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# TOPOSEQUENCE OF SOILS ON THE SOUTH SLOPE OF THE MERAPI VOLCANO TO BARON COAST, YOGYAKARTA*

by
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## ABSTRACT

*The aim of the research is to know a soil sequence based on the physiographic unit along volcanic slope and limestone area, i.e. south slope of Merapi volcano from Kaliurang to Baron coast, Yogyakarta, Central Java.*

*This research is based on topographic differences as a lithological reflection. Seven sample points are determined in order to discribe and evaluate morphological types of soil profile, physical and chemical properties, and environmental factors. Relative soil potential is analyzed on the basis of the field data. From this research the soil types found in the study area are Regosol, Cambisol, Latosol, Rensina, Grumusol, and Mediterannean.*

## INTRODUCTION

Studies in toposequence of soils in Indonesia have been scarcely undertaken. One of such studies was carried out by Subagyo and Buurman (1978) in west and east slope of LawuVolcano. According to Thompson (1952) toposequence is a soil association which is different in topography, under the same climatic condition, and with various parent materials. From the toposequence study, physical condition of environment and soil properties variation can be determined.

Soils on the slope of Merapi volcano to Baron coast have distinctive distribution, especially due to topographic, lithologic and vegetation factors. Variation in the soil forming factors can be found in every physiographic and lithologic unit and in this respect will influence soil development.

The soil development includes, for instance, differentiation in types and internal properties of soil, leaching process in the soil body and formation of soil

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horizons. Based on measurement and observation on soil forming factors, soil types and properties, and following to the soil research methodology, the sequence of soil development in the study area can be acquired.

The aim of this research is to determine soils toposequence along a tract of southern volcanic slope of Merapi through limestone area and ending at Baron coast based on the physiographic and lithologic unit.

## METHOD

In this study seven soil profile samples were examined (Figure 1). Method of determining the soil profiles observed was based physiographic and lithologic units. During the field works, observation and measurement to the environmental condition, such as topography. lithology, landuse, land management, and hydrology were carried out. The observation on the soil profiles covered horizons, physical and chemical properties observed are shown in Table 1.

**TABLE 1. SOIL PROFILE OBSERVED ON THE BASIS OF PHYSIOGRAPHIC AND LITHOLOGIC UNITS.**

| No. | Profile | Location | Elevation | Topography | Lithology |
|---|---|---|---|---|---|
| 1. | PM 1 | Kaliurang | 880 | gently-slightly steep | volcanic material |
| 2. | PM 2 | Ngemplak | 358 | gently-slope | volcanic material |
| 3. | PM 3 | Piyungan | 70 | flat | volcanic material |
| 4. | PP | Patuk | 230 | rolling b | reccia, andesit, sandstone, tuff |
| 5. | PO B | under | 110 | gently-slope | weathered limestone |
| 6. | PW | Gading | 200 | flat l | imestone, tuff, mergel |
| 7. | PT | Bintaos | 150 | gently to rolling | limestone slope |

Source: Field data (1983)

## THE STUDY AREA

The study area is situated in Yogyakarta Special Region, Indonesia. The physiographic units of the study area are Merapi volcano and Wonosari plateau. The Merapi volcano is strato and still active. The plateau of Wonosari mostly shows karst topography.

The material of Merapi volcano is composed of old volcanic deposits and young volcanic deposits. The old volcanic deposits are composed, basalt which contains augite-hyperstene and hornblende, and andesite. The young volcanic deposits are composed of augite, hyperstene andesite with subordinate hornblende not containing olivin (Bemmelen, 1969). Due to volcanic eruption of the Merapi ...



