) the inorganic enrichment by weathering and alteration of the deeper part of the soil at the contact of the bed rock.

2.1.2. Translocation of material

Translocation of material can be divided into two big movements:
i) the downward transport of soluble elements or colloids under the influence of infiltration and percolation;

ii) the upward movement of soluble elements, fine particles and colloids caused by the evaporation of soil water.

Translocation movements cause internal enrichment or loss of organic and inorganic material in the soil.

Eluvation and illuvation are two simultaneous downward translocations of fine particles in the upper part of the soil (figure 38).

i) Elluvation occurs just under the soil surface. It causes a removal of colloids in this zone and leaves behind coarse skeletal mineral grains.
ii) Illuvation is the accumulation of material carried out of an upper soil zone by elluviation mostly clay particles, humus (organic particles), iron and aluminium.

The translocation of calcium and salt through the reverse processes of (decalcification - calcification) and (desalinisation - salinisation) are also very important.

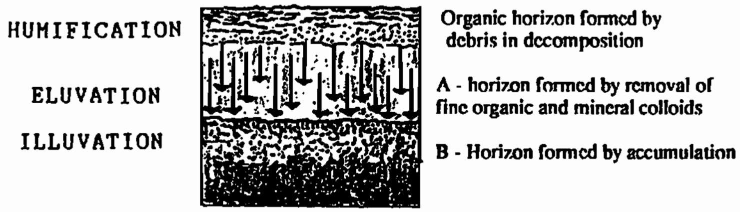

Figure 38. Humification, eluvation and illuvation

2.1.3. Transformation of material

Oxidation and hydrolysis are the main chemical processes affecting the inorganic material. They transform by decomposition primary mine-minerals such as feldspars to secondary minerals such as bauxite; new minerals can be synthesised from the products of decomposition. Humification is the transformation process affecting organic material. By humification plant tissues are transformed into humus.

2.2. HORIZONATION

2.2.1. The soil horizons

Pedogenic process cause the stratification of soil into horizons. Five horizons are commonly identified (figure 39).

a) The first horizon is an organic horizon, called 0 horizon. In fact two 0 horizons are usually identified:
   i) 01 horizon, which is formed of loose leaves and organic debris, largely undecomposed,
   ii) 02 horizon, which consists largely of humus.

b) The second horizon is the first material horizon, called A horizon. This horizon is often divided into two subhorizons called A1 and A2:
   i) the A1 horizon is a dark coloured horizon of mixed minerals and organic matter, it is rich in humus with much biological activity;
   ii) the A2 horizon is characterised by a maximum of elluvation.

c) The third horizon is still a mineral horizon called E horizon; it is a transition horizon between horizons A and B. The E horizon is characterised by a low concentration of organic and inorganic matter.

d) The B horizon is the third mineral horizon. It is characterised by a high illuvation of mineral matter which is accompanied by a maximum accumulation of silicate clay minerals or of sesquioxides and organic matter.

e) The last horizon, called C horizon, is a mineral layer of regolith or sediment with poor biological activity.

The fertility of the soil is concentrated in 0, A1 and B horizons.

2.2.2. Horizons and soil fertility in tropical forests

In tropical forest countries, the most common types of soil are "*oxisols*". They are characterised by the extreme weathering of most minerals to sesquioxides of aluminium and iron and to kaolinite.

Usually oxisol horizons are not very distinct except for the dark surface layers, 0 horizons, in which most of the fertility of the soil is concentrated. A2 and E horizons with very poor nutrient contents are very large and only the roots of the big forest trees can reach B horizon where they pump minerals accumulate by illuvation (figure 40).

2.3. SOIL AS A SYSTEM

From a cybernetic point of view, soil can be seen as a black box in contact with two types of flux:

i) soil forming factors acting as input flux in a process called pedogenesis;
ii) soil erosion factors acting as output flux in a process called morphogenesis.