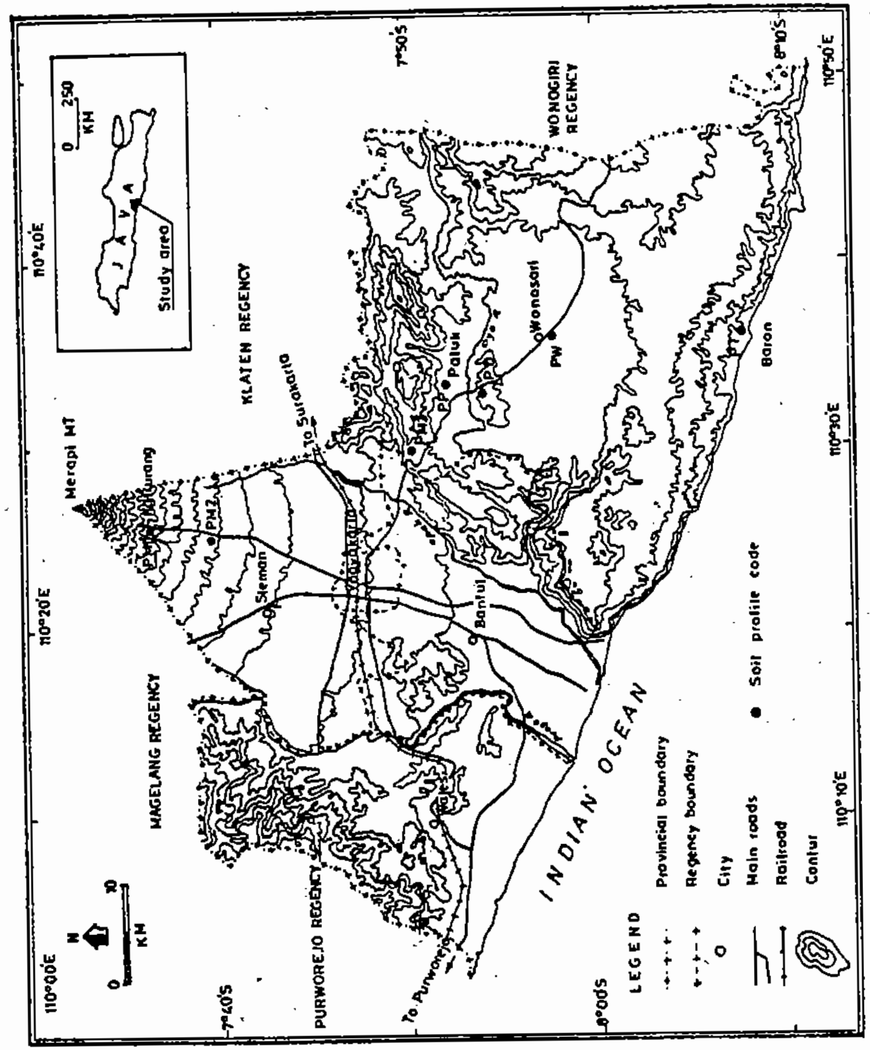



*Figure 1.* Map Showing Soil Profiles Observation

the landscape has continually altered over time, and greatly influences the soil types and patterns. The freshly erupted material accumulated near the volcanic cone; and due to gravitative force the materials fall down along the steep slope as a debris avalanche. During heavy storm, the unconsolidated material from volcanic slope flowed down as lahar. Coarser material was deposited in upslope, and the finer one was transported to lower area. Therefore, the finer soils are found at increasing distance from the volcanic cone.

The material of Wonosari plateau consist of (i) Nglanggran formation composed of andesite, breccia, sandstone, tuff, and (ii) Wonosari formation composed of weathered limestone, tuff, marl, and limestone. The differences in lithology of this units are related to the soil types and soil development.

According to Koopen (Schmidt, F.H. and Fergusson, J.H.A., 1951), climate of the study area has two types: Am for volcanic unit and Aw for plateau unit. The climate in the volcanic is characterized by mean monthly temperature varying from 25$^0$C to 27$^0$C, relative humidity ranging from 78 percent in September and 86% in January, sunshine duration from 08.00 a.m. to 04.00 p.m. varying from 45 percent in March to 60-70 percent in July and August, mean annual rainfall varying from upper volcanic slope to volcanic foot plain from 4,500 mm to 1,800 mm respectively. The climate in the plateau unit is characterized by: mean monthly temperature 26.35$^0$C, mean monthly humidity 87.23 percent, sunshine duration 56 percent and mean annual rainfall 2,073 mm.

The differences in the climate data between the two physiographic units will influence the distribution of soil types and soil development. The influence was reflected on the soil profiles as shown in Figure 2.

The two main physiographic units can be divided into several micro physiographic units. The division is needed to determine soil profile samples. The micro physiographic units in the study area and the surroundings are shown in Figure 1, and the descriptions are presented in Table 1. Among the physiographic units as shown in Figure 1 only a part is covered in the study area.

**TABLE 1. PHYSIOGRAPHIC UNITS OF THE STUDY AREA**

| Physiograpgic units | Description |
|---|---|
| MC | Merapi Cones; steep volcanic cones above 1,000 m comprising andesitic material. |
| MMS | Merapi Middle Slopes; steep volcanic slopes between 200-1,000 m elevation, comprising andesitic material. |
| MP | Merapi Lower Slopes; slightly sloping plain below 200 m. |
| WPM | West Progo Mountains;dissected, eroded mountains up to 880 m high, comprising andesitic and decitic volcanic material. |
| SH | Sentolo Hills; low (up to 200 m) dissected limestone hills. |
| BR | Baturagung Range; parallel faulted ridges of conglomerates, tuff and sandstones, up to 800 m. |
| PT | Progo Terraces; slightly undulating, eroded Holocene alluvial plain. |
| CAP | Coastal Alluvial Plain; flat. |
| CD | Coastal Dunes; [illegible] |
| K1 | Immature karst; steep sided, conical shaped limestone hills. |
| K2 | Mature karst; as K1 but valleys wider and accounting for a greater percentage of the landscape. |
| K3 | Subdued karst; has many large (100 ha) areas of near level land between the hills. |
| W | Wonosari plateau; a gently to strongly undulating plateau formed from reef and platy limestone. |
| P | Panggung massive; strongly undulating to hilly terrain and deeply incised rivers, parent materials are acid pumice-tuffs with some quartz, interbedded with andesitic tuff and breccias. |

Source: Mac Donald *et al.* (1971) (with some modification).



## RESULTS

The results of the observation and measurement to the soil profiles during field work are presented in the cross section (Figure 2) and the description of soil profiles (Appendix 1).

### Cross Section

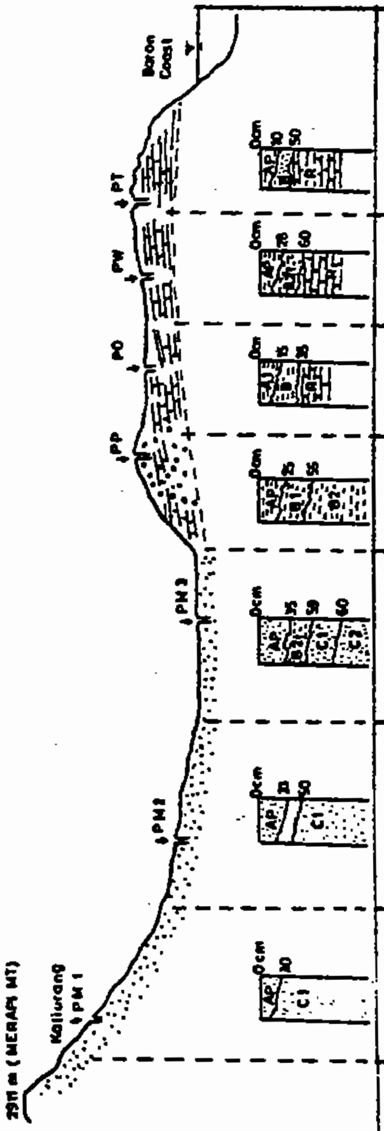
Description of the cross section gives a clear picture of external factors covering landuse, physiography, source of water, parent materials, and geomorphic processes. Furthermore, in this cross section there are some similarities and differences in conditions of the respective factor. For instance, in the physiographic units with volcanic material, water condition, and the process created *padas curi* and horizon $B_2t$ (PM 2, PM 3) as seen in Figure 2. On The upper Piyungan to Baron the lithological differences are quite markedly seen. This chiefly influences between those factors which varies from one place to another, the soil types formed are different. Observation on the distribution of horizon types or soil layers at seven investigated profiles can be used to interpret the process of soil forming factors interaction, which will be hereafter dealt with in discussion.

### Soil Classification

The soils in the study area are classified according to 'Terms of Reference Type A' (Staf Pemetaan Tanah, 1969), the system which is almost identical to the FAO system (FAO/UNESCO, 1974), and USDA Soil Taxonomy (USDA, 1960). The soil classification is tentatively undertaken on the basis of previous soil investigations, interpretation of reconnaissance soil map at a scale of 1:250,000 (Dames, 1955), and the results of the soil profiles field research, as shown in Table 3.