2.3.1. Pedogenesis

Pedogenesis is the result of six soil forming factors: climate, vegetation, animal organisms, parent material rock, relief (topography) and time. At each period of its

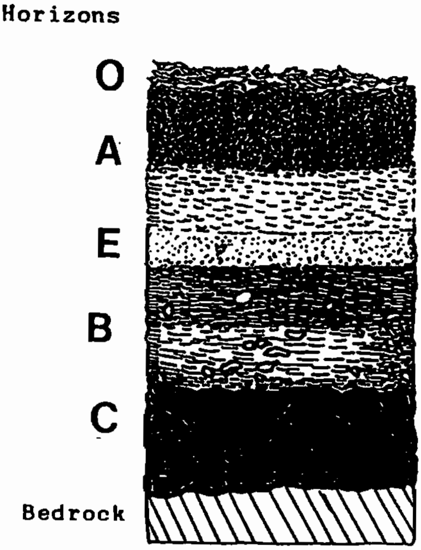

Figure 39 -

The soil horizons

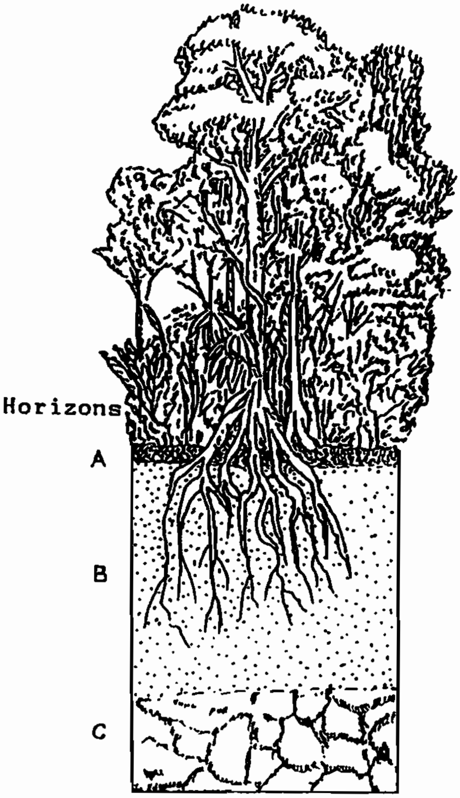

Figure 40 -

Horizons and soil fertility in tropical forests evolution a soil results from the interactions of these six variables as shown in the following equation:

$$S = f(C, V, O, P, R)\ t0$$

Where 0: animal organisms, C: climate, V: vegetation, P: post material, R: relief, t0: relative age.

2.3.2. Equilibrium between pedogenesis and morphogenesis

If soil is a function of pedogenesis as the last equation shows, soil is also a function of morphogenesis. If this morphogenesis is more dynamic than pedogenesis, a soil disappear in several weeks, months or years by erosion.

The concept of equilibrium between pedogenesis and morphogenesis leads to the typology of soils into three groups:

I) Mature soils where pedogenesis equals morphogenesis. In using EHRART's (1956) theory of biorhexistasy, we call mature soils "*soil in biostasy*".

II) Immature soils, still in formation, where pedogenesis is more intensive than morphogenesis. According *to EHRART's classification, immature soils are* "soils in positive rhexistasy".

III) Eroded soils, where pedogenesis is less intensive than morphogenesis, these soils can be called "*soils in negative rhexistasy*" according to EHRART's theory of biorhexistasy.

Figure 41 gives a summary of the soil system.

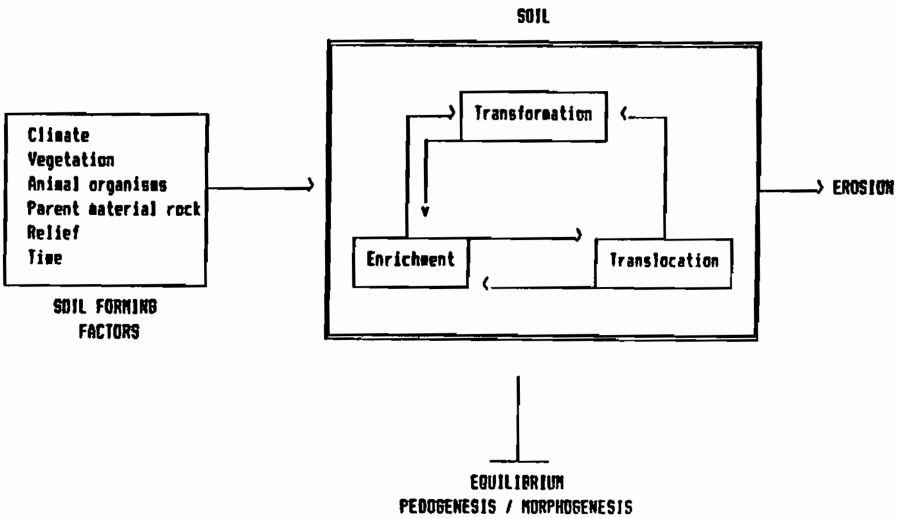

Figure 41 - The Soil System

To conclude this talk, we must keep in mind that the morphology and soils are essential parameters to explain vegetation distribution in the high islands of the Pacific. Both are very sensitive to any natural and anthropic (man made) disturbance which might cause erosion and a complete loss of soil fertility.