## DISCUSSION

Discussion of the research results is based on cross sectional characteristics and data obtained from the description of soil profiles morphology, physical and chemical properties of respec tive soil type, and soil type potential is determined by soil properties and environmental factors.



| | PM 1 | PM 2 | PM 3 | PP | PO | PW | PT |
|---|---|---|---|---|---|---|---|
| Landuse | Garden, dry field | Sawah, terrace dry field and yard | Sawah, yard/ settlement | Terrace dryfield | Terrace dryfield, forest | Terrace dryfield | Terrace dryfield, bare land |
| Physiography | Volcanic slope | Volcanic footslope | Fluvial plain of volcanic foot | Rolling, hilly | Hilly and folded | Rolling hilly | Karts Topography of Seribu Hill |
| Sources of water | Rainfed water, springs | Rainfed water, springs, Spring zone | Surface water swallow groundwater | Rainfed water spring water | Rainfed water river water | Rainfed water | Rainfed water, underground river water |
| Processes | Surface material erosion down slope | Vertical leaching | Vertical leaching | Water erosion, landslide | Solution surface erosion | Surface erosion | Surface erosion classification solution |
| Soil types | Regosol | Regosol | Kambisol | Latosol | Rensina | Grumusol | Mediteran |
| Parent materials. | Volcanic material (lava, tuff and breccia) | Volcanic material (medium sand and gravel) | Volcanic material (fine sand) | Breccia, andesit, sandstone and tuff | Soft limestone | Tuff, limestone mergel | Limestone |

*Figure 2.* Cross-Section of Kalliurang - Baron



**TABLE 3. TENTATIVE CORRELATION OF SOIL CLASSIFICATION FOR SOME SOIL PROFILES IN SOUTH SLOPE OF MERAPI VOLCANO TO BARON**

| No. | Soil Profiles | Villages | Soil Classificaton | | |
|---|---|---|---|---|---|
| | | | LPT Bogor | FAO/UNESCO | USDA Soil Taxomy |
| 1. | PM 1 | Kaliurang | Regosol | District Regosol | Udipsaments |
| 2. | PM 2 | Ngemplak | Regosol | District | Udisapments Regosol |
| 3. | PM 3 | Piyungan | Cambisol | Eutric Cambisol | Andepts / Ochrepts |
| 4. | PP | Patuk | Latosol | Humic Nitosol | Tropudults |
| 5. | PO | Bunder | Rensina | Rendzina | Ustols |
| 6. | PW | Gading | Grumusol | Pelic Vertisol | Pelluderts |
| 7. | PT | Bintaos | Vertic Mediterranean | Luvisol | Ustalfs |

Source : Dames, TWG (1955), Soil Data Interpretation.

### Regosol (Profile PM 1, PM 2)

This soil originates from the parent volcanic material of Merapi volcano; it has therefore chemical properties benefit for plant nutrient. This soil is still in its early development as indicated by existence of soil layers in which the soil structure and texture are nearly the same as that of the parent material. The upper and probably the lower soil layers contain gravel and sand varying from fine to coarse (PM 1). The condition can influence technique in the soil cultivation. Based on its physiography, volcanic slope unit requires some consideration to cultivate the soil. For instance, terraces are used to manage water from springs. Stone on the land surface constitute an hindrance factor for agricultural activities. On the volcanic slope foot unit, the soil physical properties, e.g. texture, structure, aeration, and permeability (PM 2) are such advantageous conditions for irrigated field agriculture which is supported by the sufficient and regular water availability. According to Supraptohardjo (1980) this soil belongs to very good class of regional capability, that can be cultivated for various crops.

### Cambisol (Profile PM 3)

This soil is composed of and developes from volcanic material, and distributes on fluvial plain of volcanic foot. Its physical, chemical and topographic properties are essential for the land utilization in this area. The groundwater is rather shallow and surface water sufficiently support various agricultural efforts. Stones bump on the land surface and concretion underground are rarely found. The thickness of soil solum is moderately to deep. This soil is considered having no

### Latosol (Profile PP)

This soil is composed of and develops from parent rocks of breccia, sandstone, and tuff. The soil is found on hilly rolling topography. While the soil properties are deep soil solum, much bump of breccia, easily eroded and slided, and shortage of water for agriculture. According to Supraptohardjo (1980) this soil has a regional land capability of somewhat poor class. More intensive efforts are therefore neede. The existence of coarse material in the soil body highly influences the cultivating of land. Erosion and landslide processes cause physical and chemical soil fertility to be poor. Due to these obstacles the land and water conservation are seriously taken into account in the land utilization.