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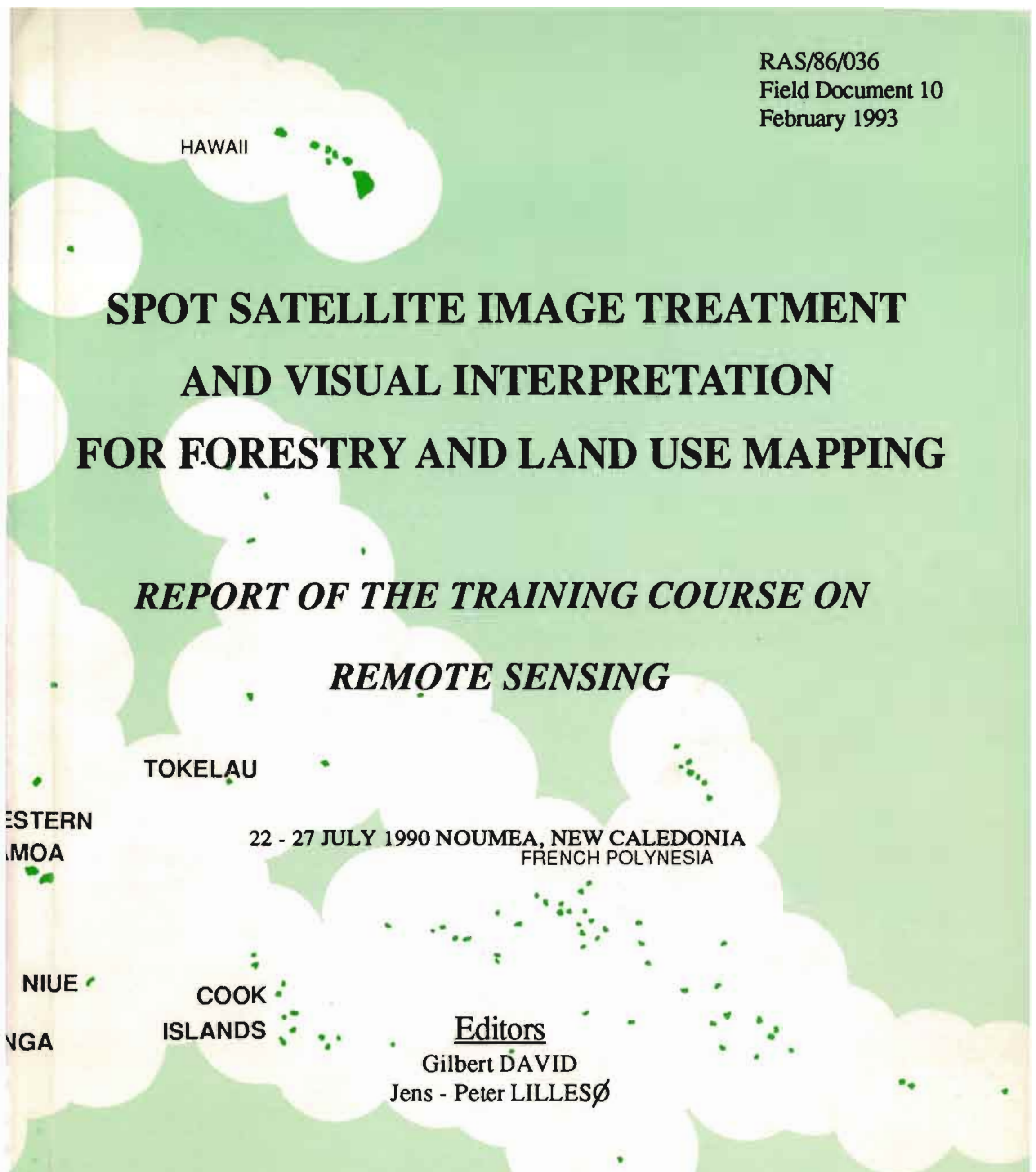
ACKNOWLEDGMENTS

I wish to thank Miss Alfreda MABONLALA for the drawings.

RAS/86/036
Field Document 10
February 1993



SPOT SATELLITE IMAGE TREATMENT AND VISUAL INTERPRETATION FOR FORESTRY AND LAND USE MAPPING

REPORT OF THE TRAINING COURSE ON REMOTE SENSING

22 - 27 JULY 1990 NOUMEA, NEW CALEDONIA

Editors
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