### Rendzina (Profile PO)

The soil is composed of and develops from parent weathered limestone. It has relatively shallow solum, with lots of coarse material on the surface, hilly topography, often lack of water in dry season. Physical properties of this soil are clay texture, plastic consistence influential to the cultivating of land. On the hand, attemps to conserve the land is needed. The rainfall highly influences the land utilization. Drought hazard in dry season makes the land utilization less intensive, while the improvement of water supply by irrigation is very limited and gets some difficulties. According to Supraptohardjo (1980) this soil belongs to the poor class of land capability.

### Grumusol (Profile PW)

This soil is composed of and develops from parent marl, tuff, and limestone material. The land capability of this soil is poor (Supraptohardjo, 1980). Some discouraging soil properties, such as shallow soil solum, gilgai micro relief, surface materials, limestone concretion, massive loamy texture or soil fracture make the cultivation difficult. The lack of water in dry season makes soil less intensively cultivated. The main source of water is rain. This area is usually for annual plants or polowijo.

### Mediterannean (Profile PT)

This soil is composed of and develops from parent limestone material. In dry season water is always less; the water supply is dependent on rain. The existing underground river of which the water used may be less developed due to topographic factors of this area. Soil properties, such as relatively shallow soil solum to completely soil are mostly found on nearly whole part of Seribu Hill of which the slope is steep, with vegetation of grass and shrubs, even the limestone lumps is dominantly visible. Except in villages where soil sediments are found, the land is cultivated for polowijo. Such an area needs land conservation and it is preferable for forestation to improve soil solum. Limestone lumps are chiefly a hindrance against land cultivation, and therefore the land management is needed for improving terraces. The terraces improvement is essential for preventing from water erosion and for depositing soil sediment, so that soil solum does not get thinner. In dry season the



needed is chosen. The distribution of this soil covers a large area as compared to the other soil types in Yogyakarta Special Region. According to Supraptohardjo (1980) the land capability of this soil type is fair.

## CONCLUSION

From the cross section description completed with descriptions of morphological characteristics of soil profiles, physical and chemical properties, in this research, some conclusions can be drawn.

The soil development of the parent volcanic material of Merapi volcano occurs on the volcanic foot to the volcanic foot plain. Process of the soil development as a result of the influence of sloping to flat topography and water condition together with the effect of man's activities in cultivating land for sawah or dry field, results in alteration of surface material.

Water constitutes the dominant energy which creates processes of surface material transport, leaching, sedimentation, and land slide. Water greatly influence soil formation and soil development in addition to parent rock and topography, weathering and soil forming processes result in different soil types and or soil sequence. The soil sequence found in the study area are covers Regosol, Cambisol, Latosol, Rensina, Grumusol, and Mediterannean.

## ACKNOWLEDGEMENTS

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## Appendix 1. Soil Profiles Description

| ...fl ...ofiles | Location | Topography | Landuse | Parent Materials | Soil Classification | Horizon Description |
|---|---|---|---|---|---|---|
| ...1 1 | Kaliurang | gently to slightly steep | field/grass, pinus, vegetables, and flower plants. | the volcanic materials of Young Merapi | Regosol (LPT, Bogor) | Ap 0-30 cm; gravelly sand, crumb to granu lair, structure friable to loose (moist), pH = 5.6 ($H_2O$), horizon boundary diffuse to<br><br>C, 30-100 cm:<br>Black, 10 YR 2/1 (moist) coarse sand with gravels granulair to single grain, loose (moist). |
| ...1 2 | Cilihan, Ngemplak | gently (9-13%) | ricefield, mixed-crops | the volcanic materials of Young Merapi | Regosol (LPT, Bogor) | Ap, 0-35 cm:<br>Dark to dark brown 10 YR 4/3 (moist), medium sand, crumb, friable (moist), non sticky (wet), pH: 6.2 ($H_2O$), horizon boundary wavy to<br><br>Aps, 35-50 cm (plough pan):<br>Dark brown (10 YR 3/3), Oxidation and reduction Fe, Mn, slightly firm, slightly impermeable, fine to medium sand with gravels, horizon boundary wavy, slightly clear to |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | $C_1$, > 50 cm:<br>Brown 7.5 YR 4/4 (humid), medium sand with gravels, crumb to granulair, non sticky (wet),friable (moist) well aeration, pH:6.2 ($H_2O$), horizon boundary broken, diffuse to fresh sand layer. |
| 3 | Jogotirto, Piyungan | flat (1-4%) | ricefield, mixed garden | the volcanic materials of Young Merapi | Cambisol (LPT, Bogor) | Ap, 0- 35 cm:<br>Dark brown 7.5 YR 3/4(moist) loamy sand, crumb, slightly sticky (wet), friable (moist) pH: 6.2 ($H_2O$), horizon boundary slightly clear to<br><br>$B_2t$, 35-53 cm:<br>Dark brown 7.5 YR 3/3(moist) very fine sandy loam, weak angular blocky, sticky (wet) pH: 6 ($H_2O$), some oxidation and reduction Fe,Mn, horizon boundary wavy, slightly clear to<br><br>$C_1$, 53-69 cm:<br>Brown 7.5 YR 4/3 (moist), medium sand with gravels, crumb to granulair structure, non sticky (wet) friable (moist) shallow groundwater, horizon boundary gradual to |



| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | $C_2$, > 69 cm:<br>Fresh sand material with gravels. |
| | Kerjan, Patuk | Hilly to rolling | field terraces, mixed garden with some trees | Breccia, andesit sandstone, and tuff | Latosol (LPT, Bogor) | Ap, 0-25 cm:<br>Yellowish red 5 YR 5/6 (moist), loamy clay, angular blocky, sticky (wet), slightly firm (moist) pH: 5 ($H_2O$), horizon boundary wavy, clear to<br><br>$B_1$, 25-55 cm:<br>Yellowish red 5 YR 4/6 (moist), clay, angular blocky to weak prismatic, very sticky (wet), firm (moist), pH: 5.5 ($H_2O$), horizon boundary wavy clear to abrupt to<br><br>$B_2$, > 55 cm:<br>The same with B1, different in oxidation and reduction Fe, Mn, as domains form. |
| | East of Bunder village | Hilly. slope gently to steepy | forest with teak, mahony, schrub and grass | soft limestone | Rendzina (LPT, Bogor) | $A_1$, 0- 15 cm:<br>Dark brown 7.5 YR 4/2(moist) clay, angular blocky, very sticky (wet) firm (moist), pH: 5.5 ($H_2O$), horizon boundary wavy, slightly clear to |

| | | | | | |
|---|---|---|---|---|---|
| | | | | | B, 15-55 cm: Yellowish red 5 YR 5/2 (moist), clay, angular blocky very sticky (wet), firm (moist), pH: 5.5 ($H_2O$), horizon boundary wavy, abrupt to<br><br>R, > 55 cm: Soft limestone. |
| Gading, Wonosari | flat to gently | rained field, mixed crops | tuff, mergel, and limestone | Grumusol (LPT,Bogor) | Ap, 0-28 cm: Gilgai relief,some fragments of limestone on the surface, very dark brown 10 YR 2/2 (moist) clay, irregular angular blocky, sticky to very sticky (wet), firm to very firm(moist),permeability slow, some cracking when dry, pH: 6.5 ($H_2O$), horizon boundary diffuse to<br><br>B2t, 28-60 cm: Very dark grayish brown 10 YR 3/2 (moist) clay, irregularangular blocky, very sticky (wet), firm to very firm (moist), permeability slow, aerasion poor, few limestone concretion, pH: 6 ($H_2O$),horizon boundary wavy, abrupt to |



| | | | | | |
|---|---|---|---|---|---|
| | | | | | ($H_2O$),horizon boundary wavy, abrupt to<br>R, > 60 cm: tuff, mergel and limestone. |
| Bintaos, Tepus | Gently to rolling | terraces field with | hard limestone | Mediterranean (LPT, Bogor) | Ap, 0-10 cm: Yellowish red 5 YR 4/6 (moist) clay, angular blocky, sticky (wet) firm (moist), horizon boundary wavy, abrupt to<br><br>R, > 50 cm. |

eld data from field work.